IAVCEI 2023
SCIENTIFIC ASSEMBLY
Ko Rūaumoko e Ngunguru Nei

30 Jan - 3 Feb | Rotorua, New Zealand

BOOK OF ABSTRACTS



1347

The Abundance of Submarine Lava Vents in Arcs and the Volcano Identification Problem in Ice Cores

Dr Dallas H Abbott[1]
[1]Lamont Doherty Earth Obs Of Columbia University, Tappan, US, [2]CCNY, New York, US

Fifty-nine percent of the Earth is covered by water. Submarine arc volcanoes should be abundant. However, only 138 Holocene arc volcanoes (15%) in the Smithsonian database emit lava from submarine vents. Because subaerial volcanoes are easier to find, this estimate is low. Using locations of active submarine hydrothermal vents and the Smithsonian database, we found 73 submarine arc volcanoes not listed by the Smithsonian. This brings the percent of submarine volcanoes up to 20%. However, 86% of the dated, active hydrothermal venting is from volcanic eruptions within the last 200 years. All are Holocene, implying an underestimate of Holocene submarine volcanoes. Baker (2017) estimated that only 18% of hydrothermal vent fields in arcs had been discovered [1]. Only 77 are on volcanoes listed by the Smithsonian. If we assume that unknown Holocene submarine volcanoes are distributed in the same proportions as unknown hydrothermal vents, then the 73 unlisted submarine volcanoes mean that there are about 406 as yet undiscovered Holocene age submarine volcanoes with active hydrothermal vents. This implies that ~48% of Holocene arc volcanoes are submarine.
This could explain why so few ice core sulfate peaks are firmly linked to a volcano. Of 23 eruptions producing the most sulfate loading over the last 2500 years, only six have an identified source volcano [2]. If almost half of all large eruptions in volcanic arcs were submarine and only 15% of these are well studied enough to be in the Smithsonian database, it is likely that the source volcanoes for many large explosive, submarine eruptions are as yet undiscovered.

[1] Baker, E.T., 2017. Exploring the ocean for hydrothermal venting: New techniques, new discoveries, new insights. Ore Geology Reviews, 86, pp.55-69.

[2] Sigl, M. et al., 2015. Timing and climate forcing of volcanic eruptions for the past 2,500 years. Nature, 523(7562), pp.543-549.

1298

Bibliometric analysis of study on active volcanoes in Indonesia from Scopus database

Mr Gamma Abdul-jabbar[1]
[1]*Universitas Indonesia, Kota Adm. Jakarta Selatan, Indonesia*

This study aims to find out the development state of the volcanological study of Indonesia's active volcanoes. We performed a bibliometrics analysis study by selecting any research articles, conference papers, and books that mention Indonesia's active volcanoes in the title. The documents are from Scopus database and restricted to volcanology and earth science studies issued between 1880 and 2022. We used 74 active volcanoes names mentioned in PVMBG's Indonesia volcanoes database (Data Dasar Gunungapi Indonesia) as keywords. This study results in total of 831 documents and 45 out of 74 volcanoes' name with non-zero results. Merapi and Krakatau are the first and second most-mentioned in the title with a total of 272 and 124 documents, respectively. These two combined account for almost half of the total documents (46.42%) while the rest of the volcanoes share less than 6% individually. The research on Indonesia's volcanoes started emerging in 1980 and there were several peaks in publication production in several years between 1980 and 2022. The peaks were related to either the release of special issues publications or significant eruptions which spark discussions. There was also a shifting of the topics being discussed from magma characteristics and compositions in around 2010 to hazard impact in around 2014 and forward. Even though this study does not represent the whole landscape of volcano study in Indonesia, the study can give us several insights on how to expand volcano-related research in Indonesia. We suggest that while we keep deepening our understanding of much-studied volcanoes, we need to expand our study to other less-studied volcanoes.

275

The role of vertical discontinuities in the evolution of intraplate magmas and associated volcanic hazards

Dr John Adam[1], Professor Tracy Rushmer[1], Dr Beverley Coldwell[2,3], Professor Simon Turner[1], Dr Matt Pankhurst[2,3], Professor Nemesio M. Pérez[2,3], Professor Shane Cronin[4]
[1]School of Natural Sciences, Macquarie University 2109, Australia, [2]Instituto Tecnológico y de Energías Renovables (ITER), 38600 Tenerife, Granadilla de Abona, Spain, [3]Instituto Volcanológico de Canarias (INVOLCAN), 38320 Tenerife, San Cristóbel de La Laguna, Spain, [4]School of Environment, The University of Auckland,, New Zealand

The hazards posed by alkaline intraplate magmas to local human populations depend (among other factors) on conditions of pre-eruptive magma storage and evolution. These conditions can usually be linked to specific vertical discontinuities, such as the MOHO and lithosphere-asthenosphere boundary. Generally, magmas that have experienced deep storage are comparatively primitive when erupted, whereas more evolved magmas are associated with shallower storage. This is because ambient temperatures increase with depth and extensive fractionation isn't favoured by high temperatures. This pattern is evident in the compositions of erupted melts and magmas since most intraplate magmas can be shown to have evolved along olivine-clinopyroxene cotectics that are strongly pressure-sensitive. Experimental calibrations of this sensitivity, in combination with analytical data for intraplate volcanic rocks, minerals and glasses, reveal variations in pre-eruptive depths of storage that are characteristic of particular localities and settings. Thus alkaline intraplate magmas from Cainozoic lava fields in eastern Australia appear to have evolved under conditions matching those of the lithosphere-asthenosphere boundary, with the same being true of the Recent Auckland Volcanic Field in New Zealand. In contrast, examples from recent eruptions of La Palma in the Canary Islands, the 2018 submarine eruption off Mayotte in the Comoros Islands, the Quaternary Eifel Province of Germany, and the Honolulu post-erosional volcanics of Hawaii, show evidence of magmas having evolved at two or more contrasting depths (sometimes sequentially). Shallower depths of storage (upper-crust to shallow lithospheric mantle) are more usually associated with bimodal volcanism and deliver the greatest potential for highly-evolved and dangerous magma types. The mechanisms associated with major pluton development and large ignimbrite eruptions appear to be different, in at least some critical respects, from those that have just been described. Whether these are simply matters of time and scale, or involve additional factors, is a matter for further research.

1066

A Review of Pre-Eruptive Dynamics at the Campi Flegrei Caldera in the last 40 ky

Dr Maurizio Petrelli[1], Mónica Ágreda López[1], Alessandro Pisello[1], Diego Perugini[1]
[1]*Department of Physics and Geology, University of Perugia, Perugia, Italy*

We review pre-eruptive dynamics and evidence of open-system behavior in the volcanic plumbing system at Campi Flegrei Caldera, together with estimates of magma residence time, magma ascent, and mixing-to-eruption timescales. In detail, we start with a review on pre- and syn-eruptive dynamics reported in the literature for a) the Campanian Ignimbrite ~40ka, b) the Neapolitan Yellow Tuff (~15ka), and c) the recent activity within the Phlegrean area. We summarize evidence (e.g., magma mixing, crystal disequilibria, vertical zonings, and isotopic records) of open-system behavior on the pyroclastic erupted in the last 40 ky at Campi Flegrei Caldera. We show that the fingerprinting of open-system dynamics is ubiquitous in the volcanic products belonging to the volcanic activity at the Campi Flegrei Caldera in the last 40 ky. Then, we describe the architecture of the magma feeding system. We point to a trans-crustal magmatic feeding system characterized by a main storage reservoir hosted at ~9 km that feeds and interacts with shallow reservoirs, mainly placed at 2-4 km. Finally, we define a scenario depicting pre-eruptive dynamics of a possible future eruption and we provide new constraints on timescales of magma ascent. Results show that considerably fast ascent velocities (i.e., units to tens m/s) can be easily achieved for eruptions fed by both shallow (i.e., 3-4 km) and deep (i.e., ~9 km) reservoirs. Comparing the results from experimental and numerical methods, it emerges that mixing to eruption timescales occurring at shallow reservoirs could be of the order of minutes to hours. Finally, we highlight the volcanological implications of our timescale estimates for magma ascent and mixing to eruption.

637

The transition between mildly-explosive to caldera-forming eruptions at Colli Albani volcano

Mrs Mónica Ágreda López[1], Corin Jorgenson[2], Luca Caricchi[2], Guido Giordano[3], Maurizio Petrelli[1]
[1]*Department of Physics and Geology, University Of Perugia, Perugia, Italy,* [2]*Department of Earth Sciences, University of Geneva, Geneva, Switzerland,* [3]*Department of Science, University of Roma Tre, Rome, Italy*

The effusive-explosive transition in mafic magmas is a complex problem still largely debated (Andújar and Scaillet 2012; Roggensack et al. 1997) and could represent a significant underestimated risk. We focus on Colli Albani volcano, an ultrapotassic caldera complex located 30 km SE of Rome. This volcano has exhibited a wide range of eruptive behaviours throughout its history, ranging from effusive activity to highly explosive eruptions (Giordano and CARG Team 2010). Here, we focus on two main eruptive sequences: The Fontana Centogocce formation (SLV), and the Villa Senni ignimbrites (VSN). SLV represents a prolonged period of mainly mild-explosive to effusive eruptions and preceded the emplacement of the 50 km3 Villa Senni ignimbrites (VSN), which represent the last caldera-forming event of the volcano.

In this study, we use field and petrographic observations together with clinopyroxene chemistry and machine learning thermobarometry to understand and constrain the factors involved in the transition from mildly-explosive to caldera-forming eruption. We propose a reconstruction of the architecture of the volcanic plumbing system and an interpretation of how the system rebuilds in its interim after one of these large events.

Andújar, Joan, and Bruno Scaillet. 2012. “Relationships between Pre-Eruptive Conditions and Eruptive Styles of Phonolite-Trachyte Magmas.” Lithos 152: 122–31.

Giordano, Guido, and CARG Team. 2010. “Stratigraphy, Volcano Tectonics and Evolution of the Colli Albani Volcanic Field.” Rendiconti Online Societa Geologica Italiana 11(1): 279–80.

Roggensack, Kurt, Richard L. Hervig, Steven B. McKnight, and Stanley N. Williams. 1997. “Explosive Basaltic Volcanism from Cerro Negro Volcano: Influence of Volatiles on Eruptive Style.” Science 277(5332): 1639–42.

329

Detecting precursory volcanic gas variations prior to Stromboli's more violent (major) explosions: close or far?

Professor Alessandro Aiuppa[1], Marcello Bitetto[1], Dario Delle Donne[2], Joao Lages[1], Francesco Paolo La Monica[1], Giancarlo Tamburello[3]
[1]Distem, Università Di Palermo, Palermo, Italy, [2]INGV-Osservatorio Vesuviano, Napoli, Italy, [3]INGV-Sezione di Bologna, Bologna, Italy

The last two decades have assisted to major progresses in our ability to instrumentally monitor, in nearly real-time, the composition and flux of volatiles released by active and quiescent volcanoes. The Multi-GAS technique has revealed especially useful in recording robust and nearly continuous volcanic gas composition time-series at open-vent volcanoes, and Stromboli (in Sicily) has been one of the preferred target for such studies. Multi-GAS volcanic gas observations at this volcano are especially motivated by the need of identifying precursors to the violent, potentially hazardous vulcanian-style blasts that frequently interrupt the "regular" mild Strombolian activity. Here, we review recent (2020-2022) volcanic gas time-series acquired at Stromboli using a permanent Multi-GAS network, in the attempt to demonstrate the utility of gas studies for detecting precursory variations in the run-up to Stromboli's "major explosions". We show these sudden, short-lived but relatively frequent blasts, >10 of which have occurred during the observation interval, are anticipated by systematic increases in the volcanic plume CO2/SO2 ratio, typically occurring weeks beforehand. We interpret these precursory variations as caused by passive CO2-rich gas bubble leakage from an accumulating foam layer on-top of a deep (>>3 km) reservoir. First example of the use of machine learning algorithms are illustrated that support robustness and statistical significance of such CO2/SO2 ratio pre-explosion changes, opening new promises for their potential use as an explosion forecast tool.

1292

Forecasting the Onset of an Eruption Using the Increase in Seismicity Due to Seismic Migration

Mr Andika Bayu Aji[1,2], Dr Benoit Taisne[1,2], Dr Lauriane Chardot[1]
[1]Nanyang Technological University, Earth Observatory of Singapore, Singapore, Singapore, [2]Asian School of the Environment, Nanyang Technological University, , Singapore

The Failure Forecast Method (FFM) has been used to forecast the onset of volcanic eruptions with various degrees of success. The method involves fitting its empirical equation with precursory observables, e.g., seismic data. However, it requires that the seismic observables be related to accelerated fracture growth and the effect of migrating sources be filtered out. In this study, we argue that the seismic increase due to migrating sources can be used for eruption forecasts using the FFM. Our argument is based on the need for magma to migrate towards the surface to produce an eruption. To test our argument, we used synthetic and real data. The synthetic data is generated using the Amplitude Source Location (ASL) model, and the real data is from Piton de la Fournaise eruption on January 2nd, 2010. We used seismic amplitudes and seismic amplitude ratios as the precursory observables, and used a combination of Simulated Annealing and Bayesian Inversion algorithms to give the best-fit parameters and their posterior distributions. For the synthetic cases, we found that the method gave reasonable estimates of failure or eruption time, suggesting that seismic amplitudes and seismic amplitude ratios can be used for forecasting. For the real cases, the results gave insight into the timing of magma chamber failure, magma propagation, and the eruption onset. Our results highlight an example of modelling volcano monitoring data with the FFM that still gives reasonable estimates of eruption time. We suggest that this may still be reasonable owing to the empirical and asymptotic nature of the FFM combined with the underlying physics of magma migration.

Keywords: Failure Forecast Method (FFM); seismic migration; amplitude ratio; Piton de la Fournaise

469

Silicic dike propagation at stratovolcanoes: A petrofabric analysis to determine magma transport directions at Summer Coon volcano, CO, USA

Gui Aksit[1], Dr. Meredith Townsend, Dr. Andrew Harp
[1]*University Of Oregon, Eugene, United States*

Dike-fed eruptions can occur at the summit or anywhere along the flanks of a stratovolcano. Accurate hazard assessment in these settings relies on understanding the factors that control dike propagation trajectories. Loading from volcanic edifice growth has been proposed to drive dikes laterally to feed eruptions at low elevations. However, dynamic processes such as volatile exsolution and crystallization can alter magma properties during intrusion, driving changes in magma buoyancy and viscosity that may also influence dike pathways. The role of internal magma dynamics on dike propagation directions in stratovolcanoes remains poorly understood.

Field exposures of dikes provide a unique opportunity to analyze magma transport directions and magma properties at a range of spatial and temporal scales. Here we present data from Summer Coon, an eroded Oligocene-aged stratovolcano located in the San Juan Volcanic Field in Colorado, USA. Three sets of radial dikes are exposed within the edifice: hundreds of early-phase mafic dikes, and approximately 20 middle- and late-phase silicic dikes. The excellent exposure and variety of dike compositions allow for detailed sampling and petrofabric analysis, which we use to test how magma flow direction is impacted by changes in magma properties, both between intrusion events and along the flow path during a single intrusion. We focus on the silicic dikes, which show a wide variety of textures related to magma emplacement, and we compare to previous data collected for the mafic dikes. Ultimately, we aim to integrate field data with modeling to gain quantitative understanding of the relative importance of internal magma dynamics and external stresses on dike propagation directions under modern stratovolcanoes.

1350

Electromagnetic studies at Taal Volcano before and after the 2020 eruption

Dr Paul Karson Alanis[1], Mr Paolo Reniva[1], Ms Princess Sharlynne Cosalan[1,2], Mr Jerome De Lima[1], Mr Allan Loza[1], Mr Juan Cordon[1], Mr Lawrence Aaron Banes[1], Mr Louie Velasco[1], Mr Ricardo Seda[1], Ms Maria Antonia Bornas[1]

[1]Philippine Institute Of Volcanology And Seismology, Quezon, Philippines, [2]Simon Fraser University, Burnaby, Canada

Taal Volcano, located approximately 60km south of Manila in the island of Luzon, is one the most active volcanoes in the Philippines. The first recorded eruption was in 1572 and its most recent activity was in 2022. Pre-2020 eruptions have resulted in thousands of casualties and considerable damage to communities, earning Taal a 1990s Decade Volcano status from IAVCEI. The volcano remained fairly quiescent after the 1977 eruption; however at the beginning of the 1990s, several phases of low-level unrest began that included episodes of seismic swarms, ground deformation, and hydrothermal activity. Such episodes recurred until explosive eruption from its Main Crater commenced in the afternoon of 12 January 2020.

Electromagnetic monitoring of Taal Volcano by PHIVOLCS began in 2005 in cooperation with IUGG-EMSEV, through which three continuous EM stations and repeat electromagnetic surveys were established. A five-year project for electromagnetic observations were later undertaken as part of the PHIVOLCS-JICA-SATREPS Project (2010-2014). Three Overhauser-type magnetometers and one fluxgate-type magnetometers were later operationalized on Taal Volcano Island. In result, magnetotelluric methods were able to image a large hydrothermal reservoir beneath Taal Volcano Island. The EM stations along with all real-time geochemical and a few geophysical and geodetic stations on Taal Volcano were lost during the eruption. From the 2020 unrest and to present, regular microgravity measurements around Taal Caldera and later on Taal Volcano Island were undertaken, providing critical constraints to post-eruptive ground deformation behavior. Electromagnetic observations have restarted in 2022 with the establishment of benchmarks around the coastline and a baseline post-eruptive total magnetic field anomaly field of Taal Volcano Island.

786

Constraints on the timing of East Asian explosive volcanism: insights from cryptotephra deposits preserved in marine and lacustrine archives

Dr Paul Albert[1], Dr Gwydion Jones[1], Prof Victoria Smith[2], Dr Victoria Cullen[2], Dr Ken Ikehara[3], Dr Richard Staff[4], Prof Takehiko Suzuki[7], Dr Hannah Buckland[1], Dr Danielle McLean[2], Prof Takeshi Nakagawa[5], Dr Takuya Sagawa[6]

[1]Swansea University, Swansea , United Kingdom, [2]University of Oxford, Oxford, United Kingdom, [3]Geological Survey of Japan, Tsukuba, Japan, [4]Scottish Universities Environmental Research Centre, Glasgow, United Kingdom, [5]Ritsumeikan University, Kusatsu, Japan, [6]Kanazawa University, Kanazawa, Japan, [7]Tokyo Metropolitan University , Minamiosawa, Tokyo, Japan

Volcanic hazard assessments are in part constrained by our understanding of the past behaviour of eruptive centres, which is largely reconstructed using tephra deposits preserved near to the volcano. However, these near-vent eruption records are often fragmentary and incomplete hampering the accuracy of hazard assessments. Gaps in these near-source records are more acute deeper in time, and consequently reconstructions are biased towards shorter-term records which do not reflect the full range and frequency of eruptive activity. While there is evidence to suggest that even large magnitude eruptions are sometimes lost from the near-source record, owing to burial and/or erosional processes, statistical analysis of global eruption databases reveals that low- to mid-intensity eruptions are especially vulnerable to under-recording.

Here we capitalise on the potential of long, undisturbed records of ash fall events preserved in East Asian marine and lacustrine sedimentary archives, typically positioned >100 km from regional volcanic sources, to plug the gaps in eruption records. The extraction and identification of microscopic ash layers (termed cryptotephra) from sedimentary archives is adopted to provide important constraints on the timing of mid-intensity explosive eruptions which are frequently under-reported at volcanic source. Specifically, following detailed cryptotephra investigations we presented a new eruption record captured by the high-resolution sediments of a Wakasa Bay (Sea of Japan) marine core, WB06, which spans the last 100,000 years. Detailed geochemical fingerprinting is used to assign 28 tephra and cryptotephra deposits to volcanic source, and where possible to known eruptions. Furthermore, these chemical signatures are used to link the WB06 tephra to those preserved in the precisely dated sediments of Lake Suigetsu (Honshu Island), providing important chronological constraints on this newly developed eruption record. Our investigations provide evidence of near-vent under-reporting (or grouping) of explosive eruptions and new insights into the repose periods between pre-historic eruptions at individual volcanoes.

261

The Role of Data Resolution in EnKF Forecasts of Volcanic Unrest: Looking Forward to NISAR

Dr John Albright[1], Dr Patricia Gregg[1]
[1]*University Of Illinois Urbana-Champaign, Department of Geology, Urbana, United States*

The upcoming NASA ISRO Synthetic Aperture Radar (NISAR) satellite is expected to provide regular high-resolution measurements of ground deformation at active volcanic systems around the world. However, satellite-based observations are often prone to long seasonal gaps in availability due to snow and ice coverage. We therefore seek to determine the impact such gaps may have on efforts to model the long-term stability of a volcano's underlying magma system, and whether ground based geodetic observations can be used to compensate. Synthetic geodetic datasets are generated above a simulated magma reservoir, each varying the size of the terrestrial observation network and the seasonal availability of satellite observations. The synthetic datasets are separately analyzed using the Ensemble Kalman Filter (EnKF), a data assimilation algorithm that uses a Monte Carlo suite of numerical models to find magma reservoir parameters consistent with the assimilated measurements. We find that the EnKF is mostly unaffected by gaps in satellite coverage, quickly converging and closely matching satellite readings whenever they become available. While ground-based geodetic stations maintain the fidelity of the inverted model during data gaps, they do not significantly improve or hinder the overall performance of the assimilation. Ultimately, the filter has some trouble exactly matching the original reservoir parameters due to the non-uniqueness of geodetic measurements. However, the EnKF still constrains the magma system to a relatively narrow range of states. Future monitoring efforts may therefore wish to focus on non-geodetic measurements that can provide alternative constraints on magma system stability.

870

PRECURSORS, DYNAMICS AND POSSIBLE TRIGGERING MECHANISM(S) OF THE 1976-1977 PHREATIC ERUPTIVE CRISIS AT LA SOUFRIERE ANDESITIC VOLCANO, GUADELOUPE

Dr Patrick Allard[1]
[1]*Institut de Physique du Globve de Paris (IPGP), Paris, France*

Phreatic eruptions - the most common type of volcanic eruptions - can either occur as intrinsic discrete events, for instance due to pressurization of a sealed hydrothermal system, or characterize the forephase of an impending magmatic eruption. They usually are sudden events, can display a wide range in magnitude and can be lethal to people close by. Deciphering their actual source mechanism is thus of outmost importance given the widely different implications in terms of hazard assessment. This can be attempted by combining geophysical monitoring, geochemical survey of hydrothermal fluid emissions, and analysis of emitted ash particles.

La Soufrière of Guadeloupe (Lesser Antilles arc) is a school-case andesitic volcano where several phreatic (steam-blast) eruptions have occurred since a last magmatic eruption in 1530 AD. As demonstrated by isotopic tracers, intense hydrothermal activity and fumarolic degassing at this volcano are sustained by the supply a heat and magma-derived gas from a reservoir emplaced at ca. 6 km depth beneath the volcano. In 1976-1977 a 7-months phreatic eruptive crisis, preceded by and associated with intense seismicity, involved 26 discrete steam-blast outbursts, making fear a forthcoming magmatic eruption and leading to the 4-month evacuation of 73,000 people. At that time a strong controversy publicly developed among French scientists about the possible source mechanism of this eruptive sequence, making it a renowned example of how bad communication during a volcano emergency can be damaging. 47 years later I propose to review the main features of the 1976-1977 eruptive crisis, in which I was personally involved, and to revisit the different interpretations proposed for its triggering mechanism.

713

The complex architecture of dykes

Miss Ceri Allgood[1], Professor Ed Llewellin[1], Dr Madeleine Humphreys[1], Dr Rich Brown[1], Dr Charlotte Vye-Brown[2]

[1]*Durham University, Durham, United Kingdom,* [2]*British Geological Survey, Edinburgh, United Kingdom*

A detailed study of dykes in the Teno Massif, Tenerife, unearthed several interesting features that challenge the way we think about dykes and their emplacement. Far from being simple, planar features, the dykes were found to have a complex geometry. Every dyke studied was segmented, with segments varying in length from tens of centimetres to a few hundred metres, and all showed vertical and lateral variations in width, dip, strike and internal textures. Most importantly, the same dyke could be found to be segmented in both vertical and horizontal cross-sections, suggesting that its overall 3D shape consists of a series of branching, overlapping, plate-like lobes. Within the dykes, textures were commonly found to show a banded pattern, either showing variation in the type, size or concentration of phenocrysts, or in the size or concentration of vesicles. Banded margins were particularly common, though not always present. The formation of banded textures could have several causes, such as sequential magma pulses, fluctuating flow rates, a changing composition, or flow differentiation. These findings provide evidence that dyke emplacement is not a simple process involving a single magma injection that propagates upwards, stalls, then rapidly solidifies. Instead, we propose that the transport of magma towards the surface is pulsatory in nature, involving stalling and restarting, splitting into segments, the development of preferential flow paths and the solidification of failed branches. The complex architecture of dykes therefore has implications for the way we interpret dykes in the field, and the way we interpret seismicity associated with subsurface magma transport.

716

Banding in the margins of dykes indicates pulsatory propagation

Miss Ceri Allgood[1], Professor Ed Llewellin[1], Dr Madeleine Humphreys[1], Dr Rich Brown[1], Dr Charlotte Vye-Brown[2]
[1]Durham University, Durham, United Kingdom, [2]British Geological Survey, Edinburgh, United Kingdom

Rock textures within exposed, solidified dykes provide a means to investigate subsurface magma flow, which likely influences the behaviour of fissure eruptions at the surface. We have found small-scale (mm – cm wide) banding features at the margins of dykes in the Teno Massif, Tenerife, and the Columbia River Basalts. These marginal bands are of particular interest because the margins are the oldest material within the dyke, and comprise the earliest magma to enter the fracture at the dyke tip. The bands therefore hold valuable information on dyke tip processes and dyke propagation.

The bands get wider and less distinct towards the intrusion centre, and are defined by variations in phenocryst concentration and vesicularity. Marginal bands showing these same trends have been found in dykes from various volcanic settings, and their similarity suggests a common, if not ubiquitous, formation process related to dyke propagation. By treating the textures as a time series, with the oldest material at the dyke wall, we determine that the cyclic variations in textures are a product of fluctuating magma flow rates and pressures within the dyke tip. Using a 1D conduction model, we find the time taken for each band to cool and solidify, which provides a timescale for the flow variations that created them. We therefore infer that propagation is not a continuous process, but occurs in pulses lasting seconds to minutes, repeatedly hindered by the solidification of magma in the narrow dyke tip. As such, these marginal bands have implications for our understanding of dyke propagation, especially around the role of solidification, and how the dyke instigates fracturing.

604

Rapid magma ascent for the Kos Plateau Tuff caldera-forming eruption recorded in quartz-hosted embayments

Chelsea Allison[1], Josef Dufek[2], Kenneth Befus[1], James Thompson[1,3], Olivier Bachmann[4], Anna Ruefer[5]
[1]Baylor University, Waco, United States, [2]University of Oregon, Eugene, United States, [3]University of Pittsburgh, Pittsburgh, United States, [4]ETH Zürich, Zürich, Switzerland, [5]Stanford University, Stanford, United States

The Kos Plateau Tuff was emplaced ~160 ka from a rhyolitic caldera-forming eruption in the Aegean arc. The >60 km³ DRE deposit consists of 6 eruptive units (A-F) in which units D and E are non-welded ignimbrite from the climactic phase. The other units are volumetrically small fall deposits and pyroclastic density currents that are partly phreatomagmatic. We assess magma ascent rates across the eruptive stratigraphy using Fourier transform infrared spectroscopy of quartz-hosted, glassy, cylindrical embayments ~150-400 µm in length. The current sample cohort includes embayments from units C, D, and E, with the majority from E. Embayments display gradients in H_2O, with interior contents between 4.5 and 6.5 wt% and contents at the exit ranging from 2.5 to 5.5 wt%. Most embayments do not contain CO_2; those with CO_2 display gradients from <100 ppm in interiors to lower contents at the exit. Volatile contents in embayment interiors are consistent with melt inclusion data from previous studies. Assuming fluid saturation, these volatile contents correspond to pressures of ~120 to 230 MPa at embayment interiors and ~40 to 170 MPa at exteriors. We use finite-difference modeling to solve for diffusion-limited decompression of the embayments in 1D. Results indicate very short ascent durations (<10 min) and rapid decompression (0.1 to 1 MPa/s). Modeling of the few embayments with CO_2 suggests that the magma may have contained a significant mass of exsolved volatiles upon the initiation of ascent. The modeled ascent rates overlap between the different eruptive phases, and they represent some of the fastest rates determined from embayments in rhyolitic eruptions.

1398

Eruptive history of the Barva volcano in the last 11,000 years

Miss Yemerith Alpízar Segura[1,2], Dr. Guillermo E. Alvarado Induni[3], Dr. Paulo J. Hidalgo-Odio[4], Deina Arroyo Alpízar[2], Carlos J. Ramírez Umaña[5]

[1]National Technical University , Alajuela, Costa Rica, [2]University of Costa Rica, San José, Costa Rica, [3]Costa Rican Electricity Institute , San José, Costa Rica, [4]Georgia State University, Atlanta, United States, [5]Environmental and Geological Service (SEGEOAM), San José, Costa Rica

At the summit of the Barva volcano, located 23 km north from the center of San José, at least seven explosive events have been recognized for the last 11,000 years, separated by apparently prolonged periods of calm. The deposits of the eruptions have been named alphabetically, naming "A" to the oldest level and "H", to the most recent unit, which corresponds to the last explosive event of this volcano. Age of Unit A, is not kown yet, but it underlies Unit B which has been dated to approximately 8700 B.C. The lapses of inactivity vary between 800 and 2800 years; approximately 680 quiescent years have passed since the last eruption, recorded at ~1340 A.D. At least one subplinian and one strombolian eruption have been recorded during the Holocene, both with deposits restricted to the summit, vulcanian activity predominating in the rest of the eruptions. If it is considered that during these last 11,000 years the Barva has not shown large or relevant eruptions in terms of affectation at the regional level, but rather that its deposits have been restricted to a radius of approximately 5 km around the cone where the crater lake is located del Barva, it is possible to affirm that it does not represent an important danger in the short or medium term, unless it evolves towards a dacitic magma with a large volume. Currently, the pyroclastic samples are being processed to carry out the geochemical, granulometric and morphological characterization by means of electron microscopy (SEM-EDS). It is still pending to establish the chronological sequence of the ten eruptive foci present at the top of Barva. This is a fundamental basis for the evaluation of volcanic hazard.

260

Degassing-derived eruptions at Deception Island (Antarctica): geochemistry of noble gas isotopes with implications for volcano forecasting

Dr Antonio M. Alvarez-valero[1], Dr Hirochika Sumino, Dr Antonio Caracausi, Mr Antonio Polo Sánchez, Prof Ray Burgess, Dr Adelina Geyer, Dr Javier Borrajo, Dr José Antonio Lozano Rodríguez, Dr Helena Albert, Dr Meritxell Aulinas, Ms Elena Núñez Guerrero
[1]*University Of Salamanca, Salamanca, Spain*

Deception Island is one of the most active volcanoes in Antarctica with more than twenty explosive eruptions in the past two centuries and characterised by three main episodes: pre-, syn- and post-caldera. The magmatic history of this volcano has been widely studied from the petrologic and geochemical perspectives(1). We combined this information with the analysis of helium, neon and argon isotopes measured in inclusions hosted in olivine samples thus offering insights into the processes governing its volcanic history. Noble gas isotopes represent an excellent tool helping to decipher the origin of the Earth materials because of their unique isotopic ratios in each geochemical reservoir. They are also particularly useful for tracing the evolution of these materials as their elemental ratios record modifications produced by key magmatic processes such as degassing, melting and crystallization(2). Our results show that: (i) ascending primitive magmas outgassed volatiles with a MORB-like 3He/4He isotopic signature; and (ii) variations in the helium isotope ratio, as well as intensive degassing evidenced by fractionated 4He/40Ar* values, occurred before the beginning of the main eruptive episodes.

At Deception Island, an upcoming volcanic eruption is a serious concern for scientists and tourists, a detriment to marine ecosystems and could have an impact to global oceanographic processes. Yet it is not possible nowadays to carry-out low and high frequency volcanic gas monitoring because of the hard climatic conditions and remote location of this volcano. Our research on the pre-eruptive signals of the volcanic activity at Deception Island contributes to a better understanding of the magmatic dynamics with the potential to improve eruption forecasting.

(1) Geyer et al., 2019. Sci.Rep.; (2) Burnard, 2001, GCA

259

Alteration-related minerals from fluid-rock interactions: implications for new clues assessing volcanic hazards

Dr Antonio M. Alvarez-valero[1], Dr Gabor Kereszturi, Dr David Benavente, Dr Bruce Christenson, Dr Adelina Geyer, Dr Mercedes Suárez, Dr Masao Ban, Dr Takumi Imura, Ms Andrea Ferre, Mr Ignacio Ledesma, Mr Oriol Vilanova, Ms Raquel Arasanz
[1]*University of Salamanca, Salamanca, Spain*

Magmatic heat and fluids can interact with a volcanic host rock to form secondary minerals, such as phyllosilicates, zeolites, sulfates, sulfides and oxides. The water-rock reactions, inducing alteration of the primary volcanic material, strongly depend on the magma chemistry and volatile flux, and the nature of the aquatic environment (i.e., sea/ocean and meteoric) and its properties such as temperature, salinity, redox and pH. The newly-grown alteration minerals result from the chemical reaction between the host rock and they can indicate particular physico-chemical conditions. Hence, the mechanisms controlling the formation of secondary mineral associations can be critical, not only for assessing the role of hydrothermally altered host rocks in moderating eruptions styles but also for volcano flank instabilities.
In this study, we applied mass balance calculations and thermodynamic modelling to establish the formation and equilibria environments of alteration minerals and hydrothermal fluids at three active volcanic suites: Ruapehu (New Zealand), Mt. Zao (Japan) and Deception Island (Antarctica). Results indicate that the secondary minerals follow different precipitation sequences as a function of the magma composition and the primary mineral assemblage (basalt-andesitic to dacitic for Ruapehu, andesitic for Mt. Zao, and basaltic for Deception Island). Temporal variations in composition and abundances of the hydrothermal paragenesis in Ruapehu and Mt. Zao determinate the evolution of acid–sulfate alteration zones.

We conclude that the combination of the proposed petrologic-geochemical approach, the regional and local tectonic features, and the spatial distribution of the alteration minerals within the volcanic edifices can be used for the assessment of future hydrovolcanic eruptions (including multiple eruption phases) and/or instability flanks episodes. In addition, the biological submarine and global change communities can also benefit from this geochemical procedure in other worldwide submarine volcanoes as the water-rock chemical reaction has direct implication in the oceanic productivity.

253

Suitability of PRISMA sensor for characterizing the mineralogical features in demanding "wet and muddy" volcanic environment

Dr Stefania Amici[1], Dr. Maria Fabrizia Buongiorno
[1]*Istituto Nazionale Di Geofisica E Vulcanologia, Rome, Italy*

Imaging spectroscopy is technology which allows to identify surface materials by analyzing the spectra which result from the light-material interaction. While the technology has been widely used at both in situ and airborne scale, the observation from space has been limited by availability of space missions equipped with such sensors.

With the new generation of hyperspectral missions (i.e. PRISMA, EnMap, Chime, SBG) the potential for mineralogical characterization in challenging environment can be potentially explored In this study we analyze imagery acquired by the PRecursore IperSpettrale della missione operativA (PRISMA) mission. PRISMA developed by Italian Space Agency and launched on March 2019. PRISMA instruments operate in pushbroom mode with a 30km wide imaging swath composed by two cameras: the optical spectrometer (hyperspectral camera) operates in the spectral range spanning between 400-2500nm with a spectral resolution ≤12 nm and at Ground Sampling Distance (GSD) of 30m/pixel and a Pancromatic camera that acquires the same area at 5m/pixel. The study area we selected, is a sediment-hosted geothermal system named LUSI which is the contraction of LUmpur SIdoarjo.

We show the potential suitability of using this kind of sensor for characterizing the mineralogical features in demanding environment such as Lusi. We use spectral library reflectance spectra like Illite, Chlorite, which are known to be associated with Lusi volcanic products and compare them with reflectance spectra from PRISMA. Finally, the obtained results are discussed and the key points for future investigation are highlighted.

1443

Phases and magnitude estimation of volcanic eruptions in Chile during the last 50 years

Dr Alvaro Amigo[1]
[1]Geological And Mininig Survey Of Chile (sernageomin), Santiago, Chile

Due to the eruption of Chaitén volcano in 2008, SERNAGEOMIN created the National Network for Volcanic Surveillance, which is currently monitoring the most active volcanoes in the country. In addition, geological studies have been done at the high-risk volcanoes in order to develop hazard maps. One of the goals of this network is to communicate future eruptive scenarios to decision-makers, local authorities and exposed communities.

In the last decades, several volcanic eruptions have occurred in both the Andean Central and Southern Volcanic Zones, which have affected zones in both Chile and Argentina, however their duration, composition of products and eruptive behavior have been diverse. For instance, some eruptions have been short but explosive such as Calbuco (April, 2015) and Villarrica (March, 2015). On the other hand, other eruptions have been long-lasting events including explosive and effusive phases such as Chaitén (2008-2009) and Puyehue-Cordón Caulle (2011-2012). Accordingly, the impacts of the eruptions have been different as well as hazard communication.

In this study a review is presented in order to better characterize the eruptive cycles in Chile occurred in the last 50 years, including magmatic compositions, phases, mass and/or volume estimations and impacts on communities. Also, when available, the timing of the unrest is discussed. This characterization will help to better indentify analog volcanoes in Chile which will help to establish future scenarios.

703

Structure and eruption sequence of an immature magma system: 61 ka Shadai eruption of Shikotsu volcano, southwestern Hokkaido, Japan

Dr Mizuho Amma-miyasaka[1], Professor Mitsuhiro Nakagawa[1]
[1]*Hokkaido Univ., Sapporo, Japan*

To understand preparation process of a large silicic caldera-forming magmatic system, we examine structure and eruption sequence of magmatic system of the 61 ka Shadai; pre-caldera eruption of Shikotsu volcano. The eruption deposits are classified into Unit A of pumice fall (4.5 km3), Unit B of scoria fall (13.0 km3) and Unit C of scoria flow deposits (33.0 km3). Juvenile components consist only of pyroxene dacitic pumice in Unit A, but olivine-bearing scoria and banded/gray scoria become the main component in Unit B and Unit C in addition to dacitic pumice (pumice:scoria=ca.1:3). According to the phenocryst assemblage and compositions of crystal-clots, zonal structure of phenocrysts and whole-rock compositions, we have recognized that plural hybrid pumice and hybrid scoria magmas with no parentage relationships should have related, and showed formation process of 'immature' magmatic system and eruption sequence of the 61 ka Shadai eruption. The andesitic and dacitic melts, probably generated by a heat of mafic magma, accumulated to form plural small magma batches of crystal-rich hybrid pumice at 4-10 kbar <450 years before the eruption. Then, large amount of mafic melts also ascended, accumulated, and incorporated pieces of hybrid pumice magma to form hybrid scoria magma batches at <2 kbar <a year before the eruption. The hybrid pumice magma independently erupted during Unit A, but the hybrid scoria magma and mingled magmas were also supplied through independent, multiple vent system during Unit B and Unit C (the mingling of hybrid pumice and hybrid scoria magmas occurred within <several weeks). The supply of large amount of mafic melts would have activated the 'immature' magmatic system and influenced the formation of 'mature' large silicic magma (melt extraction and accumulation from the mush zone) of 45 ka caldera-forming eruption.

229

Thermal continuity during magma recharge of distinct magma reservoirs at South Sister Volcano, Oregon Cascades, USA

Nathan Andersen[1], Annika Dechert[2], Mai Sas[3], Josef Dufek[2]
[1]US Geological Survey, Vancouver, United States, [2]University of Oregon, Eugene, United States, [3]Western Washington University, Bellingham, United States

Recent crystal-scale petrologic and geochronologic investigations of intermediate to silicic systems have shown distinct magma reservoirs may accumulate simultaneously within the same magma system. South Sister volcano, Oregon Cascades, USA, has repeatedly erupted rhyolite over the last 50 ka, including the late-Holocene Rock Mesa (RM) and Devils Chain (DC) rhyolites. The RM eruptions issued from a cluster of vents on the SW flank of the volcano yielding a main lava flow and several satellite domes. The DC rhyolites comprise a N-S chain of domes and flows erupted from vents 3-5 km east of the RM vents. Despite broadly similar compositions, mineralogy, and their spatial-temporal proximity, previous zircons dates and compositions indicate these rhyolites accumulated over >50 ka in physically distinct reservoirs. We present crystal-scale compositions and modeling to investigate magma recharge and the temperature changes preceding these eruptions. Several observations support the rejuvenation of the RM reservoir shortly prior to eruption: a wide range of plagioclase (plag) An and orthopyroxene (opx) Mg# compositions; rare clots containing high-An plag and olivine; and, common reversely zoned opx rims consistent with increased temperature. Initial Fe-Mg interdiffusion modeling indicates this temperature increase occurred years to decades prior to eruption. Whereas the plag in the DC rhyolite reach similar high-An compositions, the opx have a relatively restricted range of Mg# and rare reversely zoned rims. Instead, thin, normally zoned rims mantle interior reverse zoning. The interior Fe-Mg gradients are relatively relaxed compared to less mobile elements (Al, Ti, Ca), which suggests a longer period of re-equilibration. Initial modeling suggests storage for 10's-100's of years—with the longest timescales approaching the estimated repose between the RM and DC eruptions. We hypothesize that despite being derived from physically distinct reservoirs, both rhyolites record a similar period of magma recharge reflecting thermal continuity within a heterogeneous magma system.

460

Interacting with Officials and the General Public: What Geoscience Education Research Can Tell Us About Effective Hazards Communication

Dr Steven Anderson[1]
[1]*University Of Northern Colorado, Greeley, United States*

Communicating geoscience concepts to public officials and the general public is challenging, in part, because of the differences in experiences and education between the scientists (experts) and their audience (ranges from novices to experts). This is especially true when trying to convey volcanic hazards information because difficult volcanologic concepts are typically intermixed with statistics and social science issues. There is a large body of work on the differences between geoscience experts and novices in terms of understanding how volcanoes work and their potential affect on people, and this information may help those involved with hazard mitigation better communicate with their audience. First, research shows that experts tend to greatly overestimate the background and abilities of their audience, and tend to explain concepts in a manner that is too advanced. Experts attempting to make their explanations understandable typically use jargon and analogies that may confuse their audience or reinforce common misconceptions that are a barrier to learning. Visual examples in the form of images or videos are typically used by experts to communicate with novices, but experts must be cognizant of the fact that novices may have little or no experience with the concept, and that their visual example may be misinterpreted by the novice because of their lack of familiarity with scale or magnitude of movement. It is therefore more effective to show a range of examples so that the novice does not leave with a narrow view of the concept. Finally, experts need to realize that learning geoscience concepts is typically a slow endeavor, requiring a strategy that engages the novice audience numerous times over an extended period to ensure learning. Therefore, providing links to additional learning materials may be needed for learning occur.

1371

Deployment of a UAV-Borne Flask-Based Sampler for Volcanic Gas and Water Sample Collection

Dr Matthew Anderson[1], Mr Mikey Gonzalez[1], Dr Ery Hughes[2], Dr Mike Baker[1], Prof. Soon-Jo Chung[1], Prof. Edward Stolper[1]
[1]Caltech, Pasadena, United States, [2]GNS Science, , New Zealand

Continuous volcano monitoring is essential for establishing baselines at quiescent volcanoes and for detecting signs of possible renewed volcanic activity. Monitoring also provides important information for assessing volcanic hazards. Many fumarole gas and volcanic lake water measurements require samples to be returned to the laboratory and thus these measurements are often made sporadically due to the challenges of sampling in a rugged and/or remote volcanic environment. During periods of volcanic unrest, monitoring becomes increasing important, but also more dangerous especially for direct sampling of volcanic gases and lake waters.

Uninhabited Aerial Vehicles (UAVs) are increasingly being used in volcanic monitoring for tasks such as measuring selected gases in volcanic plumes with multi-gas sensors, providing accurate maps of the changing surface of the volcano, and deploying sensors to locations that would otherwise be inaccessible. However, the types of analyses that can be made with multi-gas sensors are limited compared to those that can be made in the laboratory and thus collecting volcanic gases and lake samples with UAVs has the potential to provide much more data on the state of a volcanic system compared to in-situ sensors and at a much higher sampling frequency compared to direct sampling by volcanologists (and at much lower risk). We have developed a new type of UAV-borne sampler that can be configured to capture both volcanic gas and water samples into glass sample flasks. Sample site selection is done autonomously using thermal and range-finding sensors, and our robotic sample collection system emulates human “best-practice” techniques. The system features a novel sample line purge system, relying on a sacrificial vacuum flask rather than actively pumping the connection lines, improving the reusability of the sampler over multiple missions. Capture sequences are fully programable, allowing our system to be adapted to many different scenarios.

528

Emulation of volcano deformation sources using machine learning models: a Gaussian process-based approach

Dr Kyle Anderson[1], Dr Mengyang Gu[2]
[1]U.S. Geological Survey California Volcano Observatory, Moffett Field, United States, [2]University of California, Santa Barbara, United States

Continuum mechanical models are widely used to compute ground deformations due to pressure changes in elastic magma reservoirs. Analytical models are fast but do not correctly satisfy boundary conditions for some reservoir geometries, while numerical models may require specialized expertise or software, and the simulations may be slow to run. Here we show that parallel partial Gaussian process (PP-GP) emulators, a supervised machine learning technique, can be used to produce a statistical surrogate model that can overcome these limitations, yielding fast and accurate predictions of numerical simulations for both scalar-valued outputs and vectorized outputs at many coordinates. We use a numerical (finite element) model of a spheroidal cavity in an elastic half-space to compute surface displacements and cavity compressibility as a function of material properties and cavity geometry. Using outputs from a small number of model runs (of order 1e3), we then construct PP-GP emulators which reproduce numerical model outputs at high fidelity but greatly reduced computational cost. Results include both predictions and an estimate of uncertainties in predictions, and are well-suited for use in Markov chain Monte Carlo Bayesian data inversion algorithms. They permit a comprehensive evaluation of the deviation between analytical approximations and numerical models. The general approach can be extended to more complex source geometries and material properties, improving our ability to understand and model ground deformation due to volcanic processes.

527

Morphological evolution of caldera formation at Kīlauea Volcano revealed by multitemporal high-resolution digital elevation models

Dr Kyle Anderson[1], Dr Angela Diefenbach[2], Dr Peter Cervelli[3], Dr Matthew Patrick[4]
[1]U.S. Geological Survey California Volcano Observatory, Moffett Field, United States, [2]U.S. Geological Survey Cascades Volcano Observatory, Vancouver, United States, [3]Cervelli Technical Services, Golden, United States, [4]U.S. Geological Survey Hawaiian Volcano Observatory, Hilo, United States

Few caldera collapses have occurred historically, and fewer still were observed in any detail, leading to many open questions about their governing mechanics and resulting morphological evolution. At Kīlauea Volcano in 2018, the surface expression of 0.8 km3 step-wise basaltic caldera formation was captured in thousands of images systematically acquired over the months-long eruption using aerial and satellite platforms (particularly unoccupied aircraft systems), as well as three high-resolution LiDAR surveys. We construct a time series of 0.5 m digital elevation models (DEMs) and orthophotos using stereogrammetric and structure-from-motion photogrammetric techniques, calibrated using high-rate solutions from the GNSS network. Results reveal the evolving 3-dimensional morphology of caldera formation in detail. The caldera began to grow as a rubbly pit centered on the former lava lake vent, then expanded outwards to involve subsidence of a series of semi-coherent blocks as large as 6 km2 which were separated by a growing network of surface faults and scarps. The caldera's volumetric growth rate may be compared with the rate of lava eruption from fissures in the lower East Rift Zone 40 km distant, and the changing morphology of collapse and fault growth can be related to independent constraints on magma storage geometry and the geophysical expression of collapse. We find that the average volumetric rate of caldera growth was remarkably steady for much of the eruption despite large changes in the locus and area of surface subsidence, although both the rate of caldera growth and lava effusion appeared to wane towards the end of the eruption. Collapse was likely controlled in part by pre-existing structure, consistent with asymmetry in the location of thousands of volcano-tectonic earthquakes recorded beneath the caldera. These insights can be used to directly inform models of caldera formation.

1263

Control of Eruptive Volume and Magma Viscosity on the Volcanic Landscape Evolution

Dr Harisma Andikagumi[1,2], Dr Caroline Bouvet de Maisonneuve[1,2], Dr Benoit Taisne[1,2]
[1]Earth Observatory of Singapore, Nanyang Technological University, Singapore, Singapore, [2]Asian School of the Environment, Nanyang Technological University, , Singapore

The morphology of polygenetic volcanoes is the result of complex processes involving the deposition of volcanic materials that took place over a very long period of time, spanning from hundred thousand to millions of years, making edifice growth observation is impossible to conduct. Here we use analogue modelling approach with controlled-parameters in the laboratory and utilise morphometric parameters to quantify the observation of the volcanic landscape evolution. We investigated the influence of the changes in eruptive volume and magma viscosity on the edifice morphology. We ran the experiment by ejecting vegetable oil repeatedly at a static location in a temperature-controlled room with an adequate interval between ejections to allow this material to solidify. The experiments comprised various scenarios: constant ejection volume and viscosity, decreasing ejection volume with constant viscosity, and increasing viscosity with constant eruptive volume. We described the shapes of the edifices using morphometric parameters, such as height, width, volume, slope, circularity, and regularity. The experiments with decreasing ejection volume produced edifices with taller elevations and steeper slopes, especially near the summit, compared to the edifice produced with constant ejection volume. A similar finding was also observed on the edifice resulting from the experiment with increasing viscosity. The circularity and regularity indexes were insignificantly influenced by ejection volume and viscosity changes, but these parameters vary with the height fraction of the edifice. Moreover, based on the changes of morphometric variables throughout the experiments, we propose three development stages of volcanic edifice growth: basal foundations, flank constructions, and elevation building. Therefore, the development stage in which the edifice currently grows then can be inferred by the relative changes in the eruptive volume and the magma viscosity.

624

The Fold Illusion Reloaded: Brittle-Ductile Spreading Processes Produce Ogives and Talus Blankets on Silicic Lavas

Dr Graham Andrews[1], Dr Shelby Isom[1]
[1]West Virginia University, Morgantown, United States

The tops of silicic lavas are characterized by circumferential ogives and expanses of pumiceous talus. Although long considered evidence of compression during ductile flow, i.e. folds, recent structural observations at several lavas, most notably Obsidian Dome (California), demonstrate that ogives are formed by brittle and brittle-ductile processes. In all observed cases, ogives are defined by curviplanar fractures that truncate flow-banding. Sub-vertical, often splaying, fractures are ubiquitous and follow the same general scale-dependencies of fractures in other media - deeper and longer fractures are splayed apart further and more widely spaced apart. We recognize several scales of fractures that form a continuum from small cracks to ogive-bounding crevasses. Cross-cutting relationships demonstrate that new cracks are forming throughout lava emplacement, and that cracks progressively lengthen-deepen-widen as they connect with one another along strike to produce larger-scale fractures. In rare cases the largest, and therefore possibly earliest initiated, fractures penetrated into lava that was still viscous leading to localized vesiculation, limited eruption of tuffisite, and plastic flow of the fracture walls. In all cases, the fracturing generates angular pumiceous blocks that amass in the clefts and depressions between exposed ogives and towers of obsidian. When considered along with the rheological properties of pumice and the short time scales of emplacement, we conclude that folding at the surfaces of silicic lavas is not supported and is probably impossible on Earth's surface.

625

Strain Evolution Through the Welding-Rheomorphism Continuum

Dr Graham Andrews[1], Dr Sarah Brown[1]
[1]*West Virginia University, Morgantown, United States*

Strain analysis of deformed vesicles and pumice clasts / fiamme in welded ignimbrites reveals the onset of non-coaxial shear strain (rheomorphism) and tracks the progression from medium- to extremely high-grade welding lithofacies. Macroscopic (outcrops and hand samples) and microscopic (x-ray tomography) strain analyses reveal complementary results for strain magnitude and strain shape. These strain parameters can be mapped against lithofacies and reveal that vitrophyres - black, near-avesicular, glass layers devoid of grain fabrics - correspond with significant non-linear changes in strain, implying a significant reduction in deposit strength and viscosity. We infer that primarily compaction-driven welding and coincident porosity reduction achieves the vitrophyre state when porosity is almost irradicated. Once formed, the vitrophyre is significantly weaker than the surrounding less welded deposit and concentrates shear strain parallel to the vitrophyre (i.e. perpendicular to the compaction direction). Only then can large magnitude, non-coaxial shear strains be accumulated and rheomorphic flow initiates. The presence of ignimbrites that are entirely vitrophyres indicates that these processes can occur during deposition from a pyroclastic density current and that the initial compaction-driven welding is achieved during particle aggradation at the aggrading current-deposit interface.

473

Measuring 3D turbulent velocities and air entrainment using video observations of eruption plumes and PDCs

Dr Benjamin Andrews[1], Ms. Allie Coonin[2], Ms. Ayomide Ajayi[3]
[1]Global Volcanism Program, Smithsonian Institution, Washington, United States, [2]Earth and Planetary Science, University of California Berkeley, Berkeley , United States, [3]Department of Geology, University of Maryland, College Park, United States

Turbulent air entrainment into erupting volcanic jets determines whether those jets will reverse buoyancy to rise as plumes or collapse to form pyroclastic density currents (PDCs). Similarly, air entrainment into PDCs affects current density and runout distance, and controls whether a coignimbrite plume forms. Understanding how explosive eruptions entrain air requires understanding their 3D turbulent velocity fields, but measuring those fields is challenging because of the size, hazards, and unpredictability of explosive eruptions. Here we present a recently developed technique for measuring and analyzing the 3D velocity structures of explosive eruptions using observations collected with a single motion picture or video camera. Briefly, by assuming a constant eruption cloud color, we can estimate the 3D geometry of the eruption cloud based upon the angles of the sun and camera with respect to the cloud; the brightness of any given billow on the cloud surface depends upon its orientation to the incident sunlight with bright regions normal to, and darker regions oriented away from, the sun. The turbulent velocity field of the surface is measured using feature tracking velocimetry techniques. Projecting that velocity field onto the 3D surface results in a 3D turbulent velocity field. The time resolution of the velocity fields is the same as the camera framerate (i.e., 30 or 60 Hz for HD video, and 24 Hz for historic film). We measure entrainment as the integral of the inward directed components of velocity. Application of this technique to film and video of historic and recent eruptions shows that vent-sourced plumes entrain air over a larger fraction of their surface (~30%) than PDCs and coignimbrite plumes (~10%), and that entrainment velocities are proportional to the turbulence intensity. This work builds upon work by Andrews and Coonin (in revision) and Ajayi and Andrews (AGU, 2021).

852

SNGXtal – Modeling Crystal Nucleation and Growth in Magmas

Dr Benjamin Andrews[1], Dr. Aaron Marshall[2]
[1]*Global Volcanism Program, Smithsonian Institution, Washington, United States,* [2]*Central Plateau Cleanup Company, Richland, United States*

Supersaturation Nucleation and Growth of Crystals (SNGXtal) numerically models crystal population dynamics. The model extends earlier an earlier model of plagioclase (SNGPlag; Andrews and Befus, 2020) to additional crystal phases including clinopyroxene and olivine. SNGXtal steps through a specified pressure-temperature-time path to model the evolution of the crystallizing magma through time. At any particular pressure and temperature, the equilibrium phase assemblage of a magma can be described as the composition and mass (or volume) fraction of each phase (e.g., melt, vapor, plagioclase, clinopyroxene, etc.). The degree of supersaturation $\Delta\phi$ for each mineral phase is the difference between the equilibrium and observed fractions, ϕEQB and ϕ, respectively; for example, if plagioclase has $\phi EQB=0.2$ and $\phi=0.05$, then $\Delta\phi=0.15$. The instantaneous nucleation and growth rates for each mineral phase are functions of supersaturation, and the time-integrated product of those rates describes the crystallization rate of the magma. Importantly, the crystallization rate at any moment in time depends not just on the pressure-temperature conditions of the magma, but also the numbers and sizes of crystals comprising the crystal population. SNGXtal uses instantaneous rates as reported by Marshall and Andrews (in review) and Andrews and Befus (2020), derived from experiments performed on basaltic andesite (Shea and Hammer, 2013) and dacite (Befus and Andrews, 2018). Model inputs include magma composition and initial crystallinity (volume fraction and size distribution) and pressure-temperature-time path. Model outputs include time series of crystallinity, number density, and characteristic sizes, and final crystal size distributions for each phase; these results can be compared with measurements of natural samples to study potential or likely magma decompression or cooling paths.

1258

The tephra fallout of the 2021 Tajogaite eruption at Cumbre Vieja volcano (La Palma): distribution, stratigraphy, textural and petro-compositional variations

Dr Daniele Andronico[1], Dr Elisabetta Del Bello[2], Dr Jacopo Taddeucci[2], Dr Alba Martín-Lorenzo[3,4], Dr Fátima Rodríguez García[3], Dr Alessio Pontesilli[2], Dr Piergiorgio Scarlato[2], Dr Riccardo Civico[2], Mr Francesco Pennacchia[2], Dr Tullio Ricci[2], Dr Beverley Coldwell[3,4], Dr Gladys Melián[3,4], Dr Matthew J. Pankhurst[3,4], Dr Luca D'Auria[3,4], Dr Pedro A. Hernandez[3,4], Dr Nemesio M. Perez[3,4]

[1]Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo, Sezione di Catania, Catania, Italy, [2]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Roma 1, Roma, Italy, [3]Instituto Volcanológico de Canarias, San Cristóbal de La Laguna,, Spain, [4]Instituto Tecnológico y de Energías Renovables, Granadilla de Abona,, Spain

The long-lasting Tajogaite eruption (La Palma, Canary Islands; 19 September-13 December 2021) was comprised of multiple vents which opened along a ~1 km-long eruptive fissure and simultaneous explosive and effusive activity forming a complex pyroclastic cone and a wide lava flow field.

In order to reconstruct magma processes within the magma plumbing system that were controlling eruptive dynamics, we performed detailed and repeated surveys on tephra fallout deposits at more than 120 sections, identifying stratigraphic units and measuring the deposit thicknesses. A proximal section, ~1 km SW of the active vents and along the main dispersal axis, was sampled and studied in detail. In addition, eight permanent "ash-stations" distributed proximally-distally allowed near-daily collection of samples during the eruption, providing an additional high-frequency set of samples. Grain-size, ash componentry, SEM and EMP analyses were then conducted on selected samples.

Three main stratigraphic units were identified, associated with key eruptive phases: a lower unit, mainly composed of lapilli-bearing layers, a middle unit comprised of ashy beds alternating with minor coarse-lapilli layers, and an upper unit dominated by lapilli-horizons. SEM-derived componentry, based on morphological and textural characteristics, allowed identification of transparent and fluid-shaped (A), blocky and shiny (B), and blocky opaque (C) particles, plus less abundant crystals and blocky red particles. Relative percentages of particle types can be correlated with changes in intensity and style of the activity observed during different eruption phases. Groundmass glasses have basanitic to tephriphonolitic compositions, with a markedly sodic character. A general trend of decreasing melt differentiation towards the upper stratigraphic levels suggests an increase in the fractionation of olivine relative to clinopyroxene with time, which may be related to changing magma plumbing dynamics. Finally, we link temporal variations in magma compositions with textural features within the stratigraphic sequence.

346

Volcanic Deformation Inversion Framework (VMOD)

Mario Angarita[1], Ronni Grapenthin[1], Scott Henderson[2], Kyle Anderson[3]
[1]University of Alaska, Fairbanks, United States, [2]University of Washington, Seattle, United States, [3]United States Geological Survey, Moffett Field, United States

We developed an open source, extensible Python-based framework for volcano deformation forward and inverse modeling that abstracts from specific source model implementations, data types and inversion methods. Within this, we implement the most common volcanic source models (e.g, point source, pressurized spheroid, and sill) which can be combined to model and analyze multi-source deformation. This supports common geodetic datasets: GNSS, InSAR, and tilt; others can be added with little effort. Non-linear least squares and Markov Chain Monte-Carlo (MCMC) Bayesian inversions are supported, as well as joint inversions of different types of data (e.g., InSAR, GPS) using multiple forward models. We benchmark the forward models against other published results, and test using synthetic datasets as well as observations from Alaska volcanoes, including: continuous GPS datasets from Okmok caldera during an inflation period in 2018, InSAR showing an inflation at Westdahl volcano from 2016-2021, and joint GPS campaign observations and InSAR at Fisher caldera indicating subsidence from 2003-2021. Our inversions reproduce published estimates. Our structure allows for an easy integration with Python implementations of new geodetic models. This framework is part of the NSF PREEVENTS Eruption Forecasting project and will be published as an open source package.

662

Rapid Inflation and Seismic Unrest at Mt. Edgecumbe (L'ux Shaa) Volcano, Alaska

Ronni Grapenthin[1,2], Yitian Cheng[1,2], Mario Angarita[1,2], Darren Tan[1,2], Franz, J. Meyer[1,3], David Fee[1,2], Aaron Wech[4]

[1]Geophysical Institute and Dept. of Geosciences, University of Alaska, Fairbanks, United States, [2]Alaska Volcano Observatory, Geophysical Institute, University of Alaska, Fairbanks, United States, [3]Alaska Satellite Facility, University of Alaska, Fairbanks, United States, [4]Alaska Volcano Observatory, United States Geological Survey, Anchorage, United States

In April 2022, a regional seismic network recorded a seismic swarm underneath Mt. Edgecumbe in Southeast Alaska. A similar swarm that started with a magnitude 3.0 event in January 2020 had been attributed to tectonic activity. The last eruptive activity was likely low-level basaltic activity observed about 800 years ago and described in oral Lingít history. Prior to that, several rhyolitic tephras provide evidence for explosive activity between 4-5 ka. Given the long period of inactivity, Mt. Edgecumbe did not have a ground-based geophysical monitoring network during the recent seismic unrest. The closest seismograph was located in the town of Sitka, about 25 km away.

Here we apply interferometric synthetic aperture radar analysis to ascending and descending Sentinel-1 acquisitions that reach as far back as 2014. Time series analysis of hundreds of interferograms resolves line-of-sight shortening at constant rates up to 7.5 cm/yr beginning in August 2018. Reanalysis of the single-station seismic data reveals microseismicity beginning in July 2019. This suggests the regionally recorded seismic swarms are related to inflation of the volcano, releasing stresses that accumulated given the approximately 30 cm line-of-sight shortening between 2018 and 2022. Bayesian modeling of the cumulative displacement fields in ascending and descending directions proved challenging as no simple elastic half-space source geometry fit all data satisfactorily. A coupled model of a 22 degree eastward dipping sill deflating by 0.483 km3 at 20 km depth and a magma chamber at 10 km inflating by 0.274 km3 provides a good fit to the data. The volume difference can be explained by a subvertical conduit connecting the two, which would not influence the deformation field appreciably. We expect this deformation to continue, any future rate changes could reflect changes in supply or visco-elastic dynamics as observed at similar systems.

1488

Formation of magma chambers and their ability to feed eruptions

Dr Catherine Annen

The occurrence and dynamics of volcanic eruptions is linked to the occurrence and dynamics of magma chambers. Since we cannot directly observe magma chambers, our conceptual models are necessarily based on indirect observations that are open to interpretation. These conceptual models include large magma tanks, transient, incrementally emplaced magma bodies, and melt lenses embedded in transcrustal mushes. The formation of magma chambers requires the concentration of magma in space. In solid rocks, where magma is transported through dykes, an interface in the crust between two layers with different physical properties can act as a magma trap and the magma chamber itself can act as an attractor for further injections. The ability of magma to accumulate is controlled by the thermal state of the crust and by magma flow rates. Within a mush, the formation of melt lenses results from the melt extraction process but the formation of the mush itself also requires favourable thermal conditions and high magma flow rates. Petrological and geophysical evidence indicate that many eruptions are fed by several magma reservoirs that connect before or during eruption. The size, duration, and style of eruptions depend on the number, size, and composition of the reservoirs. Yet, most magma never reach the Earth's surface; Magma chambers are not able to form or, if they form, the magma is not able to escape. Further transport of magma from a reservoir towards higher levels requires overpressure in the chamber or sufficient buoyancy forces exerted by magma or by volatiles.

Eruptive and intrusive flow rates are cyclic and follow power laws. This observation suggests some form of self-organization in the plumbing system. To understand volcanism, we need to understand magmatic systems as interconnected networks of melt and volatiles. To overcome the lack of direct observation we need to combine knowledge from the different disciplines studying magmatism and volcanism.

1256

Unsupervised detection of volcano deformation from GNSS time series

Dr Yosuke Aoki[1]
[1]*Earthquake Research Institute, The University of Tokyo, Tokyo, Japan*

Measuring surface deformation is crucial to understanding magmatic fluids' accumulation and transport in active volcanoes and forecasting possible eruptions. As many hazardous eruptions occur with tiny precursory deformation signals, detecting deformation signals even from invisible time series is crucial both from a scientific and societal point of view. Here we developed a method to detect anomalous deformation signals without a priori knowledge of the source that induces deformation signals. In other words, the method "lets the data talk" to detect anomalous signals. Simply put, this method compares the probability distribution of reference and current GNSS time series to test if these time series are generated from the same probability distribution using the Kolmogorov-Smirnov test. This test does not need to assume that the data obeys the Gaussian distribution. If the test is positive, the current series does not contain any volcanic signals because the reference signal is supposed to be devoid of volcanic signals. Otherwise, the current signal is considered to contain volcanic signals. This method is tested with synthetic signals containing realistic noise, including colored noise, and is confirmed to work well. An application to the real dataset is now on the way.

1259

Ionospheric disturbance of the 2022 eruption of Hunga Tonga-Hunga Ha’apai

Dr Yosuke Aoki[1], Taiga Seito[1]
[1]*Earthquake Research Institute, The University of Tokyo, Tokyo, Japan*

An explosive eruption of Hunga Tonga-Hunga Ha'apai on 15 January 2022 at around 4:00 UTC disturbed the ionosphere, as well as the atmosphere. We observed the ionospheric disturbance with Global Navigation Satellite System sites in Southwest Pacific, New Zealand, and Japan. Because the observed ionospheric disturbance contains a long-term fluctuation with substantial amplitude, which is unrelated to the volcanic activity, we first removed this component. The remaining component indicates the emergence of a signal with a dominant period of a few hundred seconds. In Japan, for example, this signal has been observed for a few hours since around 10:00 UTC on 15 January, consistent with the arrival of the acoustic Lamb wave. We also found that fluctuations before the arrival of the Lamb wave are observed in multiple sites. This observation resists interpretation; it could be related to the eruption itself, precursors to the eruption, or background ionospheric fluctuations. Future numerical modeling of this eruption's atmospheric and ionospheric disturbance will address this problem.

1224

Did mafic recharges trigger the historical Plinian eruptions at Sakurajima volcano?

Dr Naoki Araya[1], Prof. Michihiko Nakamura[1], Dr. Keiko Matsumoto[2], Dr. Satoshi Okumura[1]
[1]Department of Earth Science, Tohoku University, Sendai, Japan, [2]National Institute of Advanced Industrial Science and Technology, Geological Survey of Japan, Tsukuba, Japan

Mafic magma recharge of a crustal reservoir has been considered to trigger volcanic eruptions through thermal and volatile interactions in the reservoir. In many active volcanoes, however, recharges have been frequently monitored while rarely leading to an eruption, which makes their role as a trigger questionable. Detailed reconstruction of magmatic processes resulting in past volcanic eruptions is essential to deepen our understanding of the triggering mechanism. Sakurajima volcano, Japan, repeated three vigorous eruptions since the 15th century following a similar process; the recharged mixed magma was loaded into a shallow thick conduit and once stored before each eruption ("pre-charge"). We reconstructed the magma migration with a high time resolution by examining the multiple elements in different minerals. A characteristic feature is that magnetite phenocryst compositions were homogeneous within each crystal but diverse among the crystals, implying the final repose of the zoned, pre-charged magma pocket for more than dozens of days. Namely, the mafic recharge and mixing did not occur shortly before the eruption. By contrast, the reversely-zoned orthopyroxenes record a longer diffusion time (2.1–167 years). Therefore, we concluded that mafic recharge and subsequent mixing were not the immediate cause of the eruptions. Instead, crystallization-driven volatile exsolution and bubble growth in the shallow, thick conduit could have finally triggered the eruptions.

500

Sulfide melt globules in dacite magmas of the submarine Suzette Volcano, East Manus Basin.

Professor Richard Arculus[1], Dr Nick Dyriw[2], Professor John Mavrogenes[1], Professor David Gust[2]
[1]Australian National University, Canberra, Australia, [2]Queensland University of Technology, Brisbane, Australia

Sulfide saturation in arc-backarc magma systems is crucial to magmatic compositional evolution, the character of cogenetic gas phases, and the availability of chalcophile trace elements for ore formation. We report compositions of rapidly-quenched, ~10 µm-diameter, groundmass-hosted sulfide globules in dacite erupted from the submarine Suzette Volcano in the East Manus Basin (Dyriw et al., 2021). The compositions have unusually high Cu/Fe, negligible Ni, project in the sulfide melt region of the Cu-Fe-S ternary at 1000oC (Kullerud et al., 1969), are S-rich relative to bornite solid solution, and have not previously been reported in the spectrum of ridge-arc-backarc sulfide globule compositions (e.g., Keith et al., 2017; Georgatou et al., 2021). Temperature-pressure calculations yield ~1000oC and ~0.4 GPa for sparse pheno/glomerocryst assemblages (plagioclase-clinopyroxene-orthopyroxene-magnetite) in the dacite hosts, consistent with an immiscible sulfide melt origin for the globules. Thermodynamic modelling reproduces the compositional spread from andesite to dacite by fractional crystallisation of observed crystalline phases, with some magma recharge/mixing processes. The parental andesite contained ~1.5 wt% H2O at redox equivalent to the NNO buffer. But increase in ulvöspinel component of microphenocryst magnetite reflects a relative reduction from andesite to dacite. Previously, Jenner et al. (2010) invoked magnetite saturation in a spectrum of quenched basalt-andesite-dacite glasses of the Pual Ridge (40 km WNW of Suzette), as critical to reduction of the oxidation state of the magmatic system and hence saturation in sulfide, hypothesised to be bornite, due to decreases in the relative amounts of Cu and Fe in evolved glasses. We propose saturation in immiscible sulfide (Cu-Fe) melt rather than bornite, also occurred at the Pual Ridge. Ni-poor (from prior olivine fractionation) sulfide melt saturation in evolved melts may be widespread in arc-backarc magmas; the composition of quenched sulfide globules will be critical in tracking evolving chalcophile element abundances and SO2 losses.

225

Towards a combined machine-learning and physics-based model for forecasting volcanic eruptions

Dr Alberto Ardid[1], Dr David Dempsey[1], Dr Corentin Caudron[3], Dr Tarsilo Girona[5], Dr Oliver Lamb[4], Dr Shane Cronin[2]

[1]University Of Canterbury, Christchurch, New Zealand, [2]University of Auckland, Auckland, New Zealand, [3]Université Libre de Bruxelles, Brussels, Belgium, [4]GNS Science, Taupō, New Zealand, [5]University of Alaska, Fairbanks, USA

Physics-based models are essential for constraining volcanic processes generating volcano-seismic signals, because they allow us to link signal fluctuations to variations in the subsurface. They are usually tested on short-term datasets, as combining physical models with progressively larger and more sophisticated observations derived from real-time datasets has proven computationally challenging. However, robust frameworks that fuse models with large datasets are needed to exploit the full potential of both increasingly high-quality real-time observations and more accurate physical models. On the other hand, machine learning tools focus on assimilating vast datasets to detect patterns in the mathematical structure of the data but usually lack physical constraints, which makes them challenging to interpret.

We are developing a framework that combines pattern recognition from machine learning time series feature engineering with physics-based models to assimilate large seismic datasets of eruptive processes, ultimately allowing the development of a combined eruption forecasting system. We propose a novel approach for integrating physics-based models into seismic data patterns revealed by time-series feature engineers and forecasting using machine learning via Kalman filters. This will help constrain the physical interpretation of seismic observation on active volcanoes, and the use of real-time seismic data when forecasting eruptions. We will test these hypotheses for a much broader sample size, potentially including more than 20 volcanoes from several volcanic regions of the world.

223

Unravelling phreatic eruption mechanisms and seismic precursors from time series feature engineer: examples from New Zealand Volcanoes

Dr Alberto Ardid[1], Dr David Dempsey[1], Dr Corentin Caudron[3], Dr Craig Miller[4], Dr Ben Kennedy[1], Dr Shane Cronin[2]

[1]University Of Canterbury, Christchurch, New Zealand, [2]University of Auckland, , New Zealand, [3]Université Libre de Bruxelles, , Belgium, [4]GNS Science, Taupō, New Zealand

We explored pre-eruptive patterns, or precursors, in phreatic eruptions in New Zealand using an original approach that seeks to track fluid migrations and permeability changes in volcanic conduits. Discovering identifiable precursors help interpretations of sub-surface volcanic activity, and forecasting sudden and explosive eruptions, a task that has proved exceptionally challenging due to the lack of recognizable common precursors. Overall, our research addressed critical gaps in understanding volcano dynamics and instability in magma-hydrothermal systems, which are critical to eruption triggering and risk assessment.

Using time series feature engineer, a technique typically used in machine learning, we analysed seismic feature time-series prior to numerous eruptions in New Zealand and extracted latent patterns in the seismic signals that anticipated eruptions(1). A series of short-term seismic eruption precursors were found that recurred in the weeks prior to eruptions at several volcanoes. This approach helped to build a data-constraint timeline of the 2019 Whakaari eruption, where it identified how vent permeability changes promoted pressurization and created the conditions for the deadly phreatic explosion.

Also, we developed a combined analysis of seismic data along with crater lake temperature and level data from Ruapehu volcano in New Zealand. Our goal here was to improve volcanic event catalogues by locating signatures of rapid hydrothermal seal consolidations and fading. Events are located temporally within the seismic record using an empirical model of sealing/pressurization/eruption proposed for Whakaari volcano. Changes in crater lake temperature and level data are quantified during these events. The approach allows us to identify numerous fluid release events that might have been suppressed by the crater lake or been too small to be noticed by standard monitoring techniques.

274

Depositional processes in pyroclastic surges: a large-scale experimental approach

Mr James Ardo[1], Dr Ermanno Brosch[1], Professor Gert Lube[1]
[1]*Massey University, Palmerston North, New Zealand*

Dilute pyroclastic density currents (dilute PDCs or pyroclastic surges) are frequent and highly lethal phenomena found on volcanoes. They are hot flows of particles and gas that are capable of inflicting significant damage to life and infrastructure. The study and interpretation of sedimentary structures of their natural deposits have been invaluable in recognizing and characterizing their internal flow dynamics. Traditionally, these field based observations and interpretations are largely based on concepts from sediment transport mechanisms developed for fluvial and aeolian systems. Nonetheless, how well these analogies capture sediment transport in PDCs is still unclear, due to a lack of direct measurements inside these currents because of their inherent hostile nature.

We present results from large-scale experiments, where scaled hot dilute PDCs were synthesised to investigate sedimentation processes and lateral evolution of sedimentary structures. Lateral evolution of the synthesised deposit display high resemblance to deposits of natural PDCs. The proximally emplaced regressive structure composed of massive, poorly sorted lithofacies is comparable to proximal breccias observed in real world deposits. At medial to distal runout lengths, the experimental flows emplace a deposit with a characteristic 'tripartite' geometry that is often found in deposits of blast-like surges. This study finds that the tripartite geometry of experimental dilute PDCs reflects the passage of a flow with i) a head (responsible for the rapid deposition of massive layer A); ii) a body (responsible for tractional bedload aggradation of the stratified layer B); and iii) a tail and buoyant ash cloud (responsible for grain-by-grain aggradation of layer C in weakly tractive conditions). Insights from the internal flow structure (velocity, density, and dynamic pressure) reveal that non-deposition and erosional phases are characterised by the passage of coherent turbulent structures, where episodes of elevated sedimentation rates represent periods between the passage of coherent turbulent structures.

1383

A unified view of radiative transfer for remote sensing of volcanic plumes

Dr Santiago Arellano[1]
[1]*Chalmers University of Technology, Gothenburg, Sweden*

Most information about the emission of gas plumes from volcanoes is obtained by means of passive remote sensing methods from ground, air, and space. In particular, the emission of sulfur dioxide (SO2) is quantified by absorption spectroscopy using diffuse solar radiation in the near UV, as implemented for example in the COSPEC, DOAS or UV-camera techniques. It is well-known that such methods are prompt to errors caused by imperfect knowledge and/or treatment of radiative transfer, errors that are even difficult to quantify, but which could potentially yield flawed results. Efforts to correct for effects such as dilution or multiple scattering inside turbid plumes rely either on computationally demanding inversion of ill-constrained radiation transport models, or simplified application of visibility formulas conceived for homogeneous scattering and non-condensed plumes.

Here we propose a method that is simple to implement and that provides a unified characterization of radiative transfer. SODAP: Sum Over Discernible Absorption Paths, is based on the natural assumption that measured radiance spectra are formed by the aggregated effect of radiation travelling different physical paths through the atmosphere, some of which undergo extinction through the plume. Because the volcanic plume acts as a localized extinction medium and other relevant species have either a well-known path or weak or unstructured extinction spectra, it is possible to separate the effects of background and plume extinction and linearize the transmittance of the plume as a weighted sum of transmittances through different optical paths. The distribution of optical paths gives information on the amount of dilution and multiple scattering in the plume. We present the fundamentals of the method and its validation with modelled and measured data under controlled conditions. This method can be implemented operationally for a more reliable quantification of volcanic gas emission worldwide or to other species in similar measurement contexts.

1054

Hazard maps of the Chachani Volcanic Cluster, Arequipa – Peru

MSc. Nélida Manrique[1,2], PhD student Rigoberto Aguilar[1,2], PhD Benjamin Van Wyk de Vries[2], Señor David Arteaga[1], Eng Yhon Soncco[1], B. Eng. Geo. Carla Palacios[1], B. Eng. Geo. Veronica Tito[1], B. Eng. Geo. Elizabeth Pacsi[3], MSc. Sandra Sanz[4]

[1]Observatorio Vulcanológico Del Ingemmet, , Peru, [2]Université Clermont Auvergne, Laboratoire Magmas et Volcans, , France, [3]Universidad Nacional del Altiplano (UNAP), , Peru, [4]Universidad Nacional de San Agustín (UNSA), , Peru

The Chachani is a large volcanic cluster (C-LVC) composed of at least twelve volcanic edifices covering an area of ~600 km2. The eruptive deposits yield ages between 1012 ± 53 ka (U/Pb) and 56 ± 31 ka (40Ar/39Ar). The hazard maps of the C-LVC were developed based on detailed fieldwork, the knowledge of the deposits that allowed us to determine the extent of emitted products, magnitude and frequency of the eruptive events. We considered four possible eruptive scenarios: (1) effusive eruptions with lava emission; (2) dome growth accompanied by vulcanian activity; (3) growth and collapse of domes producing Pyroclastic Density Currents (PDC); and (4) sub-Plinian to Plinian eruptions with PDC generation. With this information, multiple computer-based (VolcFlow and Ash3D) simulations were carried out considering the magnitude of the eruptions and the probability of their occurrence. The C-LVC multi-hazard map is the result of combining the areas prone to be affected by PDCs, lava emissions and lahar-flows. The tephra fallout hazard map, delineates the areas of probable ash fall threat based on expected eruptive scenarios taking as reference explosive events from analogous volcanoes and integrating wind data. The lahar flow hazard map was obtained based on simulations carried out on VolcFlow algorithm for each of the 45 ravines descending from the C-LVC. Each map show high, intermediate and low hazard-levels indicated by red, orange and yellow layers respectively. In the northern part of Arequipa more than 322,524 inhabitants would be impacted even when considering small eruptions. This is aggravated by its dependence on the water and electrical network carried from the base of Chachani and Misti volcanoes. The hazard maps will provide strong arguments for timely conceiving of the emergency plans in order to face the volcanic risk in the city of Arequipa.

1068

4D dissolution kinetics of clinopyroxene in hydrous basaltic magmas

Dr Fabio Arzilli[1,2], Dr Margherita Polacci[2], Dr Giuseppe La Spina[3,2], Dr Nolwenn Le Gall[4], Professor Edward W. Llewellin[5], Dr Richard A. Brooker[6], Dr Rafael Torres-Orozco[7], Dr Danilo Di Genova[8], Dr David A. Neave[2], Dr Margaret E. Hartley[2], Professor Heidy M. Mader[6], Dr Robert Atwood[9], Professor Peter D. Lee[4], Professor Mike R. Burton[2]

[1]University Of Camerino, Camerino, Italy, [2]The University of Manchester, Manchester, UK, [3]Istituto Nazionale di Geofisica e Vulcanologia-Osservatorio Etneo, Catania, Italy, [4]University College London, London, UK, [5]Durham University, Durham, UK, [6]University of Bristol, Bristol, UK, [7]Universidad Veracruzana, Xalapa, Mexico, [8]CNR - IGAG, Rome, Italy, [9]Diamond Light Source, Didcot, UK

Crystallization and dissolution of minerals are important processes in the petrogenesis of igneous rocks, especially at magmatic storage conditions in which formation of crystal mush, magma mixing and assimilation may occur.

Disequilibrium textures that range from simple normal zoning to complex textures reflecting resorption, rapid crystal growth, and diffusive re-equilibration are associated to a transition from subliquidus to superheating conditions, and vice versa. Superheating with respect to liquidus temperature can be produced by injections of hot fresh magma into a magma storage region, and by magma mixing, anatexis and decompression. Crystallization and mineral dissolution are fundamental to estimate magma residence times before the eruption and they have strong implications for the locking and unlocking of basaltic magmas, affecting their mobility and eruptibility. This feeds into volcanic risk assessment and mitigation models and management in active volcanic areas. However, relationships between crystallinity, rheology and eruptibility remain uncertain because of the challenges associated with documenting magma crystallization and mineral dissolution in real time.

In basaltic magmas, crystallization kinetics has been extensively investigated using quench experiments with an ex situ view. Only recently they have been studied using real time experiments with an in situ view. Here we show the results of in situ 3D time-dependent, high temperature experiments under water-saturated conditions performed using synchrotron X-ray microtomography to investigate crystallization and dissolution kinetics in a basaltic magma at crustal pressure. This new 4D approach provides unique quantitative information on the growth and dissolution kinetics of clinopyroxene in basaltic magmas as function of time, undercooling and superheating. This study shows for the first time the dissolution kinetics and the textural evolution of clinopyroxene in 3D through time.

1060

In situ 4D crystallization in basaltic magmas: implications for magma mobility within the Earth's crust, fragmentation and eruptive style

Dr Fabio Arzilli[1,2], Dr Margherita Polacci[2], Dr Giuseppe La Spina[3,2], Dr Nolwenn Le Gall[4], Professor Edward W. Llewellin[5], Dr Richard A. Brooker[6], Dr Rafael Torres-Orozco[7], Dr Danilo Di Genova[8], Dr David A. Neave[2], Dr Margaret E. Hartley[2], Dr Emily C. Bamber[9], Professor Heidy M. Mader[6], Dr Daniele Giordano[9], Dr Robert Atwood[10], Professor Peter D. Lee[4], Professor Mike R. Burton[2]

[1]University Of Camerino, Camerino, Italy, [2]The University of Manchester, Manchester, UK, [3]Istituto Nazionale di Geofisica e Vulcanologia-Osservatorio Etneo, Catania, Italy, [4]University College London, London, UK, [5]Durham University, Durham, UK, [6]University of Bristol, Bristol, UK, [7]Universidad Veracruzana, Xalapa, Mexico, [8]CNR - IGAG, Rome, Italy, [9]University of Turin, Turin, Italy, [10]Diamond Light Source, Didcot, UK

The mobility and the rheological behaviour of magma within the Earth's crust is controlled by magma viscosity. Crystallization and crystal morphology strongly affect viscosity, and thus mobility and eruptibility of magma, by locking it at depth or enabling its ascent towards the surface. Due to their low viscosity, basaltic magmas can usually reach the surface producing effusive and mildly explosive volcanic activity. Highly explosive basaltic eruptions occur less frequently and their eruptive mechanism still remains subject to debate. Particularly, it is unclear how basaltic magmas can reach the fragmentation threshold, with strong implications for the significant hazard associated with explosive basaltic volcanism.

Here we show the results of in situ 3D time-dependent, high temperature experiments performed under dry and water-saturated conditions to investigate crystallization kinetics in a basaltic magma. In situ 4D crystallization experiments were performed using synchrotron X-ray microtomography, which provides unique quantitative information on the growth kinetics and textural evolution of plagioclase and pyroxene crystallization in basaltic magmas. Crystallization kinetics obtained with 4D experiments were combined with two numerical models to investigate dike propagation towards the surface and conduit dynamics during effusive and explosive basaltic eruptions.

Modelling results show that dendritic crystallization at moderate undercooling (30-50 °C) can strongly affect magma rheology during magma ascent within a dike with important implications for the mobility of basaltic magmas within the crust.

We also combine crystallization kinetics associated with a rapid perturbation of undercooling (to ≥100 °C) with a numerical conduit model to show that exceptionally rapid syn-eruptive crystallisation is a fundamental process required to trigger basaltic magma fragmentation under high strain rates. Our results show that pre-eruptive temperatures <1,100°C can promote highly explosive basaltic eruptions in which fragmentation is induced within the conduit by fast syn-eruptive crystal growth under high undercooling.

904

Phenocryst time-capsules to constrain magmatic processes at Mount Meager volcano, British Columbia, Canada

Miss Sarah Aufrère[1], Prof. Glyn Williams-Jones[1], Prof. James K. Russell[2], Dr. Daniel J. Morgan[3], Dr. Séverine Moune[4], Dr. Nathalie Vigouroux[1,5]

[1]Centre for Natural Hazards Research, Department of Earth Sciences, Simon Fraser University, Burnaby, Canada, [2]Department of Earth, Ocean and Atmospheric Sciences, Volcanology and Petrology Laboratory, University of British Columbia, Vancouver, Canada, [3]School of Earth and Environment, University of Leeds, Leeds, United Kingdom, [4]Laboratoire Magmas et Volcans, CNRS-OPGC-IRD, Université Clermont Auvergne, Aubière, France, [5]Department of Earth and Environmental Sciences, Douglas College, New Westminster, Canada

Mount Meager is a glacier-covered volcanic complex, 150 km north of Vancouver (British Columbia, Canada), that belongs to the Garibaldi Volcanic Belt – the northern extent of the Cascade Volcanic Arc. It has developed over the last 1.9 Ma and currently hosts an extensive hydrothermal system, expressed as hot springs and fumaroles. The youngest eruption occurred 2360 B.P. and comprised a sub-Plinian explosive phase (VEI 4) and a subsequent Vulcanian episode. The second most recent eruption from Mount Meager massif itself is dated at 24.3 ka. Still, key questions about Mount Meager's magmatic system persist. To this end, we have studied eruptive products from the Mount Meager volcanic complex, ranging in composition from basalt to rhyodacite. Magmatic parameters such as liquidus (1190-1250°C) and eruption temperature (1100-1150°C), as well as oxygen fugacity (-2.3 to +1.2 ΔNNO) have been determined from the whole-rock, glass and olivine compositions. Chemical zonation patterns of olivine and quartz phenocrysts in quenched volcanic material (pillow lava, tephra and pumice) vary. Olivine phenocrysts are unzoned, normally zoned, or more complexly zoned, and show at least one period of reverse zoning inbound from the normally zoned rim. Zonation in quartz, defined by CL imaging, is absent or preserves complex zoning. However, ~25% of quartz grains show reverse zoning on their rims, which may indicate an injection of more mafic magma shortly preceding the eruption. Diffusion chronometry calculations based on Fe-Mg interdiffusion in olivine and Ti-diffusion in quartz, combined with the timescale for forming facetted melt inclusions in quartz, are being investigated. A preliminary analysis of perturbation-to-eruption timescales for the Lillooet Glacier basalt olivines (<15 ka), immediately north-west of Mount Meager massif, suggests timescales in the order of less than several months. These results have significant hazard implications for this currently unmonitored, dormant volcano.

429

The volcanic/plutonic ratio in space and time; how efficiently do magmas reach the surface during planetary evolution?

Professor Olivier Bachmann[1], Dr Christian Huber[2]
[1]ETHZ, Zurich, Switzerland, [2]Brown University, Providence, USA

With the discovery of multiple crustal cross sections around our planet, the advent of high-precision geochronology, and the ever-increasing application of geophysical imaging beneath volcanoes, we now know that volcanic rocks are the tip of a magmatic “heat”berg, overlying a significant igneous plumbing system that leaves many types of plutonic lithologies in the crust. The ratio of volcanic to plutonic rocks in a given magmatic province (the V/P ratio) varies in space and in time as a function of several parameters controlled by the tectonic setting, age of the magmatic province, rheology of the crust, and state of the magma reservoirs. This contribution intends to explore these different parameters, in order to better constrain how the V/P ratios evolve in space and time in the course of planetary crust evolution. In particular, we stress that the efficiency of phase separation (in particular crystal / melt separation) in crustal magma reservoirs, fundamental to igneous differentiation and crust formation, is a key factor in controlling the V/P ratios. This efficiency, in turns, depends on parameters such as volatile content of magmas, recharge rate, and the state of the pre-existing crustal container (in particular its rheology). New thermo-mechanical modeling tools, allowing us to explore the effects of these parameters in more details, are paving the way to a more quantitative understanding of these fundamental processes.

691

Real-time monitoring and edge computing at Cleveland and Okmok volcanoes, Alaska

Dr Conor Bacon[1], Prof Terry Plank[1], Prof Einat Lev[1], Mr Nick Frearson[1], Mr Jasper Baur[1], Lingling Dong[1], Prof Yves Moussallam[1]
[1]*Lamont-Doherty Earth Observatory, Columbia University, New York, United States*

The AVERT (Anticipating Volcanic Eruptions in Real Time) project has established open-data, real-time, multi-sensor experiments on the active Aleutian volcanoes of Cleveland and Okmok, with three broad objectives: 1) to develop coupled hardware/software solutions to the challenges involved in collecting real-time data in remote locations; 2) to explore the promise of (typically mutually exclusive) low-power, high-performance edge computing to better facilitate monitoring of volcanoes worldwide; and 3) to design server-side, open, and near real-time solutions for sharing data. Here, we will discuss the latter two objectives.

We have developed an easy-to-use, end-to-end solution for volcano monitoring with real-time data telemetry via radio and satellite uplinks. The system is composed of modular nodes, capable of incorporating instruments to measure a wide range of pre-eruptive phenomena, such as seismicity, deformation, degassing, thermal emissions, and more. Each node has a single-board computer that, besides coordinating data archiving and transmission, performs on-site analysis of data recorded in real time. We will present initial findings from the edge processing applied to both seismic waveforms (for event detection and characterisation) and webcam imagery (for automatic detection of volcanic plumes), focussing on the challenges faced in developing high-performing systems on low-power devices.

Making such a diverse range of data available through public portals in near real-time also presents a critical challenge. Mature solutions exist for seismic and geodetic data, in the form of the FDSN and UNAVCO (now part of EarthScope Consortium) web services, respectively. We propose the development of a web service specification that would streamline access to the large volumes of volcano imagery being data produced by many institutions and observatories. All software products for operating an AVERT node and server applications will be publicly available, and feedback and contributions from the wider community are welcomed.

1427

Deciphering Mars Using Earth's Ignimbrite Patterns

Dr John E. Bailey[1], Dr Shan de Silva[2]
[1]Gustavus Adolphus College, Saint Peter, United States, [2]Oregon State University, Corvallis, 97331

As data from both orbital platforms and ground-based rovers on Mars has proliferated, so too has the need to understand what these images are actually showing in terms of the history of how these landscapes were formed and have subsequently evolved. The presence of ignimbrites on Mars has been debated for over three decades but has started to be accepted, partly due to evidence provided by analogous geomorphic and surface expressions seen on Earth. In particular, the large ignimbrite provinces in the Central Andes of South America have provided perhaps the best terrestrial examples of features seen in these types of environment.

Some of the prominent surface textures and patterns seen in ignimbrites on the scale of high-resolution (meters / pixel) satellite images include pervasive joints and fractures that contribute to the formation of yardangs, along with the development of prominent mounds, fissures, and fracture networks on ignimbrite surfaces. While all these features are related to intrinsic cooling and degassing processes, the involvement of external water buried by hot pyroclastic flows enhances fumarolic activity, advective cooling, and joint development, further imprinting on the patterns.

The irony that faces planetary mappers using terrestrial analogies to interpret surface lithologies on other planets is that coverage of higher resolution data that can "see" the ground, is more widely available for Mars than for Earth. But the benefits of these Earth-based analogies is that interpretation can be assisted by in-person field observations. In contrast, in-person observations on Mars remain a futurist goal but datasets such as the High Resolution Imaging Sensor Experiment (HiRISE) provide extensive, high-resolution coverage. Although it should be noted that on Mars these benefits are somewhat tempered by the extensive dust cover across the planet's surface, yet terrestrial analogies again suggest this doesn't necessarily stop identification.

1425

Drainage Patterns Around Mt. Pinatubo: A Case Study in the Evolution of Satellite-Based, Planetary-Scale Geomorphology

Dr John E. Bailey[1], Dr Stephen Self[2]
[1]*Gustavus Adolphus College, Saint Peter,, United States,* [2]*University of California, Berkeley,, United States*

In retrospect the eruption of Mt. Pinatubo in 1991 has provided a unique perspective on how images captured from space can be used to study a landscape that has been reset by volcanic activity. During the 1991 event pyroclastic density currents formed thick, topography filling ignimbrites, which were subsequently dissected as the fluvial networks in several large drainage basins re-established themselves. As the second largest eruption of the 20th century Pinatubo's activity was significant as it provided scientists, emergency managers and other interested parties an opportunity to assess the real-time regional and global impact of a magnitude seldom experienced in our lifetime.

However, it also occurred on the eve of a technological leap forward driven by the development of telecommunications and the integration of the internet into daily life. Starting in the 1970s, and expanding through the 80s and 90s, the Landsat and Satellite Pour l'Observation de la Terre (SPOT) programs provided "high" resolution satellite imagery (20 m/pixel). But with the launch of the Quickbird and Ikonos satellites in 1999-2001 the definition of (commercially available) "high-resolution" imagery was reset to m-cms/pixel range. The subsequent development of platforms such as Google Maps that made use of that quality of imagery then helped drive the demand and made it freely available to all.

In the middle of this timeline Pinatubo erupted and changed the surrounding landscape, and its continuing evolution paralleled the evolution of the quality and quantity of satellite imagery available. Thus providing a snapshot into how ignimbrite provinces (or materials of similar consistency) can evolve in environments where the whole deposit can be viewed. It therefore provides an excellent terrestrial case study when considering the task of performing large-scale, remote geology on other planets.

1354

Forecasting paroxysmal eruption cycles at persistently active volcanoes: lessons from Volcán de Fuego, Guatemala

Dr Amelia Bain[1], Dr Andrew Bell[1], Mr Amilcar Elias Roca Palma[2], Prof Silvio De Angelis[3], Dr Rüdiger Escobar Wolf[4], Prof Eliza Calder[1]

[1]University Of Edinburgh, Edinburgh, United Kingdom, [2]INSIVUMEH, Guatemala City, Guatemala, [3]University of Liverpool, Liverpool, United Kingdom, [4]Michigan Technological University, Houghton, United States

Forecasting hazardous ‘paroxysmal’ eruption cycles at persistently active volcanoes is extremely challenging. A variety of physical processes may control the transition from background activity into a paroxysmal cycle, and their signatures in monitoring data are cryptic. Seismic signals at persistently active volcanoes are dominated by tremor, explosions, and low-frequency earthquakes, with emergent onsets, extended durations, and variable amplitudes and frequency contents. Consequently, traditional processing methods which produce earthquake catalogues have limited utility, and other approaches are needed. Here, we analyse seismic data associated with paroxysmal cycles at Volcán de Fuego, Guatemala. Fuego is an open-system, persistently active basalt-basaltic andesite volcano with background activity characterised by frequent Strombolian to Vulcanian explosions (multiple times per hour) and effusive behaviour, as well as paroxysmal cycles of increased eruptive intensity and hazard. The timing of the announcement of a new paroxysmal cycle at Fuego has critical consequences for triggering processes related to civil protection. Currently, decision-making with respect to declaring the onset of a new paroxysmal cycle relies on a combination of geophysical monitoring thresholds determined by the national monitoring institution of Guatemala (INSIVUMEH), direct observations from official observers on the volcano, and the experience of INSIVUMEH staff from past events.

For several paroxysmal cycles since 2018, we develop continuous time-series metrics to quantify the evolution of the short-term amplitude and variability of seismic signals, tracking transitions in explosion rate and intensity, and the emergence of persistent tremor in the transition from background activity. Based on this analysis, we propose statistical metrics that could underpin an alert system designed to operate as an aid to decision-making. The aim of this study is to provide a data-informed tool to support decision-making during volcanic crises at Fuego, and could be adapted for crises at other persistently active volcanoes with a high baseline of seismic activity.

577

New geochemical insights into intraplate magmatism at the Cameroon Volcanic Line

Ms Sophie Baldwin[1], Prof Linda Kirstein[1], Prof Godfrey Fitton[1], Prof Adrian Boyce[2]
[1]University Of Edinburgh, Edinburgh, United Kingdom, [2]Scottish Universities Environmental Research Centre, East Kilbride, United Kingdom

The Cameroon Volcanic Line (CVL) is an intraplate magmatic province in West Africa which spans continental and oceanic lithosphere at a passive continental margin. Magmatism at the CVL began ~70Ma at the easternmost end of the line and activity persists to the present. There is a notable lack of age-progression to CVL volcanism, with the most recent activity at the centre of the line. We present in-depth geochemical work aimed at investigating the role of a volatile-enriched magmatic source region as an alternative to the commonly-invoked mantle plume model for intraplate magmatism which does not reconcile key observations from the CVL.

We focus on Etinde, a nephelinite volcano at the centre of the CVL which formed from highly volatile- and incompatible trace element-enriched magmas. We present whole-rock trace element and halogen data from 40 Etinde lavas, which range from olivine-bearing nephelinites, haüyne-rich melanephelinites to the most geochemically-evolved samples, which contain schorlomite, strontian melilite and leucite. We discuss the implications of the extraordinary geochemistry (e.g. up to 7100ppm strontium, 5190ppm fluorine) of this volcano.

Furthermore, we present novel sulphur isotope data from Etinde. Both whole-rock $\delta^{34}S$ compositions and those measured in-situ from sulphur-rich phenocrysts have substantially higher $\delta^{34}S$ compositions than the typical mantle range of -1 to +1‰ (VCDT). Whole-rock values range from +3.9 to +8.1‰ and in-situ measurements of haüyne and nosean range from +7.5 to +13.9‰. At other systems globally, elevated $\delta^{34}S$ compositions have been associated with: a metasomatic mantle source, extensive degassing, interaction with evaporite sediments and temperature and fO_2 conditions of magma generation and storage. We propose an alternative model for the generation of magmatism at Etinde linked to mantle metasomatism.

579

USGS Next Generation Volcano Hazards Assessments Project: Progress and Prospects, 2018-2023

Dr Jessica Ball[1], Joseph Bard[2], Dr. David Damby[1], Tina Neal[3]
[1]California Volcano Observatory, U.S. Geological Survey, Moffett Field, United States, [2]Cascades Volcano Observatory, U.S. Geological Survey, Vancouver, United States, [3]Alaska Volcano Observatory, U.S. Geological Survey, Anchorage, United States

The “Next Generation Volcano Hazards Assessments” (NGVHA) project was envisioned as a way for the U.S. Geological Survey to produce comprehensive volcanic hazards assessments for high-threat U.S. volcanoes. This is especially important where existing evaluations are outdated, poorly reflect the state of research, and would benefit from the inclusion of new modeling and design techniques. Originally begun with pilot projects at Kīlauea, HI (explosive) and Mount Baker, WA (explosive) volcanoes, plus topical working groups (i.e. tephra, lahars and debris flows, lava flows, user needs, communication) the NGVHA project has grown to synthesize products from multiple intertwined disciplines. These include advanced modeling and probabilistic techniques, research into usability and volcano observatory partner/stakeholder needs, new digital formats for information sharing, co-production of hazards products with stakeholders, and a Community of Practice (group of scientists whose duties involve producing volcano hazards assessments) for knowledge sharing and documentation. We will detail these efforts and how they have led to more advanced hazards assessments, hazards products that are tailored for (and more likely to be used by) stakeholders, and a compilation of best practices that will set the stage for future hazards evaluations.

578

Muddy waters: Are weather-related lahars the new norm at Mount Shasta?

Dr Jessica Ball[1], Dr. Alicia Hotovec-Ellis[1], Dr. Phillip Dawson[1]
[1]*California Volcano Observatory, U.S. Geological Survey, Moffett Field, United States*

Lahar hazards assessments at snow and ice-covered volcanoes are often based on the assumption that the most impactful hazard will be eruptive lahars where the largest flows are presented as the worst-case scenarios and smaller flows (usually seasonal) are the most likely but less destructive, scenarios. Given the widespread effects of climate change in the Western U.S., however, it may be necessary to shift emphasis to the hazards of seasonal flows at Cascade volcanoes. This is particularly relevant at Mount Shasta, one of the most southern glaciated stratovolcanoes in the Cascade Volcanic Arc, where traditional hazards assessments focused on the possibility of larger flows triggered by eruptive activity. In the past decade, Shasta's snow cover has lasted for shorter periods, leaving little to be melted in the event of an eruption. For the past two years there has been an uptick in smaller, seasonal lahars (locally called 'debris flows'), which have had significant impacts on the communities and infrastructure surrounding the volcano, disrupting major transportation routes and threatening municipal water supplies. In July 2021, for example, a flow traveled more than 12 km down the north flank of the volcano and temporarily closed a highway.

We present the results of two years of monitoring by temporary seismic deployments. Seismic signals are correlated with weather records and visual observations and compared to past records of lahar occurrence and local climate. Our initial results indicate that seasonal lahars are strongly associated with hot temperatures, suggesting melting of snow and ice creates a significant hazard in 'good' weather (unlike more tropical climates where rain is the main trigger for lahars). We also investigate whether the main source of water for these flows is Shasta's glaciers or its seasonal snow cover, and what the implications of ongoing climate change are for this water supply.

1065

Investigating the eruptive style of Palmas-type volcanism, Paraná Magmatic Province, Brazil

Dr Emily Charlotte Bamber[1], Dr Daniele Giordano[1], Dr Fabio Arzilli[2], Dr Giuseppe La Spina[3], Prof Michael R Carroll[2], Prof Valdecir de Assis Janasi[4], Prof Donald B Dingwell[5]

[1]University of Turin, Turin, Italy, [2]University of Camerino, Camerino, Italy, [3]INGV-Osservatorio Etneo, Sezione di Catania, Catania, Italy, [4]Universidade de São Paulo, São Paulo, Brazil, [5]Ludwig Maximilians Universität München, Munich, Germany

The Lower Cretaceous Paraná-Etendeka Magmatic Province (PEMP) is the second largest continental LIP on Earth. The Paraná portion of the PEMP has an estimated preserved volume of 600,000 km3, where approximately 3 % of the volume is silicic in composition. The low-TiO_2 Palmas-type sequence is subdivided into dacitic and rhyolitic endmembers and constitutes 80 % of the silicic erupted products of the PMP. Although the Palmas-type sequence is well characterised geochemically, there is an absence of primary textures indicative of an effusive or explosive mechanism due to the poor preservation of deposits, leading to a debate on the eruptive style and their emplacement.

The Caxias do Sul dacite is the first expression of Palmas-type volcanic activity and constitutes 80 % of the volume of the sequence. We provide the results of cooling and decompression experiments which constrain the nucleation and growth rates of plagioclase crystallisation within the Caxias do Sul dacitic magma. We compare our experimental textures with natural samples of the Caxias do Sul deposit and interpret the morphology and crystallisation history of natural plagioclase, to determine the nature of pre- and syn-eruptive crystallisation. Our experimental constraints and natural observations are incorporated in a 1D numerical model of magma ascent to simulate the dynamics of the eruption which emplaced the Caxias do Sul deposit. By integrating the results of experiments, analysis of natural samples and numerical modelling, we provide new insight into the eruptive dynamics, timescales, and style of this unusual silicic volcanic sequence.

1061

Outgassing behaviour during highly explosive basaltic eruptions

Dr Emily Charlotte Bamber[1,2], Dr Fabio Arzilli[3,2], Dr Giuseppe La Spina[4,2], Dr Margherita Polacci[2], Dr Lucia Mancini[5,6], Dr Mattia de' Michieli Vitturi[7,8], Dr Daniele Andronico[4], Dr Rosa Anna Corsaro[4], Prof Mike Burton[2]
[1]University Of Turin, Turin, Italy, [2]The University of Manchester, Manchester, UK, [3]University of Camerino, Camerino, Italy, [4]INGV-Osservatorio Etneo, Sezione di Catania, Catania, Italy, [5]Elettra Sincrotrone Trieste, Trieste, Italy, [6]Slovenian National Building and Civil Engineering Institute, Ljubljana, Slovenia, [7]University at Buffalo, Buffalo, USA, [8]INGV, Sezione di Pisa, Pisa, Italy

Highly explosive Plinian eruptions represent a rare, but considerable hazard at basaltic volcanoes. Basaltic volcanic systems typically produce low viscosity magma, which facilitates the decoupling of gas and melt during ascent, preventing magma fragmentation. However, basaltic Plinian eruptions have occurred, such as the Fontana Lapilli (60 ka) and Masaya Triple Layer (2.1 ka) eruptions of Las Sierras-Masaya volcano, Nicaragua, and the 122 BC eruption of Etna, Italy, ejecting > 1 km3 of tephra. The efficiency of outgassing during magma ascent depends on the development and maintenance of permeable networks within the magma and the mechanism and timescale of outgassing. Therefore, permeability depends on the physical properties of the magma, as pathways between vesicles may allow or restrict outgassing, influencing the eruptive style. However, samples of Plinian, Strombolian and lava fountain activity show similar ranges in porosity, pore connectivity and permeability, despite their differences in eruptive style.

We present 3D observations and quantification of the vesicle textures in samples of 3 basaltic Plinian eruptions, obtained using synchrotron-based X-ray computed microtomography. We compare our results from Plinian samples with those of lava fountain activity. We use this data in a 1D numerical conduit model of magma ascent, to investigate how the properties which control magma permeability influence eruptive style at basaltic volcanoes. By combining analytical and numerical techniques, we provide insight into the nature of outgassing and the dynamics of magma ascent for basaltic Plinian eruptions. We find that for the fast magma ascent rates which characterise Plinian activity, outgassing is restricted even at high magma permeability. Instead, we find that pre-eruptive conditions such as the initial temperature and crystal content have an important role in controlling the transition between a Plinian eruption and high-intensity lava fountain activity at basaltic volcanoes, due to the impact on syn-eruptive crystallisation and magma viscosity.

1264

Social media mirrors public sentiment about volcanic eruptions: case of the Ambae 2017-2018 event

Dr Philipson Bani[1], Dr Maëlle Calandra[2], Mr Dan Tari[3], Miss Christy Haruel[1]
[1]LMV/IRD-Nouméa, Nouméa, New Caledonia, [2]Laboratoire Magmas et Volcans, Clermont Ferrand, France, [3]Vanuatu Meteorology and Geohazards Department, Port Vila, Vanuatu

Volcanic eruptions usually generate a great deal of public interest and through the social media web platform, individuals can communicate, share information, express concerns, complain and even acknowledge actions related to volcanic events. From September 2017 to August 2018, Vanuatu experienced its most challenging volcanic crises since independence in 1980. In an attempt to understand how this major volcanic crisis was reflected in social media, we analysed the messages, images and videos posted in "Yumi toktok street (YTS) "throughout the period of the eruptive event. YTS is the most popular Facebook group in Vanuatu, with over 128,000 members, and was the main platform where the public followed the main eruption event in Ambae. A total of 214 posts from 111 separate identities were collected from 6 September 2017 to 28 November 2018.

The first observation that emerges from this work is the presence of episodes of high numbers of posts that coincide with the different phases of the eruptive event. The results further highlight the progressive loss of interest in this year-long eruption, contrasting with the increase in intensity of the eruption and subsequent stronger impacts. Detailed analyses reveal that the most commented messages mainly describe negative issues related to the eruption, while the most appreciated messages, although less commented, describe positive actions related to the crisis. If we consider the post-life, i.e. the time between the date of the post and the date of the last comment or like, discussions on custom beliefs, institutional decisions and donations top the list with 375 days, 368 days and 300 days respectively. The influence of social media during the Ambae volcano crisis remains to be fully investigated, but it is not non-existent.

1160

A zircon-based exposé on rhyolite petrogenesis from the Öræfi Volcanic Belt, Iceland

Dr Tenley Banik[1], Dr. Tamara L. Carley[2]
[1]Illinois State University, Normal, United States, [2]Lafayette College, Easton, United States

The Öræfi Volcanic Belt (ÖVB), home to Öræfajökull, Esjufjöll, and Snæfell volcanoes, is an off-rift petrogenetic feature in eastern Iceland. The majority of the ÖVB is obscured from view by Vatnajökull, an ice cap covering ~10% of Iceland's surface area. Historically, ÖVB volcanoes have produced jökulhlaups and explosive phreatomagmatic and rhyolitic eruptions. Changing climate, thinning ice, and isostatic rebound lead to increased concern about the productivity and stability of shallow ÖVB magma bodies. We use zircon from glacial river sediment, tephra, nunataks, and rare ice-adjacent outcrops to investigate magmatic histories and processes in this enigmatic region.

We present zircon dates, trace elements, and O and Hf isotopes—supported by whole rock geochemistry, whole rock isotopes (Hf, Nd, Pb), and petrography—from Öræfajökull in the south, Snæfell in the north, and Esjufjöll between. This evidence reveals a systematic north-to-south shift in activity, with crystallization ages 0.25–2.5 Ma at Snæfell and <0.5 Ma at Öræfajökull. The difference between known eruption ages (e.g., Öræfajökull, 1362 CE) and crystallization ages require silicic magmatic residence times on the order of 10s of thousands of years. Compositional trends reveal that southern zircon crystallized in hotter, less-evolved magmas than in the north (median Ti-in-zircon >10 ppm, Hf ~7,000–12,000 ppm at Öræfajökull vs. <10 ppm and ~6,000–11,000 at Snæfell). Zircon O isotope compositions are nearly identical between the northern and southern ends of the ÖVB (median $\delta^{18}O$ ~3.7 and ~4.0‰, respectively), suggesting ÖVB silicic petrogenesis occurs via fractional crystallization of mantle melts with a subordinate role for crustal assimilation. Zircon Hf isotope compositions are more radiogenic in the north than the south (median εHf: +14 vs. ~+12), due to heterogeneous mantle materials beneath the ÖVB. These insights into magma formation, evolution, environment and longevity are important contributions to better understanding ÖVB subglacial systems that pose future threats.

1070

Exploring Rover Autonomy Through Operations and Science in Analog Field Environments

Dr Maria Banks[1], E.Z. Noe Dobrea[2], A. Hendrix[2], C. Ahrens[1], A. Breitfeld[3], A. Candela[3], R. N. Clark[2], M. Hansen[3], G. Holsclaw[4], G. Kramer[2], M. D. Lane[5], T. H. Prettyman[2], C. Thieberger[6], S. Vijayarangan[3], S. P. Wright[2]
[1]Nasa Goddard Space Flight Center, Greenbelt, United States, [2]Planetary Science Institute, Tucson, United States, [3]Carnegie Mellon University, Pittsburgh, United States, [4]Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, United States, [5]Fibernetics LLC, Lititz, United States, [6]Northern Arizona University, Flagstaff, United States

The Toolbox for Research and Exploration (TREX) node of NASA's Solar System Exploration Research Virtual Institute (SSERVI) is investigating tools and techniques to improve operational efficiency and science yield of future missions via its autonomous science rover project. We integrated tools onto Carnegie Mellon's robotic testbed, including a decision-making technique known as the hypothesis map [e.g., 1] and the Tetracorder system [e.g., 2], enabling the rover to autonomously plan traverses, obtain observations, and provide high-level findings. Instruments (on the rover and hand operated simulating rover integration) include spectrometers observing in the 0.2–15 µm range, a gamma ray spectrometer, X-ray diffractometer, and cameras. Project objectives are to: 1) compare efficiency and science yield of different operational scenarios utilizing a semi-autonomous rover, 2) test efficacy of Tetracorder as a spectral analysis tool on a rover, and 3) test exploration strategies with rover autonomy. To achieve these objectives, we tested three operational scenarios: 1) standard rover exploration: science team chooses rover waypoints/observations based on analysis of images and multispectral data, 2) semi-autonomous rover exploration: rover chooses its path/waypoints based on an initial hypothesis map that is revised as new observations are acquired, and 3) rover with a deployed astronaut who can explore independently between waypoints (e.g., visiting outcrops inaccessible to the rover) and perform analyses/collect samples. Personnel included remote science, onsite field, and rover teams. We explored the Black Point Lava flow and associated basalt talus accumulated in eroded Permian/Triassic sedimentary rock sequences. We will discuss comparisons of our operational scenarios in this volcanic and sedimentary landscape, instrument measurement results, and applications to human and robotic exploration.

Acknowledgments: This work was funded by NASA grants: SSERVI (NNH16ZDA001N) and DDAP (Grant #80NSSC20K1153).
References: [1] Thompson, D. R., et al. (2011) J. Field Robotics, July/August. [2] Clark, R. N., et al. (2012) Icarus 218.

1480

Newly identified tuffs from the early - mid-Permian southern Sydney Basin: explosive volcanism and associated ecological mortality along southeast Gondwana.

Dr Glen Bann[1], Dr Brian Jones[1], Dr Ian Graham[2]
[1]*University Of Wollongong, Sanctuary Point, Australia,* [2]*University of NSW, Sydney , Australia*

The Sydney Basin forms the southernmost portion of the Permo-Triassic East Australian Rift System which extended along the eastern margin of Gondwana. A suite of newly identified tuffs are described from all formations from the early – mid Permian Shoalhaven and Talaterang Groups.

The tuffs, which in outcrop appear to vary from felsic to more mafic, commonly contain deformed biotite and muscovite, K-feldspar, plagioclase, volcanic quartz with embayments, metamorphic quartz, rare quartz and feldspar shards, and zircon. Trachytic microclasts and rhyolitic material are also common, along with carbonaceous material. The tuffs are commonly reworked, although a lack of abrasion on the phenocrysts, particularly the mafic material, suggests a proximal source. Numerous dropstones of tuff occur throughout the lower sequence, along with dacite, rhyolite and a few large granitic dropstones. Volcanic dropstones often dominate in the east and metamorphic cratonic types in the west.

Many of these tuffs are associated with bioturbation, including escape burrows, and death assemblages of marine fossils. Cruziana ichnogenera and glendonites, in addition to wave-generated ripples and clast concentrations, suggest deposition was dominated by episodic storm activity under cold climate marine conditions, with seasonal coastal ice sheets depositing the dropstones. Cross-bedding in the sandstone units indicate a predominantly northerly palaeocurrent direction.

The felsic tuffs likely represent small or distal components of much larger volcaniclastic aprons surrounding vents to the south or southeast, possibly within the Zealandia craton. The mafic material was sourced from more proximal island volcanoes also to the south and east of the exposed Sydney Basin. Detritus from these mafic volcanoes periodically inundated the cratonic sediments derived from the west.
Volcanism influenced the earliest stages of the evolution of the southern Sydney Basin and its ecosystems, much earlier than previously recognized.

695

Seismic imaging of the mid-crustal magmatic system beneath Ruapehu and Tongariro strato-volcanoes, Taupo Volcanic Zone

Dr Stephen Bannister[1], Dr Jessica Johnson[2], Dr Hao Guo[3], Dr Ninfa Bennington[4], Dr Wiebke Heise[1], Professor Haijiang Zhang[5]
[1]GNS Science, Lower Hutt, New Zealand, [2]University of East Anglia, , United Kingdom, [3]University of Wisconsin, , USA, [4]Hawaiian Volcano Observatory, USGS, , USA, [5]University of Science and technology of China, , China

We examine crustal seismicity, together with seismic properties P-wave velocity (Vp), Vp/Vs and Qp (1/attenuation) in the vicinity of the Ruapehu and Tongariro strato-volcanoes, Taupo Volcanic Zone, New Zealand. We derive a 3-D volume for Vp and Vp/Vs in a ~60-km radius around Ruapehu-Tongariro using double-difference seismic tomography, and seismic data collected over more than 20 years in various temporary deployments (e.g.START, SADAR, TADAR, CNIPSE), together with data folded in from the backbone GeoNet national seismometer network.

We find reduced P-wave velocities (-5%, ~5.8 km/s) at ~12 to ~22 km depth beneath and to the east of Tongariro, which we infer to represent part of the mid-crustal magmatic system for Tongariro. Above this low-velocity pocket Vp increases to ~6.3 km/s, and Vp/Vs is low (< 1.65) – indicative of the regional basement terrane. Our cross-sections of Vp/Vs show a well-defined band with low Vp/Vs (< 1.65) dipping from the Kaimanawas (Kaweka terrane) to the east, extending beneath Tongariro at depths ~6 to ~12 km. To the west of Tongariro the low Vp/Vs band extends to the surface, closely matching the location of surface geological exposures of Waipapa composite terrane.

Using the newly derived 3-D velocity model we derive relocations for more than 18,600 earthquakes (covering the 2010-2022 time period), using EQTransformer deep-learning for new P and S pick identification, NonLinLoc for initial location analysis, and tomoDD for the final locations, utilising absolute times, event-pair phase differential times and waveform-based differential times. The space-depth distribution of the new earthquake locations highlights well-defined streaks of activity (west-east and WNW-ESE trending) in the mid-crust west of Ruapehu, as well as details of a persistent mid-crustal (10-20 km deep) cluster south-east of Ruapehu. Shallow activity (< 4 km depth) is also observed immediately beneath both Ruapehu and Tongariro.

1220

The climatic and environmental impacts of New Zealand supereruptions

Dr Simon Barker[1], Mr Stephen Piva[1], Dr Holly Winton[1], Mr Alex Mattin[1], Ms Hannah Grachen[1], Dr Nels Iverson[2], Colin Wilson[1], Rewi Newnham[1], Lionel Carter[1], Alexa Van Eaton[3], Larry Mastin[3], Matt Ryan[4], Katherine Holt[5], Michael Sigl[6], Kirstin Krüger[7]

[1]Victoria University Of Wellington, Wellington, New Zealand, [2]New Mexico Institute of Mining and Technology, Socorro, USA, [3]Cascades Volcano Observatory, United States Geological Survey, Vancouver, USA, [4]PDP Wellington, Wellington, New Zealand, [5]Massey University, Palmerston North, New Zealand, [6]University of Bern, Bern, Switzerland, [7]University of Oslo, Oslo, Norway

Rapid changes in Earth's climate have been documented after historic explosive volcanic eruptions. However, the magnitude of explosive eruptions in the geological record far exceeds those witnessed in modern history, by up to one hundred times. Through simply scaling the measured impacts of historic volcanic eruptions, it has been proposed that high-magnitude volcanic "supereruptions" may have caused major shifts in Earth's past climate and severely impacted the environment. We are investigating three NZ supereruptions that spread ash across most of NZ and are exceptionally well preserved in several high-resolution palaeoenvironmental records including marine cores, terrestrial sediment and lake records and Antarctic ice cores: the 25.5 ka Oruanui (1150 km³ ash), 350 ka Whakamaru (~3000 km³ ash) and ~1 Ma Kidnappers (~2000 km³ ash) supereruptions. Using multiple climate and environmental proxies in these records we will assess the impact of past NZ supereruptions across a range of climate conditions and geographical scales. First, we will model ash plumes and deposition from past supereruptions to assess eruptive conditions and the total release of volatiles. Second, we will investigate regional impacts on NZ vegetation and landscapes by looking at mm-scale changes in pollen records from lakes and bogs around NZ. Third, we will assess multiple Antarctic ice cores records that permit vital insights into the climactic impacts of a supereruption over short, medium and long time intervals. In this presentation we will highlight our novel methodologies, preliminary findings and future research.

766

Tidy… or not tidy… a statistical secret of long time series of volcanic degassing

Ms Charlotte Barrington[1,2], Benoit Taisne[1,2], Fidel Costa[1,2,3], Santiago Arellano[4]
[1]Earth Observatory Of Singapore, Nanyang Technological University, , , [2]Asian School of the Environment, Nanyang Technological University, Singapore, Singapore, [3]Institut de Physique du Globe de Paris, Université Paris Cité, CNRS, , France, [4]Department of Space, Earth and Environment, Chalmers University of Technology, Gothenburg, Sweden

A long-standing question in Earth science is whether or not the Earth tides influence volcanism. There exists vast literature reporting periodic trends in the time series of geophysical and geochemical monitoring data which coincide with those of the dominant tidal components. In recent years the subject has gained somewhat renewed attention, particularly concerning the influence of Earth tides on volcanic degassing, with several studies making links between tidal forces and periodic trends observed in plume gases. By applying Differential Optical Absorption Spectroscopy (DOAS) to UV spectra recorded with ground-based scanning UV-spectrometers, the Network of Volcanic and Atmospheric Change (NOVAC) database provides time series of SO_2 emission rates from a total of 32 volcanoes worldwide. Here, we attempt to determine the extent to which (if any) the influence of Earth tides can be reliably observed in these time series. We model several of these time series and remove the dominant periodicities previously identified, which relate to ambient meteorological conditions. We then apply the Lomb-Scargle periodogram and calculate False Alarm Probabilities (FAPs) to determine whether additional statistically significant periodicities exist in the time series of SO_2 emission which may indicate the influence of Earth tides. In order to investigate the notion that Earth tides modulate activity only when a volcano is in a critical state, we also preformed similar analysis on the time series of SO_2 emission rate prior to, and immediately after, eruptions at several volcanoes. We seek to highlight the extent to which (if any) the influence of Earth tides can be reliably observed at open vent volcanoes.

619

Towards a simple tool to detect SO2 absorption in UV spectra of volcanic plumes

Ms Charlotte Barrington[1,2], Benoit Taisne[1,2], Fidel Costa[1,2,3]
[1]Earth Observatory Of Singapore, Nanyang Technological University, , Singapore, [2]Asian School of the Environment, Nanyang Technological University, , Singapore, [3]Institut de Physique du Globe de Paris, Université Paris Cité, CNRS, , France

Volcanic emissions of sulphur dioxide (SO_2) provide important information about processes occurring at shallow depth, and measurements of SO_2 degassing remain one of the primary parameters to identify volcanic unrest and forecast eruptive activity. A continuous record of the SO_2 emission rate is mainly obtained by ground-based UV remote sensing, where Differential Optical Absorption Spectroscopy (DOAS) is the favoured approach for quantifying SO_2 absorption from the recorded spectra. Although DOAS is a valuable technique for retrieving accurate column amounts SO_2, a complex fitting routine is required. Instead, we explore an alternative approach based on the spatial frequencies contained in UV spectra. The measured intensity of sky scattered UV spectra varies but its spatial frequency remains largely uniform due to the well-defined Fraunhofer lines. Absorption by SO_2 however, causes a change in the spatial frequency. Here, we use UV spectra recorded with calibration cells of known SO_2 concentration to compare the spatial frequencies using wavelet coherence. We find that the resulting Magnitude-Squared Wavelet Coherence (MSWC) is inversely proportional to SO_2 concentration and by applying the same approach to unprocessed UV spectra recorded by scanning UV instruments of the Network of Volcanic and Atmospheric Change (NOVAC), we identify relative amounts of volcanic SO_2. The use of MSWC has the potential to provide rapid (real-time) detection of trace gases from UV spectra and aid the selection of clear-sky reference spectra which does not already contain absorption structures due to the presence of SO_2. Using the MSWC allows us to identify spectra to analyse for the retrieval of trace gases which are not spatially uniform within the volcanic plume (e.g., halogen oxides).

687

Helium and carbon isotopes in fluids and gases from the Andean Convergent Margin

Dr Peter Barry[1], C. G. Bartels[2], Dr. D.V. Bekaert[1], J. Curtice[1], M. Hudak[1], J.M. de Moor[3], G.L. Jessen[4], D. Giovannelli[5], M. Shrenk[6], F. Augilera[7], A. Chiodi[8], C.J. Ramirez[9], K.G. Lloyd[10]
[1]WHOI, Woods Hole , United States, [2]Barnard College, New York, USA, [3]OVSICORI, Heredia, Costa Rica, [4]Universidad Austral de Chile, Valdivia, Chile, [5]University of Naples, Naples, Italy, [6]Michigan State University, East Lansing, USA, [7]Universidad Católica del Norte, Antofagasta, Chile, [8]Instituto de Bio Y Geociencias Del Noroeste Argentino, Salta, Argentina, [9]Servicio Geológico Ambiental (SeGeoAm), Heredia, Costa Rica, [10]University of Tennessee, Knoxville, USA

Convergent margins are the interface between Earth's surface and deep reservoirs, where volatiles are dynamically subducted into Earth's mantle and then returned to the surface via volcanism. During subduction, fluids migrate through the overlying mantle wedge and crust and emplaced at the surface. The efficiency of this volatile transfer to the mantle has profound implications for the geochemical evolution of Earth. Helium isotopes are sensitive to magmatic inputs and can be used to deconvolute mantle and crustal volatile pathways in arcs. Carbon is readily recycled, mostly in the form of carbon-rich sediments, and can be used to understand volatile delivery to the mantle via subduction. Further, carbon is chemically reactive, and its isotope fractionation can be used to track the main processes controlling volatile movements within arc systems.

We present unpublished He and C isotope results from fluid and gas (n=37) samples collected during a field campaign to the Central Volcanic Zone (CVZ) of the Andean Convergent Margin (ACM)1. Helium isotopes range from 0.98 to 5.80 RA in gas samples and from 0.07 to 3.87 RA in fluids, agreeing well with published data2. Carbon isotopes range from -10.6 to -3.6 ‰ vs. VPDB and also fall within expected ranges for the region2. These data suggest a much smaller mantle influence in the CVZ relative to other portions of the ACM. This is presumably associated with thicker crust masking the signal in the CVZ2, which is up to 70 km and significantly thicker than in the Southern Volcanic Zone (SVZ), where it is just 35-45 km thick3. It thus appears that crustal thickness exerts a primary control on the extent of fluid-crust interaction, as helium and other volatiles rise through the upper plate in the ACM.

[1] Bartels et al., 2022
[2] Barry et al., 2022
[3] Tassara and Echaurren, 2012

1015

Operating the Aviation Color Code system at European Volcano Observatories: experiences and challenges

Dr Sara Barsotti[1], Dr Simona Scollo[2], Dr Giovanni Macedonio[3], Dr Alicia Felpeto Rielo[4], Dr Jean-Christophe Komorowski[5], Dr Georgios Vougioukalakis[6], Dr Elske Zeeuw de-Dalfsen van[7], Dr Lars Ottemøller[8], Dr Adriano HG Pimentel[9], Dr Mauro Coltelli[2], Dr Rita Carmo[9], Dr Rui Marques[9], Dr Joana Medeiros[9], Dr Teresa Ferreira[9], Dr Sue Loughlin[10]

[1]Icelandic Meteorological Office, Reykjavík, Iceland, [2]iNGV - OE, Catania, Italy, [3]INGV - OV, Napoli, Italy, [4]IGN, Madrid, Spain, [5]IPGP, Paris, France, [6]IGME, Thessaloniki , Greece, [7]KNMI, De Bilt, Holland, [8]University of Bergen, Bergen, Norway, [9]CIVISA -IVAR, Ponta Delgada, Açores, Portugal, [10]BGS, Edinburgh, UK

Volcano Observatories (VOs) around the world are required to maintain the surveillance of their volcanoes and inform timely civil protection and aviation authorities about impending eruptions. Often, they work through procedures which allow them to respond timely to volcanic crises and provide a service aimed at reducing the potential impact of an eruption. Within the International Airways Volcano Watch (IAVW) framework, VOs are asked to operate a system designed to inform the aviation community about the status of a volcano and the expected threat associated. Despite the IAVW documentation reports the definition of the different color coded levels, operating the Aviation Color Code (ACC) can be a difficult task and VOs might adopt different strategies on how, when and why to change it.

Following the two European Volcano Observatories and VAACs meetings, in 2019 and 2021, the European VOs agreed to present an overview on how they work about ACC. This analysis reveals that not all VOs in Europe have the usage of ACC as part of their operations, mainly because of lack of eruptions in recent times. Moreover, those VOs which regularly adopt ACC, operate it differently depending on the frequency of the eruptions, the type of volcano, the historical eruptive activity, the monitoring level, but also the agreement with the local Air Transport Navigation providers. At the same time all VOs change ACC in a very dynamic way to reflect the variability in the volcanic activity, except during decreasing activity and waning phase.

This study shows that despite the ACC system is designed to provide a standard, its usage strongly depends on the evaluation of those responding to volcano emergencies. Still the usage of ACC is of relevance for the aviation stakeholders, that encourage its practice in addition to a wider dialogue with the Volcano Observatories in Europe.

1303

How are we prepared for the next explosive eruption in Iceland?

Dr Sara Barsotti[1], Dr Talfan Barnie[1], Dr Þórður Arason[1], Dr Melissa A. Pfeffer[1], Dr Björn S. Einarsson[1]
[1]*Icelandic Meteorological Office, Reykjavík, Iceland*

The most recent explosive eruption in Iceland occurred in 2011 at Grímsvötn volcano. Since then, the Icelandic Meteorological Office has improved the monitoring network, data integration, forecasting capabilities and operational response. The radar network will be the primary source of information on volcanic ash detection, providing input data to the VESPA (Volcano Eruption Source Parameters Assessment) system for a rapid estimate of plume height with a vertical resolution of up to 500 m. Calibrated streaming cameras will supplement this information by providing height estimates with a temporal frequency of 5 minutes and under optimal conditions provide a resolution of up to the order of tens of meters. Additional estimates of plume heights will come from satellite images received in near real time over the EUMETCAST satellite data dissemination service. Plume height and mass flow rates as evaluated by VESPA will be used to initialize the tephra dispersal system which will execute the NAME model over the national domain. A newly interactive portal aimed at a wide variety of end users from specialists to the general public allows the model results to be visualized and queried for georeferenced details. The model results are pushed through an internal system and made available to the forecasters on duty in near real time, within 10 minutes of the run start, for the issuance of the first two SIGMET (Significant Meteorological Event) messages while waiting for the L-VAAC official forecasts. Model results are also provided on IMO‘s website. Plume heights and additional information on the ongoing eruption will be distributed through VONAs, sent out by specialists on duty, and available on IMO‘s web-site in real time. In this presentation the operational framework of this integrated response, highlighting the expected timeline will be presented with an emphasis on testing and practicing and future steps.

402

CO2-fueled rapid ascent from Moho depths during subplinian picritic eruption at Etna (3930 BP)

Dr Anna Barth[1], Dr Maxim Portnyagin[2], Dr Yves Moussallam[3], Dr Estelle Rose-Koga[5], Dr Daniel Rasmussen[4], Henry Towbin[3], Dr Terry Plank[3]

[1]University Of California, Berkeley, Oakland, United States, [2]GEOMAR Helmholtz Centre for Ocean Research , Kiel, Germany, [3]Lamont-Doherty Earth Observatory, New York, United States, [4]Smithsonian, Washington D.C., United States, [5]Laboratoire Magmas et Volcans, Aubière, France

The 3930 BP Fall Stratified (FS) eruption at Mt. Etna is a rare example of a highly explosive eruption of picritic magma. The eruption produced ash plumes up to 20 km high, giving it an intensity of VEI 4 (Subplinian). The volatile-rich and primitive nature of the FS magma suggest that it ascended rapidly from great depths to avoid fractionation and mixing with the extensive plumbing system beneath Etna. To determine the pressures from which the FS magma derives, we performed rehomogenisation experiments on melt inclusions hosted in Fo90-91 olivines using an internally heated pressure vessel and determined primary CO2 concentrations in the magma of up to 9500 ppm. Applying the MagmaSat volatile solubility model (Ghiorso and Gualda, 2015) to the H2O and CO2 concentrations gives magma storage pressures of 630–800 MPa, corresponding to depths of 24–30 km, which is within uncertainty of the seismologically-estimated Moho.

We measured H2O concentration profiles in 18 clear, euhedral olivines and modeled these to determine magma decompression rate. The different olivines give remarkably uniform average magma decompression rates of ~ 10^-0.4 MPa/s, or ~ 12–15 m/s. The high H2O concentrations (up to 4.7 wt%) and early exsolution of CO2 in the lower crust may have driven this unusually explosive eruption from the mantle to the surface fast enough to prevent loss of gas from the magma, despite its low viscosity.

404

Knock knock—pool's there! Regular cycles of steam bubble collapse at Doublet Pool, Yellowstone

Dr Anna Barth[1], Mara Reed[1], Dr Michael Manga[1]
[1]*University Of California, Berkeley, Oakland, United States*

Doublet pool is an active hydrothermal feature located in the Upper Geyser Basin of Yellowstone National Park. While Doublet does not erupt, approximately every 30 minutes it undergoes a 10-minute period of 'thumping', with thumps that can be felt and heard from the boardwalk. During two field campaigns in November 2021 and April 2022, we deployed a hydrophone, in-situ temperature and pressure sensors, and a Go-Pro to investigate the mechanism driving Doublet's thumping cycles. Go-Pro footage reveals that the thumping corresponds to the collapse of decimeter-scale bubbles at a vent at the base of the pool. We hypothesize that these are H2O vapor bubbles, which immediately condense upon contact with the relatively cold (sub-boiling temperature) water of the pool.

In addition to the first-order thumping cycles, the hydrophone reveals a consistent period of heightened noise in the 10 minutes before thumping begins. This appears to correlate with the appearance of small (cm-scale) bubbles from the basal vent. Since these bubbles do not collapse but instead rise to the pool's surface, they likely contain non-condensable gases. Assuming a constant influx of volatiles from depth, the progression from non-condensable to H2O gases indicates the warming of the conduit system over the course of a single cycle.

1228

Particle Morphology created by high-energy, fuel-coolant fragmentation (FCI) during Tonga's 2022 Hunga eruption

Miss Rachael Baxter[1,2], Professor James White[1], Dr Tobi Dürig[3], Dr Joa Paredes-Mariño[4], Professor Shane Cronin[4], Dr Ingrid Ukstins[4], Miss Mila Huebsch[4], Dr Marco Brenna[4]
[1]Department of Geology, University of Otago, Dunedin, New Zealand, [2]Department of Earth Sciences, University of Cambridge, Cambridge, United Kingdom, [3]Institute of Earth Sciences, University of Iceland, Reykjavik, Iceland, [4]School of Environment, University of Auckland, Auckland, Auckland, New Zealand

The explosive eruption from Tonga's Hunga Volcano on 15 January 2022 sent air-pressure and tsunami waves around the globe. Particles created by this powerful eruption were ejected into both, the atmosphere and ocean. We have analysed the morphology and fracture patterns on grain-bounding surfaces of 1 phi and 4 phi ash particles from bulk samples representing material deposited on Tonga over the course of the ~11-hour eruption, collected ~ 1 week after the event.

Samples were sieved into half-phi fractions, from which 1 phi particles and 4 phi particles were selected and mounted on carbon tape for image collection using an SEM Backscattered Electron Detector (BSD). High resolution, high magnification images were collected for analysing particle fracture patterns, while higher contrast images were processed through the PARTIcle Shape ANalyzer (PARTISAN) MatLab tool. Particle populations were statistically analysed using DendroScan, another MatLab tool, to assess morphological similarities and dissimilarities with particles created in other eruptions (Havre 2012, Ubehebe, Rotomahana 1886, and experimentally created Havre particles). The shapes of Hunga ash grains most closely match those of Havre submarine rhyolite ash.

A striking feature of the exteriors of Hunga particles is the great abundance of diagnostic fracture surfaces. 1 phi particles exhibited many such surfaces, with >95% of particles analysed presenting shock wave traces (3D stepped surfaces, conchoidal fractures and 2D hackle lines). Most (>80%) 4 phi particles also exhibited these diagnostic fracture patterns. While similarity of morphology between Hunga and Havre particles indicates that a thermohydraulic mechanism drove explosions in both of these eruptions, the energy released - producing diagnostic fracture patterns across nearly all grains - was much higher at Hunga. These particles record the fragmentation process at work during one of the most powerful explosive eruptions ever recorded.

1229

Magma-flux regulated final depths of magma storage under Iceland

Miss Rachael Baxter[1,2], Professor John Maclennan[1], Dr David Neave[3], Professor Thor Thordarson[4]
[1]Department of Earth Sciences, University of Cambridge,, Cambridge, United Kingdom, [2]Department of Geology, University of Otago, Dunedin, New Zealand, [3]Department of Earth Sciences, University of Manchester, Manchester, United Kingdom, [4]Institute of Earth Sciences, University of Iceland, Reykjavik, Iceland

We created PyOPAM, an open-source software that runs in Python, to estimate the final storage depths of basaltic melts prior to eruption. This improved configuration of the Olivine-Plagioclase-Augite-Melt barometer can be used to estimate the depth where basaltic melt was last three-phase-saturated. Using 366 experimental glass compositions compiled from literature, we calibrate this barometer and constrain 1 σ to 1.26 kbar. We apply PyOPAM to a dataset of ~13,400 analyses of glass and whole-rock samples from Iceland. Of these, 3807 analyses generate robust pressure estimates, constraining final pre-eruptive magma storage depths for 23 of the 30 volcanic systems across Iceland.

Magma storage pressure is linked to input melt flux from the mantle as estimated from the product of crustal thickness and spreading rate. Independent increases in either spreading rate or crustal thickness are associated with shallowing of pre-eruptive storage depths, indicating that mantle melt fluxes dictate the long-term stabilisation of extensive magmatic storage regions at depths shallower than 10 km.
The inherited thermal structure of the crust provides a secondary control on basaltic magma storage depths. Crust away from regions of long-term magma flux (e.g. off-axis) is less likely to host basaltic melt in shallow storage regions because the upper crust has cooled. The quantitative relationships between mantle flux and storage depths can be used to test computational models of transcrustal magmatic systems.

698

Intra-eruption Forecasting Using Analogue Volcano and Eruption Sets

Professor Mark Bebbington[1], Associate Professor Susanna Jenkins[2]
[1]Massey University, Palmerston North, New Zealand, [2]Nanyang Technological University, Singapore, Singapore

Pre-eruption forecasting, particularly at poorly studied or awakening volcanoes, relies heavily on formal or informal use of information from other better observed (analogue) volcanoes. Equally as important as onset forecasting is the ability to forecast the future of an eruption currently in progress. In an earlier paper (Bebbington and Jenkins, 2019), we developed a methodology for intra-eruption forecasting, based on a semi-Markov chain model of transitions among multiple types of eruptive phases. Having further expanded the data base to now include 2670 eruptions from 353 volcanoes, we are able to examine what selection basis for analogue volcanoes provides the most accurate forecasting of eruption sequences. In particular, we consider subsetting the data according to the type (e.g., stratovolcano, shield, …) and/or dominant composition (andesite, basalt, …) of the source volcano. These were compared against the accuracy when using the entire dataset, or just the record of the target volcano itself. We found that any subset performed better than the entire dataset … apart from the up to 40% of the eruptions which could not be forecast at all(!) by the subset as they contained features that were not in the analogue set. After extending the models to cope with this problem, we find that shields are well forecast by limiting the analogue set, in contrast to domes where the entire dataset works best. Interestingly, stratovolcanoes are relatively poor predictors of their own behaviour or, in other words, are good candidates for analogue modelling. Dominant composition was not informative when selecting analogues. Apart from this, limiting the analogues set to the target volcano itself is a viable strategy when it has at least 20 eruptions in the dataset.

References.

Bebbington, M.S. and Jenkins, S.F. 2019. Intra-eruption forecasting. Bulletin of Volcanology, 81:34.

1178

A tale of two caldera systems

Professor Mark Bebbington[1], Professor Mark H. Anders[2]
[1]Massey University, Palmerston North, New Zealand, [2]Columbia University, New York City, USA

Caldera-forming eruptions have very low probability, but extremely high impact. By their very nature, such eruptions are observed almost solely in the geological record, where their size counteracts the usual preservation bias. We examine two systems where repeated caldera-forming eruptions have been identified; the central Taupo Volcanic Zone (24 eruptions from 1.6 Ma), and the Yellowstone Hotspot Track (45 eruptions from 10.4 Ma). A range of stochastic models are tested to see if they can reproduce the observed temporal-volume patterns in the observed record. Neither record is time-stationary, hence either erupted volume must be used to modulate the temporal eruption likelihood, or a waxing/waning temporal rate is required. The two systems are both well explained by a model where the eruption potential increases over time between events, and is reduced by each erupted volume. The Yellowstone system is also well described by a waning rate of eruption occurrence. Future eruption volumes in the TVZ are well described by a log-Gumbel distribution, with mean positively correlated with the previous repose length. In contrast, erupted volumes in the Yellowstone system are bimodal, and not correlated with either the previous or subsequent repose, or the previous erupted volume. We conclude that the TVZ system is, at the level of caldera-forming eruptions, volume-controlled, while the Yellowstone hotspot may not be.

1202

Volcano risk communication in Aotearoa New Zealand: A review

Dr Julia Becker[1], Manomita Das[1], Dr Emma E.H. Doyle[1], Dr Danielle Charlton[2], Dr Sally H. Potter[2], Dr Graham S. Leonard[2], Prof David M. Johnston[1], Dr Lauren J. Vinnell[1], Dr Mary-Anne Clive[2], Assoc Prof Carol Stewart[1], Kelvin Tapuke[1], Dr Sara K. McBride[3], Dr Janine Krippner[4], Dr Nico Fournier[2], Dr Craig Miller[2], Hollei Gabrielsen[5]

[1]Joint Centre for Disaster Research, Massey University, Wellington, New Zealand, [2]GNS Science, Lower Hutt, New Zealand, [3]United States Geological Survey, Menlo Park, USA, [4]University of Waikato, Hamilton, New Zealand, [5]Department of Conservation, Turangi, New Zealand

Existing volcano-focused risk communication studies in Aotearoa New Zealand mostly focus on communication and decision-making related to certain volcanic sites or hazards during volcanic unrest or eruptions. An integrated understanding of volcano communication across the differing stages of quiescence, unrest, short or long eruptive phases, and recovery remains absent. Consequently, this presentation takes a longitudinal approach and presents an overview of the range of communication and decision-making that happens during the various stages, in the context of Tongariro National Park volcanoes. The review findings suggest that communication in pre-eruptive stages happens through a range of sources like observatories, government agencies, tourism providers and others, for the primary purposes of knowledge dissemination and preparing plans. However, during unrest and eruptive stages the information flow becomes comparatively streamlined, often led by official agencies and partner organisations with defined mandates. Eventually discrete streams of communication emerge, catering to specific information requirements in the during and post-eruption stages, often being local in scale and involving responding agencies and community representatives. Specific case studies, such as that of the 2012 Te Maari eruption, highlight some of the differing types and needs of communication over various timeframes. While further study is needed on these aspects, these findings can help improve future information for decision-making purposes for different stages of volcanic activity.

365

Conducting Multi-Agency Volcanic Ash Cloud Exercises: Practicing forecast evaluation procedures and the pull-through of scientific advice to the London VAAC

Dr Frances Beckett[1], Dr Sara Barsotti[2], Dr Ralph Burton[3], Dr Fabio Dioguardi[4,5], Dr Samantha Engwell[4], Dr Nina Kristiansen[1], Dr Sue Loughlin[4], Mr Anton Muscat[1], Dr Martin Osborne[1], Mr Cameron Saint[1], Dr John Stevenson[4], Dr Declan Valters[4], Dr Claire Witham[1]

[1]Met Office UK, Exeter, United Kingdom, [2]Iceland Met Office, , Iceland, [3]National Centre for Atmospheric Science, , UK, [4]British Geological Survey, , UK, [5]University of Bari, , Italy

Practising and testing emergency procedures are fundamental for ensuring an effective operational response to a crisis. In this presentation we will introduce a new series of exercises which have been developed to test the multi-agency response needed to produce volcanic ash forecasts at the London Volcanic Ash Advisory Centre (VAAC). Our exercises have been specifically designed to practice our ability to interpret and evaluate model simulations and observations, the pull through of international scientific expertise into the London VAAC, and decision-making procedures under uncertainty.

In this presentation we will describe our exercise methodology, this includes the development of simulated observations for exercise conditions, and a framework for comparing transport and dispersion simulations generated using different model setups (multi-model ensemble). We will also discuss how we practice the necessary interactions between scientists supporting the London VAAC and external collaborators, which may include experts at volcano observatories, national/state geological or geophysical institutions, and volcano research institutions. We will present case-studies of exercises for hypothetical events in Iceland and outline the lessons learnt. Our Exercises have not only improved our ability to respond to a volcanic ash cloud event but have also driven scientific and technical improvement of the forecasts, and strengthened the relationships between collaborators and responders, with the aim of providing the best possible advice to the London VAAC.

366

Modelling the size distribution of aggregated volcanic ash and implications for operational atmospheric dispersion modelling

Dr Frances Beckett[1], Dr Eduardo Rossi[2], Professor Benjamin Devenish[1], Dr Claire Witham[1], Professor Costanza Bonadonna[2]
[1]Met Office UK, Exeter, United Kingdom, [2]University of Geneva , Geneva, Switzerland

Volcanic ash can form aggregates whose physical properties depart from the single particles of which they are composed. Neglecting aggregation in atmospheric transport and dispersion models could lead to errors when modelling the rate of removal of ash from the atmosphere and, consequently, inaccuracies in forecasts used by aviation for hazard assessment.

Here we will present a model for simulating the aggregation of volcanic ash in an eruption column. Our aggregation scheme is coupled to a buoyant plume model and uses the fixed pivot technique to solve the Smoluchowski coagulation equations, which allows us to simulate the evolution of the size distribution of the aggregates with time. We use the output aggregated size distribution of the ash at the top of the eruption column in the initialization of our atmospheric transport and dispersion model NAME.

NAME is used by the London Volcanic Ash Advisory Centre to provide advice and guidance on the location of volcanic ash clouds to the aviation industry. To understand the sensitivity of the output size distribution of the aggregates to the parameters used in our aggregation model we conducted a simple parametric study and scaling analysis. We will show that the modelled size distribution of the aggregates is sensitive to the density distribution and size distribution assigned to the non-aggregated particles at the source. Our ability to accurately forecast the long-range transport of volcanic ash clouds is, therefore, still limited by real-time information on the physical characteristics of the ash. We will also show the impact of representing aggregates on model simulations of the 2010 Eyjafjallajökull ash cloud and consider the implications for operational forecasting.

863

Applying machine learning methods to detect explosive volcanic eruptions with volcanic lightning observations

Dr Sonja Behnke[1], Dr Harald Edens[1], Dr James Theiler[1], Diana Swanson[1], Dr Seda Senay[2], Dr Alexa Van Eaton[3], Dr Masato Iguchi[4], Dr Daisuke Miki[4]

[1]Los Alamos National Laboratory, Los Alamos, United States, [2]Electrical Engineering Department, New Mexico Institute of Mining and Technology, Socorro, United States, [3]US Geological Survey, Cascades Volcano Observatory, Vancouver, United States, [4]Sakurajima Volcano Research Center, Disaster Prevention Research Institute, Kyoto University, Kyoto, Japan

Explosive volcanic eruptions often produce a repeatable pattern of electrical activity that can be used for eruption detection. Starting at the onset of an explosion, a swarm of small “vent discharges” occurs within the gas thrust region of the plume. Several seconds later, lightning starts to occur throughout the eruption column as charge begins to separate. This chronological sequence of electrical activity has been observed during eruptions from several different volcanoes, including Augustine Volcano (Alaska, USA; 2006), Redoubt Volcano (Alaska, USA; 2009), Eyjafjallajökull (Iceland; 2010), and Sakurajima (Japan; 2015; 2019; 2020). We demonstrate a proof-of-concept for our eruption detection algorithm that identifies this common and repeatable pattern. The algorithm leverages a machine learning classifier to distinguish between the characteristics of radio frequency waveforms of vent discharges and lightning. To illustrate our method, we use broadband (20-80 MHz) very high frequency (VHF) waveform data of explosive volcanic eruptions from the Minamidake crater of Sakurajima volcano in Japan. The data were collected with a flat plate antenna and PC-based digitizer between May 2019 and May 2020. We show that individual VHF waveform impulses produced by vent discharges and lightning can be accurately classified due to differences in the amount of signal clutter surrounding each type of impulse. In particular, we show that impulses from vent discharges are more isolated in time compared to impulses from lightning. The results of the signal classifier are then used to identify the characteristic pattern of volcanic electrical activity to determine if an explosive event has occurred. Implementation of the detection algorithm on an agile and deployable VHF sensor would enable a new method of volcanic eruption detection and facilitate new research targeted at incorporating lightning observations into volcano monitoring.

1118

Bayesian Heat Emission Estimates at Mt. Ruapehu Using a Non-Linear Kalman Smoother

Mr Yannik Behr[1], Steve Sherburn[1], Tony Hurst[1]
[1]*Gns Science, Taupo, New Zealand*

To link observations at volcanoes to volcanic processes we often have to solve differential equations. The corresponding models tend to have many parameters, most of which come with significant uncertainties. This can make it difficult if we want to solve the inverse problem to infer the parameters of a volcanic process that led to an observation.

Kalman Filters and Smoothers are an efficient Bayesian technique to solve such inverse problems. Results are probabilistic and can directly feed into impact-based forecasting. Their particular power, however, lies in separately accounting for uncertainties in the physics-based model and the observations. This allows us to gain insights on volcanic processes even from very simple models as long as they come with large enough uncertainties.

We show the application of a non-linear Kalman Smoother to infer the rate of heat entering Ruapehu Crater Lake (Te Wai ā-moe), a volcanic lake at the top of Mt Ruapehu volcano. For our estimates, we combine continuous observations of lake temperature and level and sporadic measurements of ion content and outflow rate with a mass and energy balance model. Our results indicate a change in the magmatic heat supply and the hydrothermal system between 2017 and 2020.

1326

Seismicity and Deformation Accompanying Eruption Cycles at Basaltic Caldera Volcanoes in the Galápagos Islands, Ecuador

Dr Andrew Bell[1], Stephen Hernandez[2], Peter LaFemina[3], Sophie Butcher[1], Mario Ruiz[2], Patricia Gregg[4], Jack Albright[4], Christopher Bean[5]

[1]University of Edinburgh, Edinburgh, United Kingdom, [2]Instituto Geofisico de le Escuela Politecnica Nacional, Quito, Ecuador, [3]Pennsylvania State University, State College, United States of America, [4]University of Illinois, Urbana-Champaign, United States of America, [5]Dublin Institute for Advanced Studies, Dublin, Ireland

Large basaltic volcanoes offer natural laboratories to study the fundamental processes of crustal deformation and seismogenesis. High rates of magma flux in to and/or out of shallow reservoirs can result in strain rates and stress regimes that seldom occur in purely tectonic settings. Eruptions at the basaltic caldera volcanoes of the Galápagos Islands, Ecuador, are often associated with particularly high amplitudes and rates of deformation, and correspondingly high rates of seismicity. Variations in location with respect to the centre of the Galápagos plume, regional structural features, and the other volcanoes, provides each system with a particular set of characteristics in terms of edifice morphology and eruptive behaviour. By understanding how these characteristics also influence the nature of seismicity, we expect new insights into the mechanisms of shallow magma emplacement, edifice deformation, and earthquake generation. Here we describe the seismicity that occurred before, during, and after recent eruptions at Sierra Negra and Fernandina volcanoes. Earthquake rates, locations, and statistics document distinct processes of magma accumulation and withdrawal, influenced by the geometry of the shallow plumbing systems and edifice structure. The nature of seismicity is, in turn, distinct from that observed at recent eruptions in Hawaii and Iceland, and in non-volcanic tectonic settings. These observations reveal how stress evolves on intra-caldera fault systems, how lateral magma intrusion is accommodated in the absence of prominent rift-zones, and some of the factors which determine whether or not caldera collapse occurs.

357

Effect, deposits and mechanism of the 2019 explosive eruption of Raikoke volcano, Kurile islands.

Dr Alexander Belousov[1], Dr. Marina Belousova[1]
[1]*Institute of Volcanology and Seismology, Petropavlovsk-kamchatsky, Russian Federation*

Raikoke - uninhabited island 2 km across located in the central part of Kurile arc. Raikoke represents subaerial summit (550 m high) of active volcanic stratocone rising from depth of 2500 m. The volcano produced 3 historical eruptions, which were not closely observed. All the eruptions were purely explosive, and led to nearly complete devastation of the island's ecosystems. Our field investigation of pyroclastic deposits of 2019 eruption, combined with the published acoustic and satellite data shown that this eruption started abruptly as phreatomagmatic Subplinian activity that lasted 4.5 h and formed pulsating eruption column up to 10 km high. The column was overloaded with fine-grained pyroclastic material and experienced partial gravitational collapse, forming numerous small pyroclastic flows, which affected the entire island and destroyed the vegetation and the habitat of numerous birds and Steller lions. The PFs deposited several fans up to 10 m thick composed of coarsely layered, poorly sorted pyroclastic material: moderately vesicular (33-40%) juvenile clasts mixed with old dense rocks. Phreatomagmatic mechanism of the initial Subplinian stage of the eruption was governed by interaction of the rising batch of basaltic andesite (52-53% SiO2) magma with ground water, which was probably represented mostly by sea water percolated inside the island's aquifer. After the eruption the sea water seeped into the deepened central crater of the volcano and formed new crater lake. During the course of the eruption, the aquifer was exhausted and the initial phreatomagmatic Subplinian activity changed to magmatic Plinian activity that lasted 3.5 h and formed eruption column up to 13 km high. The Plinian stage deposited the uppermost pyroclastic layer of the vesicular volcanic bombs and lapilli. Total volume of the erupted pyroclasts is estimated as 0.1 km3. The deposits considerably displaced the shoreline seaward and increased the area of the island by 15%.

696

Mechanism of the historical and the ongoing Vulcanian eruptions of Ebeko volcano, Northern Kuriles

Dr Marina Belousova[1], Dr Alexander Belousov[1], Dr Andreas Auer[2], Dr Thomas Walter[3], Dr Tatyana Kotenko[1]
[1]Institute of Volcanology and Seismology, Petropavlovsk-Kamchatsky, Russian Federation, [2] Shimane University, Matsue, Japan, [3]German Research Centre for Geosciences , Potsdam, Germany

Ebeko is one of the most active volcanoes of the Kurile island arc, producing frequent mild Vulcanian explosions with eruption clouds up to 5 km high. The volcano poses a serious threat to Severo-Kurilsk town with a population of 2500 inhabitants, located at a distance of 7 km on a fan of the volcano's laharic deposits. The eruptions of Ebeko span a range of mechanisms from purely magmatic to phreatic/hydrothermal. Three of its historical eruptions (the 1934–1935, 1987–1991, and the 2016–ongoing) involved fresh magma, while during the others (1967–1971, 2009–2011) fresh magma was not erupted. Juvenile material of the ongoing eruption represents highly crystalline and highly viscous (more than 108 pa s) low-silica (56–58 wt% SiO_2) andesite.

Historical data and our observations of the ongoing eruption allowed us to suggest a functional model of the volcano where Vulcanian explosions are caused by shallow intrusions of small diapir-like batches of strongly crystallized and highly viscous andesitic magma ascending into water-saturated, hydrothermally altered rocks composing the volcano summit. We suggest that the diapir's ascent is governed by their positive buoyancy. Some of the diapirs reach and breach the ground surface producing magmatic eruptions of Ebeko, while the others are stuck at the shallow subsurface level and feed intensive hydrothermal activity and phreatic eruptions of the volcano. Positive buoyancy of the diapirs is too weak to allow them to extrude high above the ground surface to form lava domes. Arrival of the first magma diapir of the diapir chain at the surface marks the onset of a new series of Vulcanian magmatic explosions composing (together with the accompanying phreatic and phreatomagmatic Vulcanian explosions) one magmatic eruption of Ebeko. Arrival of the next magma diapir to the ground surface marks the onset of the next magmatic eruption.

873

Using high-resolution SAR to observe flank motion prior to and during the 2021 lava dome building eruption at Merapi, Indonesia.

Mr Mark Bemelmans[1,2], Prof Juliet Biggs[1,2], Dr Michael Poland[3]
[1]University Of Bristol, Birstol, United Kingdom, [2]Centre for the Observation and Modeling of Volcanoes, Earthquakes and Tectonics (COMET), , United Kingdom, [3]U.S. Geological Survey, Cascades Volcano Observatory, Vancouver, United States

High-rate localised ground movement prior to or during volcanic eruptions reflects shallow processes that may be triggered by volcanic activity at depth. Satellite Interferometric Synthetic Aperture Radar (InSAR) is often used to monitor deformation at volcanoes, but very high-rate displacements, especially over short spatial scales, cause signal incoherence with InSAR that gets worse with longer orbit repeat times and coarser resolution. We use very high-resolution (≤1 m, 1-11 day repeat orbit) satellite SAR data from TerraSAR-X/TanDEM-X, COSMO-SkyMed, and PAZ, as well as open-access Sentinel-1 SAR data, to measure large displacements (>10 cm per day) on the western flank of Merapi volcano, Indonesia, in late 2020. We use a combination of conventional InSAR and feature offset tracking to obtain displacements related to flank motion prior to and during the onset of lava dome building in 2021. Conventional InSAR could not track the large (>5 m) displacements closer to the summit and was incoherent in areas covered by unconsolidated deposits; however, feature offset tracking was able to measure displacement over these areas. Our initial findings suggest that deposits on the west and northwest flank of the volcano moved downslope at maximum rates of ~11 cm per day from mid-November 2020 to the onset of eruption in early January 2021. The deformation slowed considerably in the following weeks during lava dome growth. By combining high-resolution InSAR and feature offset tracking, we aim to quantify the flank motion, assess whether this flank motion is limited to certain deposits or involves larger areas, and assess whether there is a correspondence between flank motion and eruptive activity. These observations could help to elucidate the link between surface motion and the magmatic system and will have implications for volcano monitoring and eruption forecasting.

872

High-resolution InSAR reveals localised pre-eruptive deformation inside the crater of Agung volcano, Indonesia.

Mr Mark Bemelmans[1,2], Prof Juliet Biggs[1,2], Dr Michael Poland[3], Prof James Wookey[1], Dr Susanna Ebmeier[2,4], Dr Angie Diefenbach[5], Dr Devy Syahbana[6]

[1]University Of Bristol, Birstol, United Kingdom, [2]Centre for the Observation and Modeling of Volcanoes, Earthquakes and Tectonics (COMET), , United Kingdom, [3]U.S. Geological Survey, Cascades Volcano Observatory, Vancouver, United States, [4]University of Leeds, Leeds, United Kingdom, [5]U.S. Geological Survey, Volcano Disaster Assistance Program, Vancouver, United States, [6]Center of Volcanology and Geologic Hazard Mitigation (CVGHM), , Indonesia

During a volcanic crisis, high-rate, localised deformation can indicate magma close to the surface, with important implications for forecasting volcanic activity. However, only a few such examples have been reported, because fine-scale and frequent monitoring is needed. High-resolution Synthetic Aperture Radar (SAR) is capable of achieving <1 m spatial resolution and sub-weekly revisit times but is underutilized in volcanology. Here we use high-resolution satellite SAR imagery from COSMO-SkyMed, TerraSAR-X and Sentinel-1 to detect intra-crater uplift preceding the November 2017 onset of eruptive activity at Agung, Indonesia. Processing the SAR imagery with an up-to-date and accurate high-resolution digital elevation model (DEM) was crucial for preventing aliasing of the deformation signal and for accurate georeferencing. We show that >15 cm of line-of-sight shortening occurred over a 400-by-400 m area on the crater floor in September–October 2017, accompanying a deep seismic swarm and flank dyke intrusion. We attribute the deformation to the pressurisation of a shallow (<200 m) hydrothermal system by the injection of magmatic gases and fluids. We also observe a second pulse of intra-crater deformation of 3–5 cm within 4–0.5 days prior to the first phreatomagmatic eruption, which is consistent with interaction between the hydrothermal system and the ascending magma. This phreatomagmatic eruption created the central pathway used during the final stages of magma ascent. Our observations have important implications for understanding unrest and eruption forecasting at volcanoes globally and demonstrate the potential of monitoring with high-resolution SAR.

876

D-Claw: using hypothetical landslide sources to model lahars at Mount Baker volcano, Washington, USA

Dr Mary Benage[1], Dr David George[1], Cynthia Gardner[1], Charlie Cannon[1,2]
[1]USGS Cascades Volcano Observatory, Vancouver, United States, [2]USGS Water Science Center, Portland, United States

Destructive lahars can be initiated by volcanic processes (e.g., hot rock and snow/ice interactions or landslides) or by severe meteorological conditions. Determining potential areas of future lahar inundation, which can be estimated by past events or by numerical modeling, is critical to communities living near volcanoes. At Mount Baker volcano (Washington, USA), we employ the D-Claw model to simulate hypothetical lahars resulting from landslides. The goals are to improve forecasts of inundation areas and examine dynamic properties such as lahar travel times and flow depths. D-Claw solves five depth-averaged hyperbolic partial differential equations using finite volume methods and adaptive mesh refinement. In addition to flow depth and velocity, D-Claw's model equations account for the coevolution of the solid-volume fraction and basal pore-fluid pressure, which dynamically regulate debris-flow mobility.
In this study, we compare D-Claw results against geologic constraints at Mount Baker, by varying model inputs for landslide source volumes (~10 to 300 x 10^6 m^3) and sediment material parameters that affect lahar mobility. For source volumes greater than 100 x 10^6 m^3, simulation results are well matched with mapped inundation and flow depths of past large-volume lahars (maximum ~250 x 10^6 m^3). These simulations show that mobile lahars, with sediment material properties that promote sustained basal pore-fluid pressure, could inundate communities 35 km downstream with flow depths exceeding 10 m within 20–30 minutes after landslide initiation. Less mobile lahars could inundate communities 50 km downstream within an hour. For smaller source volumes (<40 x 10^6 m^3), that could be associated with both volcanic and non-volcanic activity, the simulated scenarios indicate transient, high-sedimentation flows and potential flooding for communities within 35 km of the source area. Overall, the D-Claw results provide useful scenarios and powerful visual aids for communicating these potential lahar hazards to public officials and communities.

915

A web-based platform (VolcashDB) of ash particle images towards an automatic classification.

Mr Damia Benet Morant[1,2], Dr Fidel Costa[3], Dr Christina Widiwijayanti[1,2], Dr John S. Pallister[4], Dr Patrick Allard[3]

[1]ASE, Asian School of the Environment, Nanyang Technological University, Singapore, Singapore, [2]EOS, Earth Observatory of Singapore, Nanyang Technological University, Singapore, Singapore, [3]CNRS, Institut de Physique Du Globe de Paris, Université de Paris, Paris, France, [4]U.S. Geological Survey, Cascades Volcano Observatory, , USA

Volcanic ash provides unique pieces of information that can help understand the likely evolution of volcanic activity during early stages of a crisis and possible transitions towards different eruptive styles. Ash contains different types of particles that are indicative of ascent-related processes. For instance, identification of the so-called juvenile particles can be associated with the movement of magma at shallow depths. However, classifying ash particles is not straightforward. Diagnostic observations may vary depending on the style of eruption, and there is no standardized methodology, which leads to ambiguities in assigning a given particle to a given class. To address this problem, we created the Volcanic ash DataBase (VolcashDB), a web-based platform aimed at hosting a curated dataset of classified particle images from binocular and scanning electron microscope, and secondly, at setting up machine learning (ML)-based models for classification. We currently have a dataset of > 6,500 ash particles classified into main types that we use to train a variety of ML models. We tested models from the decision trees family and deep learning, and obtained accuracies higher than 90%. Adding classified ash images from a larger range of eruptions and volcanoes into the database should reduce potential biases, allow for comparative studies between users, and ultimately provide a more robust tracking of particle types and their evolution during volcanic crises.

1102

Clarifying Magma Storage and Transport at Yellowstone Volcanic System

Dr Ninfa Bennington[1], Prof Adam Schultz, Dr Paul Bedrosian, Prof Clifford Thurber
[1]USGS Hawaiian Volcano Observatory, Hilo, United States

Two of the world's largest volcanic eruptions were produced by the Yellowstone Volcanic System. This includes the major caldera-forming Huckleberry Ridge eruption (2.1 Ma), which emitted >2450 km3 of erupted material. To identify the geometry and composition of Yellowstone's magma reservoir, previous geophysical studies of the region have primarily relied on the inversion and interpretation of seismic data. However, clarifying magma storage based on a single type of geophysical data can be ambiguous. For example, a region of low velocity can be caused by elevated temperatures, fractures, fluids, and/or melts. To improve our understanding of the magmatic plumbing system and volcanic hazard assessments, dense magnetotelluric surveys of the region were carried out in both 2017 and 2021. These newly collected wideband data, as well as long-period data recorded from the EarthScope Magnetotelluric Transportable Array, are inverted to obtain the 3D electrical resistivity structure of Yellowstone from upper crustal through upper mantle depths. The resulting resistivity model is interpreted in a joint geophysical framework that incorporates existing seismic velocity models of the region. Since seismic and magnetotelluric datasets are sensitive to different physical properties of the subsurface, joint interpretation of these models allows for unique constraints regarding magma storage and transport. Specifically, our models provide constraints on the origin and location of magma within the upper mantle depths, the preferred pathway for melt transport through the crust, and the configuration and composition of the shallow silicic melt zone beneath the caldera.

853

The research process, data collection, and writing of the Smithsonian's Bulletin of the Global Volcanism Network

Kadie Bennis[1], Edward Venzke[1]
[1]*Smithsonian Institution, Washington, D.C., United States*

The Smithsonian Institution's Global Volcanism Program (GVP) collects and publishes information about world-wide volcanic activity for the scientific community and general audiences. The Smithsonian has been writing eruption reports since 1968, and GVP was at the forefront of distributing volcano data online starting in 1994. Observations and descriptions of recent eruptions are provided through the Smithsonian/USGS Weekly Volcanic Activity Report (WVAR) and the Bulletin of the Global Volcanism Network (BGVN) posted on the GVP website (volcano.si.edu) and on GVP social media; other content is available on volcano profile pages and image galleries. Typically, GVP publishes 120 reports annually, covering activity at the 70-80 volcanoes with eruptions each year.

Report writers collect information from volcano observatories, civil protection and emergency management agencies, Volcanic Ash Advisory Centers, satellite imagery, and other reliable sources to provide a detailed narrative of volcanic activity during a given timeframe. Additional information from scientists in the field may be included, as well as those garnered from local and international news agencies. These Bulletins are more retrospective in nature, expanding on the narratives in WVAR summaries to include detailed information and graphics of monitoring data, satellite images, and photos taken at the time of the eruption. GVP captures as much information as is accessible from multiple authoritative sources to create a thorough and detailed narrative of the volcanic activity, which is used to populate the Volcanoes of the World (VOTW) database, especially eruption dates and events. As a result, the Bulletins offer an accurate, unique, and contemporary perspective on volcanic activity reporting, which can be quickly and easily accessed by a wide variety of users that include academics, government agencies, students, and science enthusiasts.

587

Characterizing Early Holocene Vents at Askja Volcano, Iceland

Miss Brooke Benz[1], Dr. Alison Graettinger[1], Ivana Torres Ewert[1]
[1]*University of Missouri-Kansas City, Kansas City, United States*

Askja Volcano, Iceland, is a product of unique tectonic activity where rifting and hot spot volcanism meet. At Askja the volcanic activity before, during, and after the last glacial period reflect the complex plumbing activity of the volcano. Post glaciation, different types of volcanic activity are shown in lava flows, intrusions, and vents. Monitoring at Askja has shown deflation since 1983, which has been suggested to be the result of magma moving to a deeper chamber (de Zeeuw-van Dalfsan et al., 2013), however recent uplift of 35 cm since September 2021 was detected that suggests inflow of new magma (Icelandic Met Office, 2021). Previous studies at Askja have characterized major phases of the eruption history, however early post-ice Holocene vent structures are not well mapped or described. This initial investigation maps the distribution of six Holocene vent locations using satellite imagery and verification in the field as well as detailed description of the vents' stratigraphy and structure. Vents are characterized by topographic high point or a conical/semi-conical shape made of agglutinated spatter. Some vents display local collapse and overlapping cones. The Holocene vents verified in the field at Askja range in size from 5 m to 200 m in diameter and 1 m to 40 m in height, with individual spatter clasts ranging from 5 cm to >1 m and scoria clasts ranging from <2.5 cm to 50 cm. Bombs have dominant fluidal textures with lesser bread crust textures and rare cauliflower bombs at one vent. Plagioclase phenocrysts are present in the spatter at <5% of the total composition and a size of <1 mm. With fissure eruptions being the most common type of eruption at Askja, better descriptions of the Holocene vents is necessary to understand the magmatic plumbing system in case of a future eruption.

415

Constraining the limits to magma chamber evacuation during explosive eruptions

Mr Nicolas Berlie[1], Prof Shanaka De Silva[2], Prof Boris Kaus[1]
[1]Johannes Gutenberg University Mainz, Mainz, Germany, [2]CEOAS, Oregon State University, Corvallis, USA

Only a fraction of the magma generated in the earth finds its way to the surface during volcanic eruptions, while most of it will cool down and crystallize at different depths in the crust. Of particular interest is the pre-eruptive level, typically between 10km to 2km. Here, understanding the ratio erupted vs non-erupted magma has implications for volcanic eruption forecasting, long-term magmatic evolution, pluton formation, volcanic cyclicity, and post-eruptive geophysical monitoring. With a special focus on crystal-rich or mushy magmas, we address this problem by exploring, once a conduit reaches the surface, how efficiently the magma reservoir gets depleted and what regions of the reservoir are affected. We address those questions here using an unstructured finite element code, Gridap, written in Julia (Badia et al. 2020).

We benchmark our model using analytical solutions (Blake, 1981) and 1D numerical results from Spera et al. (1986). The numerical experiments are designed to test the effects of lateral changes in rheology, magma density, viscosity, overburden rheology, channel properties, reservoir geometry and size on pipe flow rate. Results show that 3 modes of magma advection exist: the classical pipe flow mode, a stokes flow mode where magma does not make it to the surface despite the open connection but in which the reservoir changes its shape, and an intermediate mode. We derive scaling laws that describe the rising velocity in each of the modes and show how this affects the region of the reservoir that is evacuated. We will discuss the application of the results to natural cases.

References cited

Badia, S., & Verdugo, F. (2020). Journal of Open Source Software, 5(52), 2520.
Blake, S. (1981). Journal of the Geological Society, 138(3), 281–287.
Spera, F. J., Yuen, D. A., Greer, J. C., & Sewell, G. (1986). Geology, 14(9), 723–726.

835

Explosive-effusive-explosive: the role of magma ascent rates and paths in modulating caldera eruptions

Mr Olivier Bernard[1], Dr Weiran Li[2], Dr Fidel Costa[1,3], Dr Steve Saunders[4], Dr Ima Itikarai[4], Mikhail Sindang[4], Dr Caroline Bouvet de Maisonneuve[5,6]

[1]Institut De Physique Du Globe De Paris, Paris, France, [2]University of Cambridge, Department of Earth Sciences, Cambridge, United Kingdom, [3]Université Paris Cité, Paris, France, [4]Rabaul Volcano Observatory, Rabaul, Papua-New-Guinea, [5]Earth Observatory of Singapore, Singapore, Singapore, [6]Asian School of the Environment, Singapore, Singapore

One of the biggest challenges in volcanology is to assess the role of magma properties (volatile budgets, storage depths, and ascent rates) in controlling eruption explosivity. Here we use a new approach based on apatite to estimate volatile contents and magma ascent rates, from a sequence of sub-plinian, effusive, and vulcanian eruption deposits at Rabaul caldera (Papua-New-Guinea) in 2006 to probe the mechanisms responsible for the sudden transition in eruption styles. Our findings show that all magmas were originally stored at similar conditions (2–4 km depth and 1.8–2.5 wt% H2O in the melt); only the magma that formed the lava flow stalled and degassed at a shallower level (0.2–1.5 km) for several months. A more energetic batch of magma rose from depth, bypassed the transient reservoir, and ascended within ≤ 8 hours to the Earth's surface (mean velocity ≥ 0.2 m/s), yielding the initial sub-plinian phase of the eruption. The shallowly degassed magma was then able to reach the surface as a lava flow, likely through the path opened by the sub-plinian magma. The magma of the last vulcanian phase ascended without storage at a shallow depth, albeit slower (ascent rate: 0.03–0.1 m/s) than the sub-plinian magma. Our study illustrates how the complexity of plumbing systems may affect eruption styles, which may occur at other volcanic systems and have implications for interpreting volcano monitoring data.

834

Magma ascent rates, what do we measure? Insights from field, texture and petrology on the 1257 CE Samalas eruption

Mr Olivier Bernard[1], Dr Fidel Costa[1,2], Dr Jean Christophe Komorowski[1], Dr Céline Vidal[3]
[1]*Institut De Physique Du Globe De Paris, Paris, France,* [2]*Université Paris Cité, Paris, France,* [3]*University of Cambridge, Cambridge, United Kingdom*

Magma ascent rate is currently a hot topic in volcanology and rightly so, as it is one of the most influential factors on eruption dynamics. It is a difficult parameter to determine directly, and it requires lots of field, petrological and/or textural data to estimate it. Moreover, there is a range of methods to calculate a "magma ascent rate", but it is unclear what a given ascent rate corresponds to, as magma ascent velocity is generally not a constant parameter and vary from reservoir to surface as well as within the course of an eruption.

Here we attempt to clarify the various magma ascent rates calculation methods by focusing on the Samalas 1257 CE eruption (Indonesia), one of the largest explosive eruptions in the last 2000 years. We benefit from the previous detailed sampling of the whole deposit column, the published physical volcanology and petrology of the erupted products. We use vesicle number density (VND, textural method), magma discharge rate (modelling/field method) and diffusion modelling of H in orthopyroxene (petrological method) to estimate magma ascent rates and then compare these results with outputs from the Confort 15 numerical conduit model. We find ascent rates of 3–5 m/s in average with H diffusion in orthopyroxene, 70–80 m/s with VNDs and 50–75 m/s with mass discharge rates at fragmentation level/post-fragmentation. These results fit well with the ascent rate profile given by conduit modelling for Plinian eruptions with a drastic final acceleration that is captured by petrological, textural and field-based methods. In addition, it shows that depending on which method is chosen to estimate magma ascent rate for a given eruption, results drastically change and give insights at different stages of ascent. These results will contribute to improve the volcano monitoring and assessment of probable eruption scenarios at volcanoes undergoing unrest.

750

Secondary Explosions on Rhyolitic Lava Flows: A Case Study From Banco Bonito Rhyolite Lava Flow, New Mexico

Jessie Bersson[1], Dr. Amanda B. Clarke[1,2], Dr. Ramon Arrowsmith[1]
[1]Arizona State University, Tempe, United States, [2]Istituto Nazionale di Geofisica e Vulcanologia, , Italy

The Banco Bonito Rhyolite Lava Flow (~68ka), the youngest eruptive element of New Mexico's Valles Caldera, is dotted with dozens of previously unstudied secondary explosion pits. These pits, thought to be the scars of steam-driven explosions, are common on basaltic and pyroclastic deposits, but have rarely been documented on rhyolitic lava flows. We document the characteristics of these scars and investigate the mechanism that drove the explosions that formed these features. Here we employ field and remote mapping to quantify pit morphometry and explosion dynamics, as well as to contribute to the advancement of our conceptual model for rhyolite lava flow emplacement. Lidar data collected in 2011 (ground returns gridded at 1 m raster resolution to produce a digital terrain model) proved to be an important dataset in characterizing the forested Banco Bonito.

Preliminary mapping of the Banco Bonito (up to 149 m thick) reveals ~50 explosion pits ranging from 50 to 184 m in diameter and 10 to 62 m in depth, with volumes on the order of 104 to 106 m3. We observe a positive correlation between pit depth and diameter, perhaps reflecting the greater gas energy required to drive an explosion from greater depths. Nearly every pit is ringed by a debris apron up to 10 m in height and composed of ejecta from the interior of the lava flow. Measured depths were used to estimate explosion pressures; estimates are sensitive to assumed tensile strength of the impermeable obsidian cap, increase with increasing pit depth, and are 1 MPa or greater.

Previous drill cores and our additional field observations show that the Banco Bonito exhibits textural zonation with depth, ranging from coarsely pumiceous to glassy. A coarsely vesicular pumice horizon capped by an impermeable obsidian layer may have accumulated and pressurized steam, thus driving the explosions.

751

Petrogenesis of Dacite at Glacier Peak, a Very High Threat Volcano in the Cascades Volcanic Arc

Jessie Bersson[1], Dr. Christy B. Till[1], Dr. Susan DeBari[2]
[1]*Arizona State University, Tempe, USA,* [2]*Western Washington University, Bellingham, USA*

Glacier Peak (Dakobed) is a Pleistocene dacitic stratovolcano in the northern Cascade Volcanic Arc designated as Very High Threat by the U.S. Geological Survey. Despite Glacier Peak's explosive history, its location among the rugged peaks of Glacier Peak Wilderness Area render it overlooked and understudied relative to other very high threat volcanoes. Dacite is the main eruptive product at Glacier Peak, and mafic flows show evidence of mixing with a dacitic component. The relative influence of fractional crystallization and crustal melting in the petrogenesis of the Glacier Peak dacites, however, is poorly constrained.

Here we attempt multiple geochemical methods to determine if the Glacier Peak dacites can be derived exclusively through fractional crystallization or if additional igneous processes (i.e., crustal melting) are needed to achieve the observed eruptive products. We have compiled known geochemical compositions of eruptive products from Glacier Peak, allowing us to test this question using well established fractionation models and incorporating experimental determined amphibole compositions for the mid to low crust appropriate for hydrous arc magmas.

Preliminary results indicate fractional crystallization alone is not sufficient to achieve the observed dacite compositions, suggesting crustal melting plays a role in the petrogenesis of the Glacier Peak dacites. Given the ubiquity of dacite in Glacier Peak's eruptive products these results have significant impacts for our conceptual model of Glacier Peak’s magmatic system. This work further aims to contribute toward the overarching question of the role of crustal melting in producing evolved compositions in the Cascade Volcanic Arc and at other arcs.

400

Inferring the magmatic roots of volcano-geothermal systems in the Rotorua and Okataina calderas with Magnetotelluric models

Dr Ted Bertrand[1], Dr Peter Kannberg[2], Grant Caldwell[1], Dr Wiebke Heise[1], Dr Steve Constable[2], Dr Stephen Bannister[1], Dr Geoff Kilgour[3], Brad Scott[3]
[1]GNS Science, Avalon, New Zealand, [2]Scripps Institute of Oceanography, San Diego, United States, [3]GNS Science, Wairakei, New Zealand

A combination of 365 land and 34 lake-bottom magnetotelluric (MT) measurements at ~2 km spacing are used to investigate the structure of magmatic systems that drive high-temperature geothermal fields and volcanism in the northern part of the Taupo Volcanic Zone, New Zealand. These data encompass the Rotorua Caldera and Okataina Volcanic Centre, covering an area of 2,800 km2, and were inverted to create an image of the 3-D electrical resistivity structure of the crust to a depth of 20 km. Below shallow layers of quaternary volcanic deposits the model is everywhere resistive in the greywacke basement, except for a singular conductive zone (~500 km2) below ~8 km depth, and four additional conductive 'fingers' that rise towards the surface from locations around the margin of the deeper conductor. Consistent with other geophysical and geological data, this model resistivity structure is interpreted as a large magmatic system with intrusions of silicic melt ascending into the brittle crust. Using petrologic data and MT model resistivity, melt fraction estimates of these fingers supports their interpretation as magmatic intrusions with an overlying lens of exsolved hypersaline fluid. These fingers therefore mark the pathways of fluid and heat transport from the underlying magmatic system into the overlying brittle crust, localising the upward convective transport of heat that forms the geothermal fields.

While three of the conductive fingers connect directly with the Rotorua, Taheke-Tikitere and Waimangu geothermal fields, the fourth rises beneath the Haroharo Dome complex within the Okataina Volcanic Centre where 39 km3 of silicic magma has been extruded in the last 9,000 years. These recent domes, which are electrically resistive, appear to cap and arrest this conductor at ~2 km depth, with surface geothermal activity displaced to the northeast, and along lake shorelines at the margin of the dome complex.

1029

Numerical modelling integrated with field observations and analytical studies to assess eruptive style transitions at basaltic volcanoes

Dr Elisa Biagioli[1], Dr Giuseppe La Spina[1,2], Dr Margherita Polacci[1], Mr Jorge Eduardo Romero[1], Dr Barbara Bonechi[1], Prof Mike Burton[1], Dr Mattia de' Michieli Vitturi[3]
[1]Department of Earth and Environmental Sciences, University of Manchester, Manchester, United Kingdom, [2]National Institute of Geophysics and Volcanology, Catania, Italy, [3]National Institute of Geophysics and Volcanology, Pisa, Italy

The eruptions of low viscosity basaltic volcanoes commonly produce abrupt transitions in eruptive style. The volcanic risk is strongly affected by such unexpected changes in activity, potentially damaging infrastructures and threatening people living in the surrounding area. The recent 19th September - 13th December 2021 Cumbre Vieja eruption on La Palma, Canary Islands, represents an ideal case to investigate the mechanisms underlying such transitions. To this aim, we use our 1D steady-state numerical model for magma ascent, which accounts for the complex and non-linear coupling between changes in temperature, viscosity evolution, non-ideal gas behaviour, outgassing, and both crystallization and exsolution disequilibrium [1,2]. Furthermore, we constrain numerical results adopting data from field observations and analytical studies of the eruption. The overall result provides an improved understanding of volcanic activity and magmatic processes interactions and forecasting in basaltic systems.

[1] G. LaSpina, F.Arzilli, E.W. Llewellin, M.R. Burton, A.B. Clarke, M. de' Michieli Vitturi, M. Polacci, M.E. Hartley, D. Di Genova, H.M. Mader, Explosivity of basaltic lava fountains is controlled by magma rheology, ascent rate and outgassing. Earth and Planetary Science Letters 553 (2021).

[2] M. de' Michieli Vitturi, A. Aravena, Numerical modeling of magma ascent dynamics. Forecasting and Planning for Volcanic Hazards, Risks, and Disasters (2020).

1260

Deciphering the spatio-temporal evolution of compound impacts from lava flows and tephra fallout on buildings

María-Paz Reyes-Hardy[1], Sébastien Biass[1], Chris Gregg[1,2], Lucia Dominguez[1], Corine Frischknecht[1], Costanza Bonadonna[1]

[1]*Department Of Earth Sciences, University Of Geneva, Geneva, Switzerland,* [2]*Department of Geosciences, East Tennessee State University, Johnson City, US*

Eruptions being multi-hazard events, associated impacts are typically compound. Compound impacts result from the interaction of various hazardous phenomena (e.g., tephra fallout, lava flows) often exhibiting multiple impact mechanisms (e.g., dynamic pressure, static load and thermal radiation of lava flows) evolving in space and time. Improving the accuracy of volcanic risk analyses requires investigating the spatio-temporal evolution of hazards during volcanic crises and characterizing how the interactions modulate the resulting impact sequence. Here, we present a post-event building impact assessment for the 2021 Cumbre Vieja eruption, characterized by a 3-months long hybrid explosive/effusive activity. We focus on Corazoncillo, a locality affected by tephra fallout from the beginning and by lava towards the end of the eruption. We combine field-based (i.e., deposits mapping, post-event impact assessment) with remote sensing methods (i.e., structure-from-motion, Lidar and crowdsourcing) to investigate the impact on ~20 buildings. Specifically, we i) reconstructed the chronology of hazard occurrence and mitigation actions, ii) constrained the spatio-temporal evolution of hazard metrics and iii) linked these to observed impacts. Results reveal the dynamic nature of building impacts, with most buildings following a sequence composed of i) early tephra fallout, the impact of which was mitigated by regular roof cleanups, ii) initial lava inundation from immature 'a'ā flows, with dynamic pressure causing minimal impacts on the walls but thermal radiation burning some structural components, iii) inflation of the flow up to roof level and iv) roof inundation by late-stage pāhoehoe toes causing roof collapse from static load. Results also highlight the complex impact mechanisms associated with lava flows, which evolve as a function of such aspects as effusion rate and top-down (e.g., surge) versus bottom-up (e.g., drainage) events, all modulated by the microtopography of urban areas.

1261

Tephra fallout impact on vegetation and crops: bridging field-based with remote sensing observations

Sébastien Biass[1], Noa Ligot[2], Pierre Delmelle[2], Alex Poulidis[3], Susanna Jenkins[4,5]
[1]Department Of Earth Sciences, University Of Geneva, Geneva, Switzerland, [2]Environmental Sciences, Earth and Life Institute, UCLouvain, Louvain-la-Neuve, Belgium, [3]Institute of Environmental Physics, University of Bremen, , Germany, [4]Earth Observatory of Singapore, Nanyang Technological University, Singapore, Singapore, [5]Asian School of the Environment, Nanyang Technological University, Singapore, Singapore

Improving our understanding of how tephra fallout impacts vegetation in natural and cultivated systems is a critical aspect of the development of efficient risk reduction and adaptation strategies in highly populated, volcanically active regions. In situ post-event impact assessments, whilst revealing an increasingly complex and dynamic interplay between hazard, vulnerability, mitigation and resilience factors, remain too limited in time and space to robustly help estimating impacts of future events. In parallel, remote sensing provides a powerful approach to capture and document spatio-temporal impacts on vegetation and recovery after eruptions. The recent development of dedicated spatial data infrastructure offers an unprecedented access to petabytes of remote sensing data which, when analyzed using dedicated methods, provide a new insight on the complex surface processes controlling vegetation vulnerability through time and space. We provide here a first comparison between field-based and remote sensing-based impact quantification using the 2020 Taal eruption (Philippines) as a case study. Specifically, we rely on two post-event impact studies conducted in 2020 and 2022 and consisting of semi-structured interviews with farmers and compare them with impact quantification from various MODIS products. Further investigations (i.e., modelled hazard impact metrics, role of precipitations and wind) reveal how a big Earth Observation data approach can complement and potentially help generalizing lessons learned in the field, opening the way to multi-scale risk models.

1346

In-flight fragmentation of pyroclasts during lava fountaining activity at Etna (Italy) and Cumbre Vieja (La Palma, Canary Islands) in 2021.

Dr Clothilde Biensan[1], Dr Jacopo Taddeucci[1], Dr Piergiorgio Scarlato[1], Dr Daniele Andronico[2], Dr Tullio Ricci[1], Dr Elisabetta Del Bello[1], Dr Luca D'Auria[3,4], Dr Maria Asensio-Ramos[4]
[1]Istituto Nazionale Di Geofisica E Vulcanologia, Rome, Italy, [2]Istituto Nazionale Di Geofisica E Vulcanologia, Osservatorio Etneo, , , [3]Instituto Tecnológico y de Energías Renovables, , , [4]Instituto Volcanológico de Canarias, ,

Magma fragmentation is usually considered the main process determining the grain size distribution of pyroclastic deposits. While fragmentation is mostly assumed to occur within the volcanic conduit, there is growing evidence that, especially in mafic magmas, it continues also after pyroclast ejection from the vent, both in-flight and on landing. How and how much in-flight fragmentation occurs is still poorly known, fragmentation remaining one of the most elusive parameters to measure in the field. Here, we document abundant in-flight fragmentation that occurred during lava fountaining activity of the 2021 Tajogaite Eruption (La Palma, Canary Islands, Spain) and 2021 Etna paroxysms. High-speed and high-resolution videos have been acquired during both eruptions with two different types of cameras: an Optronis camera (frame rate 250 to 500 frames per second (FPS) and 0.021-0.147 m/pixel resolution at the vent, 1280 x 1024 pixels) and a Sony camera (24 to 25 FPS, 0.03-1.2 m/pixel ca., 3840 × 2160 pixels). Video processing has been done by using: (i) the Optical Flow Matlab© routine, which determines the motion and deformation of pyroclasts, and (ii) visual inspection of the videos and manual tracking of the pyroclasts. From these analyses, we determined the size of the bombs, their fall velocity and their relation to one another at fragmentation. It was also possible to determine an approximate percentage of in-flight fragmented bombs. Other information on pyroclast dynamics, such as cooling, elongation, stretching and inflating of the bombs, has been quantified and related to secondary fragmentation. Our results reveal multiple secondary fragmentation processes with variable efficiency and operating both in the ascending part of the pyroclasts trajectory and in the descending one.

883

PROMETHEUS: PRObability in the MEditerranean of TepHra dispErsal and the evalUation of the completenesS of the medial-distal archives.

Ms Elisabetta Billotta[1], Mr Roberto Sulpizio[1], Mr Jacopo Selva[2], Mr Antonio Costa[2]
[1]Universita' Degli Studi Di Bari Aldo-moro, Bari, Italy, [2]Istituto nazionale di geofisica e vulcanologia (INGV)- Bologna, Bologna, Italy

Wind statistics at different altitudes in the Mediterranean area, terminal velocities of volcanic particles and their combination allowed us to produce probability maps. These probability maps identify the positions of tephra with a given size, coming from a volcanic source in deposits around the eruptive source. The input parameters are eruptive column height (characterising eruption intensity), wind statistics (directions and intensity) using a 30 years data base, and tephra deposits of a selected grain size. In particular, the parameterizations provided by Costa et al. (2016) made it possible to identify the minimum centre of mass sampling distance associated with a given particle size class. The volcanoes considered in our study are Campi Flegrei, Somma-Vesuvius, Aeolian Islands, and Mount Etna, while the heights of eruptive columns are discretized as 5-10-20-30 km. The comparison of probabilistic maps with tephrostratigraphy of known marine and terrestrial cores will allow the statistical quantification of the completeness of the recovered tephrostratigraphy. On the other hand, the probability maps will guide the location of sampling sites for a certain tephra deposit. The probability maps might also support the study of the completeness of the overall eruption catalogues through time, allowing to study the cyclical and non-stationary behaviours of eruption frequency of different volcanic sources, correlating these behaviours with possible external forcing from geodynamics or climate change.

1444

Age of the magma chamber and its physicochemical state under Elbrus Greater Caucasus, Russia: Zircon petrochronology and modeling insights

Mr Ilya Bindeman[1], Professor Oleg Melnik, Dr Marcel Guillong, Dr Ivan Utkin, Dr Jorn-Frederik Wotzlaw, Professor Axel Schmitt, Dr Richard Stern
[1]*Earth Sciences, University of Oregon, Eugene, United States*

Mount Elbrus, Europe's tallest and largely glaciated volcano, is made of silicic lavas and is known for Late Pleistocene and Holocene eruptions, but the size and state of its magma chamber remain poorly constrained. We report that high spatial resolution co-registered U-Th-Pb ages, as well as O and Hf isotopic values in zircon and these span ~0.6 Ma in each lava, documenting magmatic initiation that forms the current edifice. We use a 2D thermochemical modeling of Melnik et al. (2021, JGR) of magma fluxes by either basaltic or rhyolitic magma fluxes adjusted to Elbrus parameters. The model computes zircon crystallization ages and O and Hf isotopic ratios, by using a 50k individual points within a mesh, by using Bindeman and Melnik (2016 JPet) code with zircon crystallization from a melt cell. The best-fit of the model constrains magmatic fluxes at 1.2 km3/1000 yr in the form of random dike and sill intrusions by hot (900°C), zircon-free dacite from depth into a vertically extensive magma body, which has developed since ~0.6 Ma between depths of 4 and 8 km. Incubation periods without major accumulations of eruptible magma at these recharge rates are 0.4 Ma, whereas a volcanic episode with eruptible magma present only extends over the past 0.2 Ma, matching the age of oldest lavas. Simulations explain the total magma volume of ~ 180 km3 and temporally oscillating δ18O and εHf values in zircon, and wide-range of zircon age distributions in each sample. Zircons in 0.7 Ma ignimbrites in the western base of Elbrus also contain diverse zircons but appear unrelated to the current activity. These data provide insight into the current state and the potential for future activity of Elbrus and demonstrate that similar zircon records worldwide require continuous intrusive activity by magmatic accretion of silicic magmas generated at depths.

1432

Zircon crystallization software for geological sciences

Mr Ilya Bindeman[1], Professor Oleg Melnik
[1]*Earth Sciences, University of Oregon, Eugene, United States*

In-situ zircon dating and elemental/isotopic investigation is paramount tools for petrologic investigation to reconstruct magma origin, storage, and eruption conditions and timescales. We here present an updated version of the Bindeman and Melnik (2016 JPet 57, 437) MATLAB code easy to use by anyone without programming experience to investigate user-specific zircon crystallization/dissolution in diverse temperature-composition-time paths. Users need to have an access to Matlab and are able to change parameters (Zr concentration, temperature history, co-crystallization of major minerals, and their partition coefficient, etc) to get a ready to plot text file of results and graphs of zircon crystallization histories. The new version implements zirconium isotopes and Hf and other trace element concentrations and their ratios. It has two moving boundaries targeting zircon crystallization in the center of the sphere of melt, with other minerals crystallizing in the outer boundary. Crystallization of the other phase on the outer boundary may pile up Zr and other trace element concentrations in the melt favoring more rapid zircon growth. We incorporated a phase diagram and diffusion and partition coefficients for isotopes and trace elements, diffusion coefficients are parametrized for water concentration in melt. Kinetic vs equilibrium fractionation and partitioning processes can be investigated. For example progressively lower δ94Zr values in zircon develop during: rapid crystallization, lower water contents, crystallization in lower T range, and while surrounded by Zr-poor phase; trace elemental crystallization can be modeled to result from the kinetic elemental partitioning from a boundary-layer processes during slow/fast zircon crystallization. Temperature history with oscillations of several degrees can result in continuous zircon growth and oscillatory zoning, greater oscillation cause zircon dissolution. We further explore zircon dissolution/crystallization history from a 2D thermochemical model of magma chamber accretion (situations with different magma flux rates), and applied these to explain zircon record in Elbrus Volcano, Greater Caucasus.

1475

Volcanic clouds detection and classification using radio occultation profiles

Dr Riccardo Biondi[1], Mohammed Hammouti
[1]Università Degli Studi Di Padova, Padova, Italy

The bending angle anomaly, retrieved from GNSS Radio Occultation (RO) profiles, has recently been used to determine the cloud top height of volcanic clouds and their impact on the atmospheric thermal structure. This methodology is very accurate in altitude estimations. We developed an algorithm to automatically classify the cloud type and to determine the height of dense clouds in the upper troposphere and lower stratosphere. The extreme weather clouds and volcanic clouds have a similar impact on the GNSS RO profiles, however a machine learning algorithm is able to distinguish and classify the different cloud types. We collocated the GNSS RO profiles with volcanic clouds and “non-eruptive” data to build a statistically relevant training dataset. The algorithm receives in input the cloud detection from different instruments and the vertical profile from RO, it learns how the atmospheric parameter changes as a function of the altitude and how to identify the discontinuities due to the presence of a cloud. The output is an estimation of the presence of the volcanic cloud based on a dataset including about four thousand collocations between RO and clouds in the period 2008-2015. From the entire dataset we have randomly selected 80% of the collocations used as training, 20% used as testing, and applied the cross-validation technique in order to validate the model performance to an independent dataset that was not used in estimating it. The probability of detection of volcanic clouds is usually around 80% with peaks of detection of 85% for Grimsvotn 2011. The RO bending angle profile usually performs better than other parameters, however the use of the variable absolute values does not provide a good classification performance. The use of the anomaly, instead, provides better results increasing the performances by about 20%-30% depending on the volcano.

682

Temporal variability of explosive activity and ash plumes from ground-based infrared and visible cameras at Cumbre Vieja Volcano

Ms Janine Birnbaum[1], Dr Einat Lev[1], Dr Pedro Hernandez[2,3], Dr José Barrancos[2,3], Dr Germán Padilla[2,3], Dr María Asensio-Ramos[2], Dr David Calvo[2], Dr Fátima Rodríguez[2], Dr Nemesio Pérez[2,3], Dr Luca D'Auria[2,3], Dr Sonia Calvari[4]

[1]Columbia University, Palisades, United States, [2]Instituto Volcanológico de Canarias (INVOLCAN), La Laguna, Spain, [3]Instituto Tecnológico y de Energías Renovables (ITER), Granadilla, Spain, [4]Istituto Nazionale di Geofisica e Vulcanologia (INGV) Catania, Catania, Italy

During the 2021 eruption at Cumbre Vieja volcano (La Palma, Spain), ground-based thermal and visual photos and videos proved to be a valuable resource in documenting explosive activity including Strombolian eruptions, lava fountaining, and white and gray gas-and-ash plumes. We analyze short (<5 min) opportunistic IR videos and visual photos taken at least daily over the course of the eruption from multiple ground-based locations, and continuous time-lapse IR photos over the period November 16 to November 26.

We show good agreement between plume size estimates from different angles and vent-camera distances, but demonstrate the importance of considering viewing angle in elongate multi-vent systems to minimize activity from one vent obscuring another. We investigate the temporal variability of velocities and fluxes at the vent over multiple time scales (seconds-minutes, hours, and days-weeks), and correlate conditions at the vent to changes in vent geometry and daily observations of plume height.

683

Towards lava flow breakouts: finite element modeling of free-surface flows with a solidifying crust

Ms Janine Birnbaum[1], Dr Einat Lev[1], Dr Hannah Dietterich[2]
[1]*Columbia University, New York, United States,* [2]*Alaska Volcano Observatory, Anchorage, United States*

Lava flow breakouts shape flow field evolution, sometimes accounting for the majority of flow propagation, and pose hazards during volcanic crises. For example, the 2013 eruption of Cordón Caulle propagated primarily through lava flow breakouts (Tuffen et al. 2013) and the 2014-2015 Pāhoa flow at Kīlauea stalled and experienced a breakout 15 km from the front and dominated subsequent flow evolution (Poland et al. 2016).

Despite their clear importance, predicting the timing and location of lava flow breakouts remains a challenge. Lava flow emplacement is impacted by complex feedbacks between evolving lava properties, changes in effusion rate, and interactions with the external factors such as pre-existing topography. Loss of heat to the surrounding environment cools lava flows, driving crystallization and solidification. A coherent, solidified crust can arrest flows, but rupture of this crust in response to continued magma supply can reinitiate flow, often in a different direction. Traditional lava flow models that attempt to simulate the effects of breakouts typically do so by requiring specified timing and location of a breakout, or by incorporating breakouts through a stochastic process which can help constrain flow-field scale risk over the course of an eruption. Neither of these approaches lend insight to the physical processes that cause breakouts.

We investigate the conditions that promote lava flow breakouts using numerical simulations on the scale of an individual lobe. Our finite element model uses a Python implementation based on the GetFEM library to model cooling, free-surface flows with a solidifying crust in two and three dimensions. Stress is modeled through time in the crust to identify regions most likely to rupture in response to changing upstream conditions. We benchmark the code against laboratory-scale molten basalt experiments that produced breakouts and identify potential precursors to breakouts in surface temperature and deformation that could inform hazard assessment.

195

Primitive volcanism at Clear Lake volcanic field, California: a window into subduction-modified sub-continental lithospheric mantle

Dr Dawnika Blatter[1], Dr Seth D. Burgess[1]
[1]*USGS California Volcano Observatory, Menlo Park, United States*

Clear Lake volcanic field (CLVF) is the northernmost and youngest (~8 ka to ~2 Ma) of the volcanic centers distributed along the San Andreas transform fault in the California Coast Ranges. The initial phase of CLVF eruptive activity (~1.3 to 2 Ma) extends ~35 km SE of Clear Lake forming a nearly continuous upland plateau capped by lava flows, with isolated volcanic outcrops on the NE periphery. Three distinct compositional end members occur within this initial phase of volcanism. The first and most voluminous erupted along the main axis of volcanism and is characterized by high-MgO (8-14 wt.% MgO), med-K2O, calc-alkaline basalts through andesites that contain olivine (Fo88-93) phenocrysts with Cr-spinel inclusions +/- subordinate clinopyroxene, orthopyroxene, and plagioclase phenocrysts. High Mg#s (68-78) and high Ni and Cr abundances (154-439 and 340-1124 ppm, respectively) indicate that these are primitive melts from depleted harzburgite or pyroxenite lithospheric mantle. The second compositional series occurs in small-volume peripheral outcrops of high-MgO andesites and dacites with phenocrysts of orthopyroxene (En90) that contain spinel inclusions (Cr# = 82) and extremely Ni-rich (10,000 ppm) olivine cores (Fo90). These andesites and dacites have high Mg#s (75-82), high Ni (150-223 ppm) and Cr (283-475 ppm), and strong depletions in the HREE (Yb = 0.6 ppm), indicating they are derived from siliceous melts that interacted with garnet-bearing and depleted ultramafic rocks. The third series of early, primitive CLVF lavas are calc-alkaline basalts with somewhat less MgO (8-10 wt.%), Ni (103-262 ppm), and Cr (284-609), and lower Mg#s (66-70) than the main phase, but higher mantle-incompatible element concentrations (Al2O3, TiO2, and CaO), indicating a more fertile mantle source. The compositional differences in these initial CLVF lava groups indicate differing sources and thermal conditions, providing insight into the processes of melt generation and interaction during slab window initiation beneath this region.

207

Trace element chemistry of geothermal brines from four young magmatic systems

Professor Jon Blundy[1], Dr Brian Tattitch[2]
[1]University of Oxford, Oxford, United Kingdom, [2]University of Western Australia, Perth, Australia

Co-recovery of heat and metals from geothermal systems represents a novel strategy for 'green mining' and/or reducing the costs of generating geothermal power. Conventional geothermal fluids from the hydrothermal realm are dominated by heated meteoric water or seawater with limited metal endowment. In contrast, hotter, deeper supercritical geothermal fluids at the magmatic-hydrothermal interface are predominantly magmatic in origin. highly saline and much richer in dissolved metals. To evaluate the economic potential of such fluids we analysed quartz-hosted fluid inclusions from four young magmatic systems: Kakkonda (Japan), Larderello (Italy), Montserrat and Ascension Island. Samples from the first three sites come from drillcore (1.5 to 4.6 km depth); Ascension samples are from plutonic xenoliths. Fluid inclusions and brines with homogenisation temperatures of 280 to 670 °C and salinities of 30 to 60 wt% NaCl(eq). At Kakkonda and Larderello fluid inclusion trapping temperatures match well-bore temperatures at the sampling depth. Trace metal concentrations, determined by LA-ICP-MS, are significantly higher than typical geothermal fluids with considerable variations according to tectonic setting, magma type and temperature. Maximum concentrations of selected elements are: 7 wt% Ca, 0.27% Sr, 3 ppm Au (Larderello); 2.7% Mn, 0.9% Zn, 0.7% Cu, 0.3% Pb, 0.11% As, 350 ppm Li (Kakkonda); 0.5% B, 900 ppm Ba, 500 ppm Li, 90 ppm Ag (Montserrat); 0.19% Rb, 350 ppm Mo, 180 ppm W, 4 ppm Au (Ascension). Most metal concentrations are higher by one to two orders of magnitude than extracted Salton Sea brines of non-magmatic origin. Based on dimensions of the underlying electrical conductivity anomalies the total metal resource value, assuming 100% recovery and refined metal prices, at each site exceeds $50 billion. Recovery of just a fraction of this value would greatly reduce geothermal electricity prices. For Au, Rb, Mn and Ag metal value is significant in its own right.

206

Chemical Differentiation by Mineralogical Buffering in Crustal Hot Zones

Professor Jon Blundy[1]
[1]*University Of Oxford, Oxford, United Kingdom*

Mineralogical buffering of melt chemistry in hot zones is proposed as an important mechanism of chemical differentiation. Mineralogical buffering can operate at the low melt fractions observed in geophysical surveys of igneous crust, providing an alternative to traditional concepts of assimilation-fractional crystallization and liquid lines of descent. Reaction between buoyant, percolating melts and surrounding mush leads to chemical buffering by the local mineral assemblage. Where this assemblage has low thermodynamic variance the resultant multiply-saturated melts will show limited chemical variability. I use the concept of multiple saturation to explore the chemical consequences of percolative reactive melt flow using data from published experiments on a wide variety of starting materials. I show that the common, low-variance hornblende gabbronorite assemblage clinopyroxene-hornblende-orthopyroxene-magnetite-plagioclase-ilmenite (CHOMPI) coexists with fluid-saturated melt over a wide range of pressure (1 to 10 kb) temperature (800 to 1050 °C) and fluid composition (XH2O of 1.0 to 0.3). CHOMPI melts cover a wide compositional range (54 to 74 wt% SiO2; 4.4 to 0.1 wt% MgO) that can be parameterized in terms of five independent variables: pressure, temperature, fO2, molar CO2/H2O in the fluid and melt K2O content. Melt composition can be inverted to recover pressure (±1.3 kb), temperature (±16 °C) and fluid molar CO2/H2O (±0.43) of CHOMPI-saturated melts. If a natural magma composition can be shown to lay on or close to the CHOMPI saturation surface then the conditions under which the melt was last in equilibrium with this hot zone mineral assemblage, prior to ascent and eruption, can be established. I apply this method of magma source thermobarometry and hygrometry to recent eruptions from fifteen Cascades arc volcanic centres. Calculated pressures range from 1.3 to 5.8 kb (5 to 21 km depth) with significant along-arc and temporal variation. These variations have implications for mush architecture and dynamics beneath the arc.

446

Developing and ground truthing a proxy for passive spaceborne detection of volcanic CO2 emissions

Mr Robert Bogue[1], Dr. John Stix[1], Dr. Peter Douglas[1], Dr. Joshua Fisher[2]
[1]*Mcgill University, Montréal, Canada,* [2]*Schmid College of Science and Technology, Chapman University, Orange, USA*

Volcanic carbon dioxide emissions provide crucial information about deep magmatic activity but often go undetected due to the difficulty of reliably measuring them with ground or satellite based approaches, creating a need for a proxy which can be consistently measured. Increasing concentrations of CO2 can promote photosynthesis, directly linking volcanic CO2 emissions and plants. Satellites can detect changes in photosynthesis, which makes commonly used vegetation indices such as NDVI (Normalized Differential Vegetation Index) a potentially viable proxy for passive detection of volcanic carbon dioxide emissions from space. In a recent study we tested this method by analyzing Landsat images of the rapidly evolving Tern Lake Thermal Area (TLTA) in northeast Yellowstone from 1984-2020. A previous study based on visual image analysis and infrared temperature measurements suggested that activity at the TLTA started around 2000-2001 and then escalated significantly from ~2006-2012, but we found evidence of consistent hydrothermal activity from 1984 onwards. These findings suggest that plants are sensitive to relatively minor levels of volcanic unrest which may not be detected by other remote sensing methods. Here we present preliminary results from dendrochronological analyses of wood samples from the TLTA which will provide ground-truthing for our previous remote sensing approach. We sampled both live trees on the boundaries of the hydrothermal area as well as dead trees within the hydrothermal area and in order to analyze their radiocarbon variations over the last several decades. We will compare radiocarbon data from these trees to a series of nearby control trees unaffected by hydrothermal activity to create a decades-long record of CO2 emissions from the TLTA. Comparing this record with our previously established satellite record of hydrothermal activity at the TLTA will yield valuable insights on how this approach could improve remote sensing based approaches to studying active volcanoes and volcano monitoring.

718

Novel insights into dynamics and timescales of vesiculation in basaltic magmas: the contribution of synchrotron X-ray radiography

Dr Barbara Bonechi[1], Dr Margherita Polacci[1], Dr Fabio Arzilli[2], Dr Giuseppe La Spina[3], Jean-Louis Hazemann[4], Prof Mike Burton[1], Dr Richard Brooker[5], Dr Robert Atwood[6], Sebastian Marussi[7], Prof Peter Lee[7,8]
[1]Department of Earth and Environmental Sciences, The University of Manchester, Manchester, United Kingdom, [2]School of Science and Technology, Geology Division, Camerino, Italy, [3]Osservatorio Etneo, Istituto Nazionale di Geofisica e Vulcanologia, Catania, Italy, [4]Université Grenoble Alpes, CNRS, Grenoble INP, Institut Néel, Grenoble, France, [5]School of Earth Sciences, University of Bristol, Bristol, United Kingdom, [6]Diamond Light Source, Harwell Science and Innovation Campus, Harwell, United Kingdom, [7]Department of Mechanical Engineering, University College London, London, United Kingdom, [8]Research Complex at Harwell, Rutherford Appleton Laboratory, Harwell, United Kingdom

Transitions between effusive and explosive styles at basaltic volcanoes are strongly affected by magma permeability, which is controlled by bubbles nucleation, growth and coalescence during ascent. A series of in-situ vesiculation experiments were performed using a synchrotron radiation source on basaltic samples from Mt Etna, Italy. Experiments were performed at HP-HT under water saturated conditions at Diamond Light Source, UK. X-Ray synchrotron radiography was combined with a unique IHPV to simulate magma storage and ascent within the crust at P≤100 MPa.

This new study provides unique quantitative information on bubble growth, expansion and coalescence through time, as function of water content and decompression rate. All these parameters are strongly dependent on melt viscosity: for low viscosity conditions bubbles are spherical and can easily grow and coalesce, while for more viscous conditions (e.g. due to higher crystal content) bubbles are always deformed and growth and coalescence are strongly inhibited. We noticed that, for the investigated decompression rates (0.05-0.1 MPa/s), bubble growth decreases with time, as previously reported in the literature. Furthermore, we observed that bubbles nucleated at later times grow faster than those nucleated at earlier times. Regarding coalescence, we recorded this process, occurring in the order of tens of seconds, at high temporal and spatial resolution. We captured when separated bubbles enter into contact, thin their walls, rupture their film and finally coalesce up to recover a spherical shape. Finally, we observed through time with decreasing pressure an increase in the coalescence events of several bubbles that tend to form a single large bubble.

This new apparatus combined with X-Ray synchrotron radiography is an invaluable tool to capture and quantify bubble kinetics in basaltic magma at natural pre- and syn-eruptive conditions, which are fundamental to improve our understanding of magma behaviour and mitigating the volcanic risk associated with basaltic systems.

795

Propagation of perturbations in lower and upper atmosphere over Central Mediterranean, driven by the 15 January 2022 HT-HH volcano explosion

Dr Alessandro Bonforte[1], Dr Alessandro Bonaccorso[1], Dr Luigi Carleo[1], Dr Claudio Cesaroni[2], Dr Gilda Currenti[1], Dr Sofia De Gregorio[3], Dr Bellina Di Lieto[4], Dr Marco Guerra[2], Dr Paolo Madonia[1], Dr Luigi Pasotti[5], Dr Rosario Peluso[4], Dr Michael Pezzopane[2], Vito Restivo[5], Dr Pierdomenico Romano[4], Dr Mariangela Sciotto[1], Dr Luca Spogli[2]

[1]Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo, Catania, Italy, [2]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Roma 2, Roma, Italy, [3]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Palermo, Palermo, Italy, [4]Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Vesuviano, Napoli, Italy, [5]Servizio Informativo Agrometeorologico Siciliano, Catania, Italy

Hunga Tonga-Hunga Ha'apai is a mainly submarine volcano, located in the south-western Pacific Ocean, whose most recent eruption culminated in a cataclysmic explosion at about 04:00 UTC on 15 January, 2022, the most energetic volcanic explosion ever occurred in the last 138 years. It generated a volcanic plume more than 58 km high and triggered several disturbances in the fluid Earth at a global scale, including tsunami waves, a huge increase of the Total Electron Content (TEC) in the ionosphere, and a pressure wave travelling in the troposphere at 305 m s-1.

We collected and analysed data over the Mediterranean to study the propagation of the disturbances that involved the entire atmosphere, from the ionosphere to the troposphere. Ionograms considered for the present study are those recorded by the AIS-INGV (Advanced Ionospheric Sounder-Istituto Nazionale di Geofisica e Vulcanologia) ionosonde (GM037) installed at the ionospheric observatory of Gibilmanna (Sicily, Italy). Data from selected Italian RING (Integrated National Network) GNSS stations were used for retrieving the ionospheric TEC. Data from barometric and infrasonic stations, installed on Italian volcanoes (Phlegrean Fields, Stromboli and Mt. Etna), were analysed for investigating the lower atmosphere pressure waves. Barometric data from the INGV-TROPOMAG and SIAS (Sicilian Agro-meteorological Information System) networks allowed us to investigating the interaction between orography and the pressure waves.
In correspondence of the first barometric variations, the analysis of ionograms shows that a medium scale TID (Traveling Ionospheric Disturbance), with a horizontal wavelength of about 220 km and a period of about 35 minutes, propagated through the ionospheric plasma.

The analysis of ground level barometric data highlights that pressure waves were reflected and diffracted by the topographic surface, creating a complex space-time dynamics of the atmospheric disturbances traveling over Sicily, driven by the interference among the different wavefronts.

252

Study of the effects preceding and following the 2022 Hunga Tonga-Hunga Ha'apai eruption in the view of Lithosphere-Atmosphere-Ionosphere Coupling models

Dr Alessandro Bonforte[1], Dr Serena D'Arcangelo[1,2], Dr Angelo De Santis[1], Dr Salvatore R. Maugeri[1], Dr Loredana Perrone[1], Dr Maurizio Soldani[1], Dr Giovanni Arena[3], Dr Federico Brogi[1], Dr Massimo Calcara[1], Dr Soaia A. Campuzano[2], Dr Gianfranco Cianchini[1], Dr Alfredo Del Corpo[1], Dr Domenico Di Mauro[1], Dr Cristiano Fidani[1], Dr Alessandro Ippolito[1], Dr Stefania Lepidi[1], Dr Dedalo Marchetti[4], Dr Adriano Nardi[1], Dr Martina Orlando[1], Dr Alessandro Piscini[1], Dr Mauro Regi[1], Dr Dario Sabbagh[1]
[1]Istituto Nazionale di Geofisica e Vulcanologia, , Italy, [2]Complutense University of Madrid (UCM), , Spain, [3]ISPRA, , Italy, [4]Jilin University, , China

The 15 January blast of Hunga Tonga-Hunga Ha'apai volcano focused researchers on refining and improving the submarine volcano hazard evaluations. This event was unique for the pressure waves produced and sent around the globe and for the extraordinary plume soaring into the upper atmosphere, and because it was captured by several Earth-Observing satellites.

Due to the rareness of such a large event and the large availability of observations, many recent studies tried to define, with an unprecedented level of detail, the main physical parameters of this eruption and the subsequent local and global effects. We investigated the possible precursors and the global effects of this volcanic activity, including especially the effects theorised by the Lithosphere-Atmosphere-Ionosphere Coupling (LAIC) models. Before the eruptive event, we observed a slight increase in the regional seismicity and anomalies in the atmospheric parameters (especially the Outgoing Longwave Radiation). During the explosive sequence of 15 January 2022, a signal was individuated in the ionospheric electron density measured by CSES-01 LAP and a curious activation of Schumann frequencies in the Finnish pulsation magnetometers network. Among the post-effects produced, we saw a peak of the atmospheric pressure measured by barometers across the Italian territory, related to the arrival of the Lamb wave. Multiple ionospheric anomalies were also detected, including a) transient signals in electron density detected by CSES-01 and Swarm satellites following the Lamb wave; b) abrupt decrease of the TEC, in contrast with the recovery phase of geomagnetic storm; c) magnetic field fluctuations (of components and first differences of scalar intensity) at Swarm altitude (460-510 km) above the volcano, several hours after the explosion. These results confirmed and expanded the research on the global wide effects previously reported on this large eruption and support the existence of a Lithopshere-Atmosphere-Ionosphere-Coupling before and during such a violent volcanic eruption.

817

The Cheakamus Basalts: Agents of derangement and recorders of rapidly changing valley systems in the Garibaldi Volcanic Belt, British Columbia

Ms Annie Borch[1], Professor James Russell[1], Dr Rene Barendregt[2]
[1]Volcanology and Petrology Laboratory, University Of British Columbia, Vancouver, Canada, [2]Department of Geography and Environment, University of Lethbridge, Lethbridge, Canada

In southern coastal British Columbia, Canada, the Late Quaternary was a period of glacial advance and retreat, punctuated by eruptions of the Northern Cascade Volcanic Arc. Interactions between volcanic activity and glacial ice are well-studied, especially in the Garibaldi Volcanic Belt (GVB), where tuyas and ice-dammed lavas are common. However, interactions between eruptions and valley systems and the impacts of volcanism on valley evolution are not well constrained. The Cheakamus basalts are voluminous, Late Quaternary (23.9 ± 15.7 Ka) valley-filling lavas that record a complicated history of interaction with fluvial systems, valley ice, and post-Fraser Glaciation flood events. Mostly subaerial in nature, localized-inter-flow, normally graded sands, silts, and cobbles indicate syn-eruption fluvial overtopping of the lavas. Downstream sections of the lava are characterized by well-developed lower colonnades capped by thick entablatures comprising fine, disorganized joints, and lack any visible upper colonnade, indicating water infiltration suggestive of syn-eruptive damming and flooding. Isolated domains of lava display evidence of localized ice contact, including fanning, irregular joint orientations and palagonitization. Well-developed glacial striae show extensive post-eruptive glaciation in the valley, evidence for which is overprinted by erosional features of syn- or post-glacial flooding. Higher erodibility of the extensively jointed Cheakamus basalts amplifiies the erosional evidence of the flood in lava-filled areas. Scabland-like morphology, amphitheatre-headed canyons, dry channels, and misfit streams characterize the current valley system, and differ drastically from the morphology of other lava-filled valleys in the area. In short, the basalts both interfered with and recorded the local valley environments at their time of eruption. Paleomagnetic results show that this eruption occurred within a single paleomagnetic moment (<2,000 years). Thus the lavas offer direct evidence for a highly dynamic and varied eruption environment pre- and post- Fraser glaciation within the Cheakamus valley.

785

Dynamics of rain-triggered lahars inferred from infrasound array and time-lapse camera correlation at Volcán de Fuego, Guatemala

Ms Ashley Bosa[1], Armando Pineda[2], Jerry Mock[1], Jeffrey Johnson[1], Amilcar Roca[3], Gustavo Bejar[4], Greg Waite[4], Scott Gauvain[1], Tamara Satterwhite[5], Beth Bartel[4]

[1]Boise State University, Boise, United States, [2]Independent Contractor, Guatemala City, Guatemala, [3]INSIVUMEH, Guatemala City, Guatemala, [4]Michigan Technological University, Houghton, United States, [5]Oregon Hazards Lab, Eugene, United States

Lahars are among the most destructive natural processes at active volcanoes, including at Volcán de Fuego (Guatemala) where the people and property are exposed. Secondary lahars at Fuego (and at other volcanoes) transport large volumes of material and flow at high velocities making them erosive and destructive, capable of depositing material many meters above the flow path. This study's objective is to monitor rain-triggered lahars occurring in the Las Lajas drainage on the southeast side of Volcán de Fuego using remote-sensing tools. Over the course of the 2021 rainy season (May-October), we maintained various sensors and cameras to detect, track and characterize multiple lahar events. These data are used to quantify the frequency of occurrence and the velocity of multiple lahars, as well as confirm infrasound-detections of lahar passages and channel morphological changes (e.g., entrainment of larger material, aggradation, erosion, or shifts in channel geometry). In addition, tracking lahar energetics over the flow path can facilitate understanding of bulking/debulking processes and a detailed evolution of these flows over numerous sites along the channel. Energetic thresholds exist when using infrasound to detect small lahars, in which case, seismic data and time-lapse imagery become the primary detection methods. Time-lapse imagery (2 s frame intervals) of lahar passage is compared with signal characteristics of the infrasound and seismic data. Flow behavior and energetics are often composed of events with multiple pulses seen as rising and falling flow stages. Compilation of a catalog of more than 20 rain-triggered lahar events in Las Lajas over a season permits a dataset amenable to statistical analysis. Our goal is the development of new generation geophysical monitoring tools that will be capable of remote and real-time estimation of flow parameters in both the Las Lajas drainage and other drainages around Fuego.

1236

Quantifying and interpreting the complex Spectral evolution of the 2021 Kilauea eruption in a windy environment

Mrs Lorène Boulvais[1,2], Dr. Jeffrey B. Johnson[2], Dr. Arthur D. Jolly[3], Dr. Sylvie Vergniolle[4], Dr. Alexis Le Pichon[5]

[1]Institut de Physique du Globe de Paris IPGP, Paris, France, [2]Department of Geosciences, Boise State University, Boise, USA, [3]USGS Hawaiian Volcano Observatory, Hilo, USA, [4]Équipe de Dynamique Des Fluides Géologiques, Institut de Physique du Globe de Paris, Sorbonne Paris Cité, Université Paris Diderot, UMR CNRS 7154, 75238, Cedex 05, Paris, France, [5]Commissariat à l'Energie Atomique (CEA), Direction des Applications Militaires (DAM), Campus Île-de-France (DIF) , Bruyères-le-Châtel, 91297 Arpajon, France

Our work focuses on the recovery of the infrasound source spectrum at Kilauea Volcano (Hawaii) during an eruptive interval starting 30 September 2021. We highlight strategies for extracting infrasound signal in a noisy environment using a network of 3 infrasound arrays situated less than 3 km from the vent. We identify interesting spectral characteristics that we believe are particular to Kilauea's wide crater geometry (~2.5 km), which includes a nested 1-km-radius crater Halemaʻumaʻu.

We developed an efficient technique for wind noise reduction technique based on estimation of power spectral amplitudes for wind to differentiate wind noise and sustained volcanic tremor using non eruptive period as control. Frequency peaks from the cleaned power spectra can be identified and we note differences for signal acquired at the different arrays pointing to the importance of path effects.

We focus on the first month of the eruption, from 30 September to 5 November, and find two distinct periods associated with eruption source locations, which are determined through an inversion based upon cross-correlation travel time differences across the network. The first days of the eruption show increase in frequency associated with fountaining activity and competing sources. After 5 October, the primary frequency peak stabilizes at 1.1 Hz as activity is focused on the Halemaʻumaʻu West wall vent.

We argue that frequency peaks at Kilauea reveal source radiation complicated by crater response due to steep-walled echoes and multi-pathing and can be explained by Halemaʻumaʻu unique crater geometry. This type of crater response is distinct from that at smaller craters (Etna, Villarrica, or Halemaʻumaʻu in 2008) where spectra is attributed to organ-pipe modes or Helmholtz resonances. Our next steps are to understand the Green's functions particular to Kilauea and attempt to recover the source processes to give further insights into complex eruption dynamics such as lava fountaining.

1418

Role Of Small-Scale Geochemical Variability In Understanding Magma Evolution And Eruption Dynamics

Jade Bowers[1], Darin Schwartz[1], Dorsey Wanless[1]
[1]*Boise State University, Boise, United States*

The scale of compositional variation, or lack thereof, in juvenile pyroclasts, indicates magma dynamics prior to and during eruption. Rarely are measurements of compositional variation across an outcrop and within a depositional horizon compared, despite the complex deposition of juvenile clasts during ignimbrite aggradation. This is further complicated for pyroclastic deposits with aliquot mass requirements (>50 mg) requiring multiple pyroclasts from a single sample horizon. The Curacautin ignimbrite (CI), a large-volume, mafic ignimbrite produced by Llaima volcano (Chile), is an ideal natural laboratory due to its pristine, vertically extensive exposures and no visible evidence of mingling.

Using XRF and ICPMS, we chemically characterized groundmass aliquots of 71 juvenile samples; forty were stratigraphically collocated in six well-exposed outcrops. These data showed an extensive compositional range (50.4-57.3 wt% SiO_2, Y = 14.2-36.1 ppm, La = 6.3-13.5 ppm), generally evolving stratigraphically, but initial thermodynamic models and chemostratigraphic correlations are inconclusive. To explore variability within a depositional horizon, we developed a sample preparation methodology for solution-ICPMS to allow for analysis of 5 mg pyroclast groundmass aliquots. We selected four depositional horizons of interest, top and base of the ignimbrite and two representing enrichment end-member compositions, and analyzed ten pyroclasts from each horizon. In one sampling horizon, ten pyroclasts span the CI compositional range (Y = 18.4-32.4 ppm, La = 5.7-11.5 ppm). Using the χ^2 distribution theorem for sample variance, we identified true variability for more than half of the trace elements measured for each sampling horizon. Small-scale sampling detected previously unseen geochemical variability and constrained end-member compositions for geochemical models. By analyzing one 50 mg composite aliquot from each sample, erupted magma composition appeared to evolve over time, but in reality, the juvenile composition is variable throughout the eruption. Using principal component analysis, we investigate potential controls on the observed variability.

1138

Spatial and temporal variations in primary magmas recorded by inclusions in the most magnesian olivines from the Taupo Volcanic Zone

Dr Raimundo Brahm Scott[1], Professor Vadim Kamenetsky[2], Professor Georg F. Zellmer[3], Dr Daniel A. Coulthard Jr.[4]
[1]School of Geography, Environment & Earth Sciences, Victoria University Of Wellington, Wellington, New Zealand, [2]School of Natural Sciences, University of Tasmania, Hobart, Australia, [3]School of Agriculture and Environment, Massey University, Palmerston North, New Zealand, [4]Magma Dynamics Laboratory, US Geological Survey, Menlo Park, USA

Stratovolcano-forming intermediate magmatism distinguishes the southern Taupo Volcanic Zone (TVZ) from caldera-forming felsic magmatism within the central TVZ. This difference is caused by an increase in extensional strain northward along the continental rift. These variations also affect the melting conditions in the mantle wedge, which can be studied by analysis of primitive olivine-hosted melt inclusions. Pukeonake and Waimarino basaltic andesites contain the most Fo-rich olivine populations found in the TVZ (up to Fo_{95}). These olivine crystals, alongside hosted spinel and melt inclusions are the first available record of the primary magma liquidus assemblage for the southern TVZ.

Geochemical characteristics of the olivines and their inclusions indicate a significant increase in slab components compared to the central TVZ. Olivines have low MnO and high NiO contents (up to 0.66 wt% NiO), agreeing with a magmatic origin with participation of pyroxenite(s) in the source, which has been previously proposed to be generated by SiO_2 addition of hydrous slab melts to the mantle. Extremely high Cl contents found in hosted melt inclusions (up to 1.3 wt% in Pukeonake) positively correlate with Na_2O, indicating influence of saline fluids. Negative correlation between CaO and SiO_2 contents of melt inclusions implies that the CaO enrichment compared to central TVZ is caused by participation of slab-sourced carbonates. Large ion lithophile trace elements are also greatly enriched compared to melts from the central TVZ.

The increase in the participation of slab melts in arc magma genesis southward can be tied to the decrease of extensional stresses in the southern TVZ, reducing the effect of decompression on melting. This spatial transition from decompression-dominated melting to slab flux-dominated melting from north to south could also explain the temporal variation of magmatism in the central TVZ. Prior to caldera-formation, magmatism within the central TVZ was also dominantly intermediate in composition.

705

Extent and depths of buried lava flows in the Schiller-Schickard region on the Moon from radar observations

Professor Ali Bramson[1], L.M. Carter[2], G.W. Patterson[3], M.M. Sori[1], G.A. Morgan[4], L.M. Jozwiak[3], C.A. Nypaver[5], J.T.S. Cahill[3]

[1]Purdue University, West Lafayette, United States, [2]University of Arizona, Tucson, United States, [3]Johns Hopkins University Applied Physics Laboratory, Laurel, United States, [4]Planetary Science Institute, Tucson, United States, [5]University of Tennessee, Knoxville, United States

Volcanic eruptions are an important part of the Moon's geologic and thermal history. Maria (singular: mare) are the effusive, basaltic lava flows at the surface of the Moon. Cryptomaria is the term for those lava flows that were subsequently buried (and thus “hidden”) by higher-albedo basin and crater ejecta. Radar is a key remote sensing technique for probing the subsurface for geologic units otherwise not apparent at the surface. Some basaltic minerals like ilmenite are particularly attenuating to radio waves, so lunar basaltic regoliths tend to exhibit characteristically low radar backscatter. We analyzed radar datasets from the Arecibo and Green Bank Observatories and NASA’s Lunar Reconnaissance Orbiter to characterize maria and cryptomaria in the Schiller-Schickard region of the Moon. We found that there is significant variability in the radar backscatter across the region that does not correspond to previously mapped boundaries of volcanism. Our new areas of mapped cryptomaria are generally contiguous with known maria, and we therefore propose that we are observing the transition of mare lava flow units to cryptomare units as they become buried at mare/highlands margins. We present a new map of Schiller-Schickard cryptomaria and use the reduction in radar backscatter to estimate the burial depths of cryptomaria across the region. We find burial depths ranging from over 100 meters in the deepest areas to just a few-to-tens of meters at the shallowest. These shallow cryptomaria are particularly prominent in the southeast, furthest from the Orientale impact basin, which is thought to be the main supplier of the ejecta that covered this region. Our findings, recently published in Bramson et al. (2022, the Planetary Science Journal), find that cryptomaria in this region may be 170% more widespread (by area) than previous mapping using surface geochemical analyses, suggesting that current estimates of cryptomaria volumes may be underestimated.

1341

From Earth to Mars: Remote predictive mapping and mineral analysis of gossans, Axel Heiberg Island, Nunavut, Canada

Ms Éloïse Brassard[1], Ms Myriam Lemelin[1], Ms Marie-Claude Williamson[2]
[1]Université de Sherbrooke, Sherbrooke, Canada, [2]Geological Survey of Canada, Ottawa, Canada

Gossans are rust-coloured surficial deposits that are generally a few dozen meters in size. They are the product of weathering of sulfide and oxide minerals in host rocks, and if large enough, can be detected using satellite imagery. This study focuses on gossans preserved in volcanic terrain in the High Arctic Large Igneous Province (HALIP) exposed in central Axel Heiberg Island. In the Expedition Fiord region, perennial springs associated with evaporite domes have long been studied as terrestrial analogues for Mars. In this presentation, we show that alteration zones and gossans in permafrost could also provide analogues for similar deposits on Mars. Several of these gossans may be related to ancient hydrothermal systems which are postulated to have existed on Mars. The T-MARS project is the first to address potential genetic links between surficial gossans and hydrothermal systems in the Expedition Fiord region.

Our main objective is to improve geological and remote sensing knowledge of gossans to assess their detection potential using satellite imagery. In July 2022, fieldwork was conducted on Axel Heiberg Island to collect gossan samples and reflectance data. Laboratory analyses will be conducted to determine the spectral characteristics and chemical and mineralogical composition of the sampled gossans. A spectral library of analogue materials will then be created with these data, leading to the application of remote sensing methods such as spectral unmixing to assess the detection potential of terrestrial gossans using WorldView and PRISMA imagery. The spectral library of analogue materials will then be used to explore the detection potential of Martian gossans from CRISM imagery. This presentation will outline the results from this ongoing project, which aims to develop refined mapping techniques to identify gossans, which could be applicable to space missions and have implications for the search for ancient traces of life.

345

Cone Alignments in the South Auckland Volcanic Field (New Zealand) and their Implications for Inherited Structures and Regional Stress Regimes

Miss Maggie Bray[1], Dr James Muirhead[1]
[1]*University Of Auckland, Auckland, New Zealand*

Magma feeder systems beneath monogenetic fields are highly variable and sensitive to regional stress regimes as well as pre-existing structures within the crust they propagate through. In many cases monogenetic fields are situated in close proximity to human populations (i.e., Auckland, New Zealand) and so understanding the controls on magma propagation through the crust is important for volcanic eruption hazard forecasting. We present an analysis of vent alignment trends for the extinct South Auckland Volcanic Field to examine the controls on dike propagation within its magma feeder system. Recent studies have used high resolution 1 m Lidar DEM data, paired with extensive field work, in-order to determine vent localities within the highly eroded South Auckland Volcanic Field. Using the new vent locality data, a 3-point alignment analysis was performed to determine probable orientations of feeder-dikes within the crust below the South Auckland Volcanic Field, revealing dominant NW-SE and NE-SW trends. When comparing these vent alignment orientations to regional faulting trends and nearby tectonic features, we observe a dominant NW-SE and ENE-WSW structural fabric throughout this part of the northern North Island, with possible evidence for reactivation of inherited structures.

332

The rheology of polydisperse granular mixtures: implications for pyroclastic density currents

Mr Eric Breard[1], Dr Chris Ness[1], Pr Jin Sun[1], Pr Eliza Calder[1], Dr Fullard Luke, Pr Josef Dufek
[1]*University Of Edinburgh, Edinburgh, United Kingdom*

Geophysical flows such as pyroclastic density currents pose some of the largest hazards around volcanoes. To date, models used to forecast their dynamics are highly empirical. This is largely due to a lack of knowledge regarding the rheology of polydisperse granular mixtures. Here we investigate the rheology of polydisperse and polyphasic (various solid density) granular assemblage in plane shear using the discrete element method (DEM). Due to the wide size dispersity of natural volcanic flows, these mixtures can span viscous (Stokes number<<1) to inertial regimes (Stokes number>>1). By investigating small polydispersity (size ratio <5), we show in the inertial regime how the stress ratio and solid concentration can be scaled using a unified μ(I)-rheology using the volume mean diameter (D43) as the characteristic grain scale and volume-mean density to define the inertial number. Since granular temperature is a key physical parameter controlling force fluctuations and generation of seismic signals as well as the cause of non-local behavior of granular flows, we attempt to link the Kinetic Theory to the μ(I)-rheology. We find the collapse of all our data requires the definition a the new μ(I,Θ, ϕ)-rheology, with Θ as the scaled granular temperature and ϕ is the scaled concentration. Finally, we explore the scaling in bimodal highly polydisperse size distributions (size ratio up to 100), relevant to block-and-ash flows wherein viscous and inertial regimes co-exist.

217

The fragmentation-induced fluidization of pyroclastic density currents

Mr Eric Breard[1], Pr Josef Dufek, Dr Sylvain Charbonnier, Dr Valentin Gueugneau, Dr Thomas Giachetti, Dr Braden Walsh
[1]*University Of Edinburgh, Edinburgh, United Kingdom*

Pyroclastic density currents (PDCs) are the most lethal volcanic process on Earth. Forecasting their inundation area is essential to mitigate their hazards, but existing models are limited by our poor understanding of their dynamics. Here, we explore the role of evolving grain-size distribution in controlling the runout of the most common and deadliest PDCs known as block-and-ash flows (BAFs). Through a combination of theoretical investigations, analytical and experimental study of natural mixtures, we show that rapid changes of the grain-size distribution transported in BAFs result in the rapid reduction of pore volume (compaction) within the first kilometres of their runout. We then use a multiphase flow model to show how the compressibility of granular mixtures leads to fragmentation-induced fluidization (FIF) and excess pore-fluid pressure in BAFs. This process dominates the first ~2 km of their runout, where the effective friction coefficient is progressively reduced. Beyond that distance, the flows are dominated by diffusion of the excess pore pressure formed. Incorporating a parameterization for fragmentation-induced fluidization in a depth-average approach provides a physical basis for the decades-long use of low effective friction coefficients in flows models required to match observed inundation areas.

1109

MULTIPLE SUBDUCTION-RELATED METASOMATIC PULSES IN MANTLE XENOLITHS FROM THE KARIOI VOLCANO, NORTH ISLAND, NEW ZEALAND

Dr Barbara Faccini[2], Dr Marco Brenna[1], Prof Massimo Coltorti[2], Dr Federico Casetta[3], Mr Luca Faccincani[2], Prof Roger Briggs[4]

[1]University Of Otago, Dunedin, New Zealand, [2]Università degli Studi di Ferrara , Ferrara, Italy, [3]University of Vienna , Vienna, Austria, [4]University of Waikato , Hamilton, New Zealand

Calc-alkaline and alkaline magmatism generally occur separate in space and time at convergent margins, with the latter possibly related to slab retreat or to the formation of a slab window inducing asthenospheric upwelling. Irrespective of the mechanism, how this succession is reflected in the mantle sources is still largely unknown. Some clues may come from ultramafic xenoliths found in pyroclastic deposits of the Alexandra Volcanics in the North Island (New Zealand), where calc-alkaline and alkaline eruptive products are randomly intercalated in the volcanic sequence of the Pliocene-Quaternary Karioi and Pirongia stratovolcanoes.

The xenoliths include typical mantle lithotypes (lherzolites and harzburgites, characterized by medium to coarse-grained protogranular, porphyroclastic and equigranular textures) as well as abundant olivine-clinopyroxenites, dunites and wehrlites with cumulitic and protogranular textures. Disseminated and vein amphibole is present in some olivine-clinopyroxenites and dunites. Reaction textures with formation of secondary, newly-generated phases and glass are widespread in all nodules but especially in the cumulates, where distinct metasomatic episodes have been recognized even within a single sample.

The lithospheric section represented by Karioi peridotites underwent partial melting (F%) between 5 and 15%, as confirmed by spinel, olivine compositions and clinopyroxene HREE contents. Samples showing the highest F% degree are characterized by orthopyroxenes and clinopyroxenes with the highest LILE, LREE and MREE enrichment. A post-depletion metasomatic event occurred from interaction with a calc-alkaline melt similar in composition to arc lavas found in the Alexandra Volcanic Group. On the other hand, mineral compositions in the olivine-clinopyroxenites and dunites indicate their origin as deep fractional crystallization products of the same calc-alkaline magmas, which most probably also repeatedly infiltrated all lithologies, giving rise to multiple metasomatic pulses. A final metasomatic infiltration occurred, generating amphiboles with trace elements (particularly Nb) suggesting a different magmatic affinity, that was probably transitioning toward the alkaline type.

831

Metasomatised lithospheric mantle beneath an intraplate alkaline province, Auckland, New Zealand

Dr Marco Brenna[1], Dr Alessio Pontesilli[2], Dr Michael Palin[1], Dr Sébastien Pilet[3], Dr Barbara Faccini[4], Prof. Massimo Coltorti[4]

[1]University Of Otago, Dunedin, New Zealand, [2]Istituto Nazionale di Geofisica e Vulcanologia, Roma, Italy, [3]Univeristé de Lausanne, Lausanne, Switzerland, [4]Università degli Studi di Ferrara , Ferrara, Italy

Intraplate alkaline provinces, particularly those forming fields of small volcanoes, often display a range in basaltic composition spanning the alkaline to subalkaline spectrum. Traditional geochemical models justify this range by various degrees of partial melting of garnet to spinel lherzolite as well as involvement of non-peridotitic source lithologies. Alternative scenarios involve stepwise interaction and metasomatism of the lithospheric mantle by asthenosphere-derived silicate fluids and subsequent remelting and percolative reaction to form alkaline to subalkaline primary magmas. The Auckland Volcanic Field (AVF) is a unique case study to unravel the "primary magma conundrum" because of the detailed knowledge of products from its ~50 eruptions and occurrence of mantle xenoliths. Here we present the first microchemical investigation of mantle peridotite xenoliths from the Auckland Volcanic Field with the aim of understanding metasomatic modification of the lithospheric mantle. Xenoliths consist of lherzolite, harzburgite and dunite with occurrence of phlogopite and Cr- and Na-rich diopside. These phases show sieve/breakdown textures and are surrounded by secondary olivine +/- clinopyroxene and vesiculated glass. Glass associated with green clinopyroxene is characterized by HFSE depletion, Th, Pb and Sr enrichment and concave up MREE to HREE enriched patterns. 87Sr/86Sr ratios of metasomatic glass and clinopyroxene are <0.7027 and overlap with the most alkaline samples of the AVF. Glass surrounding phlogopite has Rb, Nb, Ta, K, Pb, Zr and Hf enrichment and variable Th, U, La and Ce depletion. Mineral and glass record involvement of different metasomatic fluids, partial melting and crystallization. Metasomatic green clinopyroxene likely formed from percolative reaction of ancient subduction derived fluids and may be a late stage percolative fractionate after amphibole vein formation, whereas phlogopite formed in response to percolation of asthenospheric OIB-like fluids. The lithospheric mantle beneath Auckland has experienced several episodes of metasomatic modification that impacted the alkaline-subalkaline spectrum of erupted lavas.

1046

The permeability of loose magma mush

Miss Eloise Bretagne[1], Mr Fabian B. Wadsworth[1], Mr Jérémie Vasseur[2], Mrs Madeleine C. S. Humphreys[1], Mr Donald B. Dingwell[2], Ms Katherine J. Dobson[3], Mr Martin F. Mangler[1], Mr Shane M. Rooyakkers[4]
[1]Durham University, Durham, United Kingdom, [2]Earth and Environmental Sciences, Ludwig-Maximilians-Universität, Munich, Germany, [3]Department of Civil and Environmental Engineering, University of Strathclyde, Glasgow, United Kingdom, [4]National Isotope Centre, GNS Science, , New Zealand

Models for the evolution of magma mush zones are of fundamental importance for magma storage, differentiation in the crust, and melt extraction processes that prime eruptions. These models are underpinned by calculations of the permeability of the evolving crystal frameworks in the mush. Existing approaches for estimating the crystal framework permeability do not account for crystal shape. Here, we represent magma mush crystal frameworks as packs of hard cuboids with a range of aspect ratios, all at their maximum random packing. We use numerical fluid flow simulation tools to determine the melt fraction, specific surface area, and permeability of our 3D digital samples. We find that crystal shape exerts a first-order control on both the melt fraction at maximum packing, and on the permeability. We use these new data to generalize a Kozeny-Carman model that has been validated previously for packs of polydisperse spheres, in order to propose a simple but effective constitutive law for the scaling between permeability and melt fraction that can be used to account for specific crystal types in upscaled mush dynamics simulations. Our results suggest that packs of prolate cuboids (i.e. needle-habit; e.g. amphibole phenocrysts), are fundamentally more permeable than a pack of oblate cuboids (i.e., tabular habit; e.g. plagioclase phenocrysts), with key implications for crustal melt-crystal separation rates, and potentially for the depths at which melts stall and accumulate in the crust. We stress the importance of better petrological constraints on the relative size of the three principal axes of mush-hosted phenocrysts in order to assess the percolative hydraulic properties of mushes via our model.

1036

Developing a model for the excitation of acoustic-gravity waves from volcanic explosions

Dr Federico Brogi[1], Alessandro Bonforte[1], Simone Colucci[1], Chiara Montagna[1]
[1]*Istituto Nazionale di Geofisica e Vulcanologia, , Italy*

On 15 January 2022, the Hunga Tonga - Hunga Ha'apai volcano eruption produced one of the largest explosions ever detected by modern geophysical instrumentation. A range of atmospheric waves have been detected on a global scale, including sound, infrasound, and acoustic-gravity waves such as Lamb waves that traveled several times around the Earth.

Large volcanic explosions are well known to be capable of exciting acoustic-gravity waves (AGW), that, due to efficient propagation, can be recorded at very large distances from the source. Understanding their generation and propagation is important to correctly interpret recorded signals and retrieve source parameters, as well as to study atmospheric phenomena of the upper layers of the atmosphere, such as the formation of ionospheric traveling disturbances associated with propagating Lamb waves, also recorded during the 2022 Hunga Tonga event. Most AGW studies rely on models based on a simplified (linearized) version of the Navier-Stokes equations that do not allow to fully investigate the effects due to the complexity of volcanic sources of AGW (presence of gas particle mixtures, shock waves, directivity related of the volcanic jet) and non linear propagation phenomena. Here, we present our preliminary results and efforts to test, within the open source MagmaFOAM framework based on the OpenFOAM library, a numerical model that solves the full set of equations for compressible fluids, including the presence of multiple phases (e.g. gas-particles) and components (e.g. air-water vapor) but still considering relatively large atmospheric domains that are required to study AGW.

1142

An internally-heated pressure vessel for in situ observation of magmas; A window into sub-volcanic processes

Dr Richard Brooker[1], Dr Marion Louvel[2], Dr Denis Testemale[3], Dr Jean-Louis Hazemamm[3], Alain Prat[3], Eric Lahera[4], Sophie Min[4], Dr Aneta Slodczyk[2], Dr Fabio Arzilli[5], Dr Barbara Bonechi[5], Dr Margherita Polacci[5], Dr Giuseppe La Spina[5,6], Prof Mike Burton[5]

[1]University Of Bristol, Bristol, United Kingdom, [2]Université d'Orléans-CNRS-BRGM, Institut des Sciences de la Terre d'Orléans, Orléans, France, [3]Université Grenoble Alpes, CNRS, Grenoble INP, Institut Néel, Grenoble, France, [4]Université Grenoble Alpes, CNRS, Grenoble INP, OSUG, Grenoble, France, [5]Department of Earth and Environmental Sciences, University of Manchester, Manchester, UK, [6]Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo, Sezione di Catania, Catania, Italy

We trace the continuing development and practical application of a novel internally-heated pressure vessel (IHPV) fabricated with windows that allow in situ characterisation of samples at pressure and temperature using optical or x-ray spectroscopic techniques. The early experimental design [1] allowed for the study of trace element speciation in hydrothermal fluids (T<600C) by in-situ synchrotron X-ray absorption spectroscopy (XAS), including critical metals Cu, Au and REE [2,3]. This design was also adapted to make Raman measurements on water and carbon dioxide from ambient to supercritical conditions [4].
More recent developments led to observation of haplogranite and rhyodacite melting to 900°C and 130 MPa, and in-situ synchrotron XAS studies of bromine [5] and strontium speciation and distribution between haplogranite and H_2O fluids to 800°C and 100 MPa. With further improvement to the furnace design, we now achieve higher temperatures (1200°C) and pressures (200 MPa) allowing in situ observation of bubble evolution in a decompressed basaltic melt using synchrotron radiography. The introduction of a magnetically coupled rotation device will soon permit 3D and 4D tomography of volatile rich magmas. 4D tomographic observations of a magma subject to dynamic changes in P and T will greatly improve our understanding of sub-volcanic processes such as the effect of decompression on bubble and crystal nucleation and growth.

[1] Testemale et al (2005) Rev. Sci. Instrum. 76; 043905. [2] Louvel et al (2015) Chemical Geology 417; 228-237. [3] Louvel et al (2017) Chem. Geol. 466;500-511. [4] Louvel et al (2015) J. Mol. Liq. 205;54–60 [5] Louvel et al (2020) Am. Mineral. 105;795–802

257

Magmatic volatile content and the overpressure 'sweet spot': implications for volcanic eruption triggering and style

Ms Anna Brookfield[1], Dr Mike Cassidy[2,1], Dr Gregor Weber[1], Dr Razvan-Gabriel Popa[3], Professor Olivier Bachmann[3], Dr Michael Stock[4]
[1]University Of Oxford, Oxford, United Kingdom, [2]University of Birmingham, Birmingham, United Kingdom, [3]ETH Zurich, Zurich, Switzerland, [4]Trinity College Dublin, Dublin, Ireland

Crystallisation and volatile-exsolution within a cooling magma reservoir result in changes to system volume, compressibility and overpressure. Exsolution-driven overpressurisation is an implied trigger for many volcanic eruptions, yet it is relatively poorly understood. As with any triggering process, the timescale of overpressurisation is important, and there are questions as to whether volatile exsolution can occur rapidly enough to trigger an eruption. Thermodynamic models can help to understand overpressurisation, but they do not provide any information on timescales, or consider how magma behaves at reservoir-scale, where variations in temperature and crystallinity are important. Here, we couple thermodynamic and thermal models to determine the magnitude, timescales and spatial extent of overpressurisation with varying volatile content.

We find that the highest overpressures occur in magmas which are initially at their H_2O solubility limit - these magmas at the volatile 'sweet spot' therefore have the greatest eruption triggering potential. The addition or removal of H_2O either side of the solubility limit results in a decrease in peak overpressure, suggesting that triggering by volatile exsolution becomes less likely for these magmas. We also find that overpressure decreases with the addition of CO_2 (decreasing XH_2O). Peak overpressure at the volatile sweet spot coincides with an increased incidence of explosive eruptions at water contents ~4 - 5.5 wt.%. We propose that higher magmatic overpressures may produce more explosive eruptions, by driving faster initial ascent rates and decreasing outgassing efficiency in the conduit. Our thermal modelling demonstrates that, for small magmatic systems, exsolution-driven overpressurisation operates on shorter timescales than crustal relaxation, and therefore is a viable eruption trigger. Timescales and rates of overpressurisation to critical levels also vary with initial volatile content. Our results could be coupled to conduit models, where variations in overpressure and other properties upon exiting the reservoir all contribute to volcanic eruption style.

273

Runout behaviour and flow front characteristics of dilute pyroclastic density currents inferred from large-scale experiments.

Dr Ermanno Brosch[1], Gert Lube[1], Tomaso Esposti-Ongaro[2], Matteo Cerminara[2], Eric Breard[3], Eckart Meiburg[4]
[1]*Massey University, Palmerston North, New Zealand,* [2]*INGV, Pisa, Italy,* [3]*University of Edinburgh, Edinburgh, UK,* [4]*University of California Santa Barbara, Santa Barbara, USA*

Dilute pyroclastic density currents (dilute PDCs) or pyroclastic surges race at tens to hundreds of meters per second down the flanks of volcanoes. Measuring their propagation velocity and assessing their runouts are priorities in volcanic hazard modelling. Direct measurements are however very limited or non-existing due to the hostile nature of these turbulent gas-particle flows, leading to a lack of important front propagation velocity information.

Here we present results on the processes governing the propagation of dilute PDCs, obtained from the international eruption simulator PELE, where we generated fully turbulent and scaled natural analogues using naturally occurring volcanic material.

The generated fully turbulent PDCs are characterised by four dynamic regimes of variant flow behaviour and variant balance of flow forces. Direct measurements inside these flows show that they transition from characteristic fast, high density-ratio, inertia-dominated flows to slow, low-density, pressure-drag force dominated ones. Transitions between dynamic regimes are triggered both by the intrusion of internal gravity waves propagating from the flow body into the frontal flow head, and by the cessation of internal gravity waves arrival. This leads to the generation of a distinct flow hazard boundary during propagation, from where the main flow hazards (velocity, temperature, and dynamic pressure) rapidly decline until flow propagation stops.

Concomitantly, during propagation of these high-density ratio flows, the head Froude number varies as a function of time and distance. This contrasts with existing low-density aqueous gravity current investigations, where measurements on their propagation inform a number of existing PDC flow propagation models used for hazard impact analyses. Our study shows that currently deployed analytical gravity current models largely mispredict both the actual flow front velocity of dilute PDCs and the entrainment of ambient air into the flow.

1079

Raised Rim Depressions: Maar Craters on Saturn's Moon Titan?

Ms Gwendolyn Brouwer[1], Dr Sarah Fagents[1], Dr Lauren Schurmeier[1]
[1]*University Of Hawai'i at Mānoa, Honolulu, United States*

Saturn's moon Titan is the only other body in the solar system besides Earth to have liquid lakes and seas on its surface. The lakes and seas are composed of liquid hydrocarbons formed by Titan's active alkanological cycle (analogous to Earth's hydrologic cycle). A class of these lakes and depressions, raised rim depressions, in Titan's north polar region have been proposed to have formed in a manner analogous to terrestrial maar explosions, via explosive vaporization of liquid nitrogen or hydrocarbon liquids. Raised rim depressions are characterized by their raised rims, circular planform shapes, and radar-bright halos. We explore the conditions necessary to form these morphologies with the aim of assessing whether a maar-like formation hypothesis is feasible. We identify nine raised rim depressions with observable ejecta halos and measure the crater radii and extents of the bright halos. We use topographic measurements of Titan's lakes to estimate the depth and size of a subsurface zone of pressurized gas, and model the feasible pressure conditions necessary to launch ejecta to the extent of the radar-bright halos. We find that pressures greater than the tensile strength of ice (0.1 - 2.5 MPa) are necessary to produce the morphologies of Titan's raised rim depressions, indicating rapid pressurization. Such rapid, high overpressure is consistent with a maar-like scenario, in which an overpressure develops rapidly from the explosive vaporization of a volatile fluid by a warmer material (water and magma on Earth, methane or nitrogen and an aqueous cryomagma on Titan). We constrain a range of gas pressures and gas chamber sizes that can be used in future studies that assess the maar-like explosion formation hypothesis of raised rim depressions.

344

The Volcanology of the Coalstoun Lakes Volcanic Field

Ms Catherine Brown[1]
[1]*Queensland University Of Technology, Brisbane, Australia*

Previous studies have shown that magma composition can influence eruptions. However, there remains uncertainty if eruption compositional changes influence lava field architecture. This study aims to determine if late-erupted magmas, being more silica-saturated, reflect more significant degrees of partial melting and whether this influences the volume of available melt and mass eruption rate. Furthermore, the study aims to determine if compositional variation results from magma ponding and pooling in the crust, influencing a more explosive eruption earlier and later effusive, suggesting a decrease in the mass eruption rate.

This may be answered by a young (600Ka) and little-known well-exposed, intra-plate, monogenetic lava flow in Coalstoun Lakes, Australia. We studied the physical and chemical volcanology of the Barambah Basalt and associated volcanic centres of Coalstoun Lakes to elucidate the influence of compositional variation on eruption duration, rate and lava flow architecture of monogenetic basaltic volcanoes.

Building on previous work from 1960/70s, reveals a small-volume (12km^3) long-lava flow from 5 eruptive centres, with multiple flows and well-preserved flow structures. The reinterpretation of 250 hydrogeology drill logs reveals up to 6 discrete flows, with instances of total thicknesses exceeding >175m metres proximal to the vent. Whole-rock geochemistry, collected using X-ray Fluorescence (XRF) on 35 samples, demonstrates chemical variability, including subtle increases in SiO^2 (48 wt% - 53 wt %), Al2O3 and CaO with a concomitant decrease in MgO, and an increase in Mg# from 50.4 wt % to 61.3 wt %.

Few studies have examined links between the existence and magnitude of short-term temporal compositional trends and eruptive volume and mass eruption rate. It is expected that this study will contribute to understanding intraplate, monogenetic basaltic volcanism by monitoring the degree of silica saturation in a lava flow and correlating this to melt source changes and how this influences lava field architecture.

666

Yellowstone hotspot - lithosphere interactions (U.S.A.): <10 Ma off-axis magmatism in northwest Wyoming distinct from the Yellowstone hotspot track

Dr Matthew Brueseke[1], Alexander Karrasch[1], Alyssa Endrich[1], Dr. Dave Adams, Dr. Daniel Miggins[2], Dr. Jeff Benowitz
[1]Department Of Geology, Kansas State University, Manhattan, United States, [2]College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, Corvallis, United States

Hotspot identification centers on the identification of clear, time-transgressive, linear chains of magmatic products across the crust. These age-progressions are ambiguous when volcanism along a hotspot "track" does not temporally fit in the age progression and is therefore, out-of-sequence and at times off-axis. Complicating Earth's record of hotspot volcanism is the paucity of continental hotspots that have been identified in the geological record and the relationship between upwelling mantle and upper-plate processes, such as lithospheric extension. The Snake River plain-Yellowstone (SRPY) volcanic province is the archetypal example of a continental hotspot, where the postulated mantle plume is now under the >2.1 Ma Yellowstone Plateau volcanic field. South-southeast of Yellowstone and the SRPY axis, are primarily monogenetic, ~9 to 0.5 Ma volcanoes (e.g., Upper Wind River Basin volcanic field and Jackson Hole volcanics; UWRB-JH) that are distinct from YSRP volcanism. UWRB-JH magmatism is spatially coincident with a migrating ~100-200-km-wide topographically high region of active continental extension (e.g., Yellowstone Crescent of High Terrain, YCHT) defining the leading edge of SRPY. These off-axis and out-of-sequence SRPY rocks define two chemical groups, a K-rich, alkaline to transitional group, and a calc-alkaline group. Rocks from both groups, however, have large ion lithophile element enrichments, high field strength element depletions, and other geochemical characteristics associated with subduction zone magmatism, though they formed in an intraplate setting. New Sr-Nd-Pb-Os isotope data, including results from the least evolved rocks, show that these magmas were sourced from Archean, metasomatized lithospheric mantle. Similar small volume off-axis volcanism has been identified adjacent to other locations where voluminous mantle upwelling occurs regardless of cause (e.g., oceanic hotspots and continental/oceanic rifts). Thus, UWRB-JH magmatism represents an example of this phenomena, where continental hotspot-related off-axis magmatism occurs due to mantle melting and associated YCHT lithosphere extension, which facilitates small volume melt production and eruption.

1271

Complex precursory activity before a large magnitude eruption: new insight from the C.7700 YBP climactic Mazama eruption

Dr Hannah Buckland[1,2], Professor Katharine Cashman[2,3]
[1]Swansea University, Swansea, United Kingdom, [2]University of Bristol, Bristol, United Kingdom, [3]University of Oregon, Eugene, United States

Large magnitude (≥7) explosive eruptions (≥ 40km3 DRE) can result in devastating global impacts due to long distance volcanic ash transport and climate disruption caused by volcanic sulphate aerosols. Our understanding of what conditions lead to large eruptions and whether there are precursory indicators of the pending eruption size is limited because only 1-2 magnitude 7+ eruptions occur every 1000 years. Therefore, we must characterise the precursory activity of prehistoric eruptions using the geological record to determine if large eruptions have unique runups that reflect the scale of eruption. Here we re-examine the c.7700 yr B.P. eruption of Mount Mazama that produced Crater Lake, Oregon. We know that complex precursory activity from the Cleetwood vent occurred months to weeks before the climactic eruption. Similarly, the main climactic eruption has been previously split into lower and upper Plinian phases defined by an intermediary divider ash. Here we present new evidence that the lower pumice can be further subdivided into two distinct eruptive phases based on textural and geochemical analysis. The glass of earliest lower pumice records a wide range of SiO_2 (70-78 wt%) compared to the subsequent phases (~72-74 wt%) which we suggest is evidence that a distinct but related melt body was tapped prior to evacuation of the main rhyodacitic magma. Textural evidence also shows an increased proportion of microlite and lithic rich components in both lower pumice phases which could indicate separate vent clearing events. These findings support an extended runup period to the climactic Plinian phase analogous to the 4-month build-up to the 1883 magnitude 6 eruption of Krakatau, Indonesia. The occurrence of multiple Plinian eruptions prior to caldera forming eruptions pose a serious challenge for volcano monitoring agencies and poses new questions regarding how large volumes of magma are amalgamated and mobilised to produce large eruptions.

1270

Integrating offshore tephra deposits with near-source eruption records in Japan to better constrain eruption source parameters

Dr Hannah Buckland[1], Dr Paul Albert[1], Dr Ken Ikehara[2], Dr Gwydion Jones[1], Dr Christina Manning[3], Dr Danielle McLean[4], Professor Takeshi Nakagawa[5], Professor Victoria Smith[4], Professor Takehiko Suzuki[6]
[1]Swansea University, Swansea, United Kingdom, [2]Geological Survey of Japan, Tsukuba, Japan, [3]Royal Holloway University of London, Egham, United Kingdom, [4]University of Oxford, Oxford, United Kingdom, [5]Ritsumeikan University, Kusatsu, Japan, [6]Tokyo Metropolitan University, Hachioji, Japan

Japanese volcanoes are responsible for three of the largest explosive eruptions on earth during the last 150 ka, with total erupted volumes believed to have exceed 400 km3. Given Japan's island arc setting, the tephra produced during large magnitude eruptions is frequently transported and deposited offshore meaning that data from marine realm is required to effectively estimate eruption source parameters (ESPs), such as the total erupted volume and total grain size distribution (TGSD). In this study we present new thickness and grain size data obtained from tephra layers preserved in IODP cores collected from around Japan. Here we focus on four large Magnitude (>7) eruptions; the AT (~30 ka), Aso-4 (~87 ka), Ata (~99 ka) and Aso-3 (~130 ka), deposits from these events were identified in multiple studied cores using detailed chemical fingerprinting. All eruption deposits source from caldera-systems located in the southern Japanese island of Kyushu. We discuss the challenges of obtaining thickness and grain size data from offshore cores, particularly due to the prevalence of remobilised or overthickened deposits, and the small sample volumes available for grain size analysis. However, we show that by carefully navigating the limitations of offshore records we can extract valuable data for the four above mentioned caldera-forming eruptions. We then combine the offshore data with data collected during more traditional tephra studies of proximal deposits on-land. This integrated dataset will now be used to improve estimates of the ESPs for use in volcanic ash transport and dispersion models. New estimates of volume will also be valuable for magnitude frequency relationships which are particularly important for studying large magnitude (>7) eruptions as we have such limited observations due to their long recurrence interval.

631

Using hierarchical clustering to identify analogues for Melimoyu, a long-dormant and data-limited volcano in Chile

Vanesa Burgos[1,2], Susanna F. Jenkins[1,2], Laura Bono Troncoso[3], Constanza V. Perales Moya[3], Mark Bebbington[4], Chris Newhall[5], Alvaro Amigo[3], Jesus Prada Alonso[6], Benoit Taisne[1,2]

[1]Earth Observatory Of Singapore, , Singapore, [2]Asian School of the Environment, Nanyang Technological University, , Singapore, [3]Servicio Nacional de Geología y Minería (SERNAGEOMIN). Red Nacional de Vigilancia Volcánica, , Chile, [4]School of Agriculture and Environment, Massey University, Palmerston North, New Zealand , [5]Mirisbiris Garden and Nature Center, , Philippines , [6]Escuela Politécnica Superior, Universidad Autónoma de Madrid, Madrid, Spain

Forecasting when, or if, a volcano will erupt again in the future is challenging, even more so for volcanoes with scarce or non-existent eruption records. As a result, we often have to use data from analogue volcanoes to fill the gaps in the eruption record. This is the case for Melimoyu (Chile), a long-dormant stratovolcano with two confirmed VEI 5 Holocene eruptions. In this study, we apply Agglomerative Nesting, a bottom-up hierarchical clustering algorithm, to cluster 438 subduction zone volcanoes into analogues based on 37 quantitative variables describing the tectonic setting, composition, and morphology. We quantify the (dis)similarity between volcanoes and select the best linkage method that produces the strongest clustering structure. We also perform a sensitivity analysis on the input data by using three datasets: i) raw data, ii) output from a Principal Component Analysis (PCA), and iii) weighted data tuned to minimise the interquartile range of the eruption rates as a function of VEI derived from the set of analogues. Findings suggest that the raw data generates better results, providing a list of 55 potential analogues for Melimoyu, of which 23 have produced at least one VEI≥4 eruption in the Holocene. This objective grouping of volcanoes has been combined with the expert knowledge of the local volcanologists to assess their appropriateness as analogues. The best analogue (i.e., most similar) proposed by this approach is Mocho-Choshuenco, a Chilean stratovolcano with seven Holocene confirmed eruptions, four being VEI 5. Other similar volcanoes with a history of large-explosive eruptions are Quetrupillan, Michinmahuida, Callaqui, Calbuco, and Corcovado. The records from a selection of 19 analogue volcanoes have been used to derive the empirical F-M relationship and its uncertainty. Future work will also explore the application of the distance metric as weights on the F-M estimation to penalise dissimilar analogues.

879

Applications and challenges of laser-ablation ICP-MS zircon U-Pb and U-series dating of young Quaternary tephra beds

Serhiy Buryak[1], Britta Jensen[1], Alberto Reyes[1], Yan Luo[1]
[1]*University Of Alberta, Edmonton, Canada*

Tephrochronology is one of the most effective ways to correlate and date Quaternary deposits across large distances. However, it can be challenging to obtain direct ages on tephra beds when they are beyond the limit of radiocarbon dating, do not contain mineral phases suitable for Ar/Ar dating, or suitable glass shards for fission-track dating. Silica-rich tephra usually contain several accessory minerals that can be dated using U-based methods, including zircon. Zircon U-Pb and U-series dating by LA-ICP-MS is a useful technique for rapid in-situ dating of very young tephra beds (< 300 ka). Here we present U-Pb and U-series zircon ages for Woodchopper (~100 ka), PAL (~200 ka), and Biederman tephra (~180 ka)—three important Quaternary tephra deposits in Yukon and Alaska that have inferred ages based on stratigraphy but have never been directly dated. Our zircon ages derived from these two U-based chronometers are in agreement and consistent with the existing stratigraphic and/or palaeoecological constraints of these tephra. Their ages offer much need direct age control to the rich stratigraphic record of eastern Beringia (unglaciated Yukon and Alaska), in particular to late marine isotope stage 7 to 5 sediments that have recently had their age assignment questioned. Furthermore, we discuss analytical and data processing challenges, including: (1) instrumental conditions, (2) essential data corrections, (3) strategies for optimizing the likelihood of calculating the deposition ages from complex heterogeneous populations of U-based zircon ages. Our results highlight the potential of LA-ICP-MS U-based zircon dating to young Quaternary tephra in northwestern North America, with some important caveats that are applicable to other similar studies.

535

Combining InSAR and thermal modeling to constrain the cause of multi-decadal subsidence at Medicine Lake Volcano

Becca Bussard[1], Dr. Josef Dufek[1], Dr. Meredith Townsend[1], Dr. Christelle Wauthier[2]
[1]University of Oregon, Eugene, United States, [2]Penn State University, State College, United States

As remote monitoring of volcanic systems becomes more widely used and relied upon, it is important to understand potential long-term deformation signals at volcanoes so they can be isolated from deformation caused by new movement of magma. At Medicine Lake volcano, located in the southern Cascade Volcanic Arc adjacent to the Basin and Range extensional province, the long-term deformation signal is one of broad and steady subsidence across the region that reaches a maximum at the center of the volcano and decays radially outward. Previous leveling data spanning 1954-1989 (Dzurisin et al., 2002), campaign GPS data (Poland et al., 2006), and InSAR data spanning 2004-2011 (Parker et al., 2014) have consistently shown this peak subsidence to be on the order of 8 mm/yr. Hypotheses to explain the subsidence include surface loading, basin and range extension, and cooling of magma beneath the surface. This study seeks to add to the geodetic record of Medicine Lake by providing over 1000 interferograms of Sentinel-1 ascending and descending data spanning 2015-2021. The interferograms are then inverted to produce line-of-sight time-series data and average vertical and east-west velocity maps of the region that are compared with GPS data from stations within the region. The resulting deformation field will then be inverted using an Okada model to constrain the geometry of a contracting sill. Ultimately these results will provide constraints for a thermal model to test whether cooling of a sill can explain the observed long-term subsidence.

1339

Co-eruptive seismicity and caldera subsidence during the June 2018 eruption at Sierra Negra, Galápagos Archipelago

Dr Sophie Butcher[1], Andrew Bell[1], Peter La Femina[2], Patricia Gregg[3], Jack Albright[3], Stephen Hernandez[4], Mario Ruiz[4]

[1]University Of Edinburgh, , United Kingdom, [2]The Pennsylvania State University, , USA, [3]University of Illinois, , USA, [4]Instituto Geofísico de la Escuela Politécnica Nacional, , Ecuador

The large summit caldera at Sierra Negra is defined by a complex asymmetric trapdoor fault system (TDF), which protrudes over 150m above the caldera floor. This fault is a permanent record of resurgence and deformation within the caldera during previous eruptions. Over 6.5 m of uplift was recorded in the 13 years prior to the 2018 eruption, driven by magma accumulation and storage pressures. The 2018 eruption lasted two months, with fissures opening across the north and northwestern flanks of the volcano. During the co-eruptive period, the caldera subsided by over 8 m, whilst seismicity continued at a decreasing rate. Here we describe and analyse the co-eruptive seismicity for the 8 weeks following the eruption onset. We use PhaseNet, a deep neural network phase picking method, to generate an updated catalogue of seismicity. In particular, this approach identifies low magnitude events during episodes of persistent tremor, which have been previously hard to identify. We further examine discrete episodes of tremor which continues for weeks after the eruption onset and relate these episodes to trends in the seismicity and subsidence rates. We also demonstrate evidence of a multi-phase subsidence process, with a complex interaction between deflation and seismicity. The total subsidence experienced in the caldera in 2018 was nearly twice that recorded in 2005 (5.0 m). Additionally, reinflation of the caldera did not commence until 60 days after the 2018 eruption onset, in contrast to 2005 when inflation was recorded after only 10 days. A net uplift of ~1.5 m and pre- and co-eruptive M>4 earthquakes indicate anelastic deformation of the caldera. We discuss the implications this has for further dynamical modelling and explore further the complex role that intra-caldera fault systems can play on influencing co-eruptive subsidence.

1242

Estimates on the Frequency of Volcanic Eruptions on Venus

Professor Paul Byrne[1], Dr. Siddharth Krishnamoorthy[2]
[1]Washington University, Saint Louis, United States, [2]Jet Propulsion Laboratory California Institute of Technology, Pasadena, United States

Is Venus volcanically active today? Circumstantial evidence for active volcanism comes in the form of anomalously high thermal emissivity values of stratigraphically young flows. The planet's atmosphere may also record the effects of ongoing volcanism, with the global H_2SO_4 cloud layer likely maintained by the release of sulfur and water from the interior within the last several tens of millions of years. But how often might a volcano erupt on Venus? We collated eruption data from the Smithsonian Institution's Global Volcanism Program database, extrapolating those findings to Venus to estimate the frequency of eruptive events there. We identified 1,400 individual volcanic eruptions from 276 unique volcanoes within our analysis period of 1980.01.01–2021.01.21. Most eruptions on Earth are relatively short-lived, with 14.7% ending within a day and 57.8% within 100 days; only 12.5% of eruptions persist beyond 1,000 days. We find that an average of 5.6 new eruptions ($\sigma = 2.5$) of any duration are expected on Earth in any 60-day period. When considering both new and ongoing eruptions that endure 100 days, 10.9 ($\sigma = 3.7$) events are expected within 60 days. That frequency increases to 27.4 ($\sigma = 5.4$) eruptions lasting ≤1,000 days. We extrapolated our findings to Venus by assuming that eruptive frequency can be directly scaled first by surface area (0.902, from land surface on Earth to planetary surface on Venus), and then by planetary mass (0.816), resulting in a final scaling ratio of 0.736. We thus ran our bootstrap trials for Venus with a randomly selected subset containing 73.6% of the Terran eruption record. Bootstrap analyses for Venus indicate that eight eruptions take place in a random 60-day interval on Venus when considering new and ongoing eruptions, with as many as 20 eruptions lasting up to 1000 days.

1141

Investigating the origin of Yellowstone geothermal gases through noble gas isotope anlaysis

Dr David Byrne[1,2], Dr Peter H Barry[3], Dr Michael W Broadley[2], Dr David V Bekaert[2], Mr Matthieu G Almayrac[2], Dr Rebecca L Tyne[3], Prof Chris J Ballentine[4], Prof Bernard M Marty[2]
[1]GNS, Wairakei, New Zealand, [2]Centre de Recherches Pétrographiques et Géochimiques, Nancy, France, [3]Woods Hole Oceanographic Institution, , USA, [4]University of Oxford, , UK

The Yellowstone Plateau volcanic field is a major degassing site, providing a window into the deep mantle as well as fluids derived from shallower regions of Earth's crust [1]. Numerous and diverse geothermal features show the spectrum of degassing behaviours observed during the interaction of plume-source volcanism with thick continental lithosphere [2]. The noble gas component within these geothermal gases contains isotopes that may have been trapped within the deep Earth since accretion, recycled into the mantle during subduction, or produced over time via radioactive decay within the Earth [3]. We present full noble gas isotope abundance and composition data for samples taken from 35 distinct geothermal features across Yellowstone. Variations in 3He/4He ratios from 0.66 to 13.6 Ra show varying levels of mantle vs crustal derived fluids across the park. This is further evidenced by Ne isotopes, which show crustal radiogenic contributions towards the caldera edges but primordial solar-like signatures at the more central degassing sites. The mixing line defined by these central samples is amongst the most primitive, 20Ne/22Ne-enriched samples observed worldwide. Coupled with the relatively low 3He/4He ratios compared to other plume-source localities, this implies a 3He/22Ne for the Yellowstone source very close to the assumed protosolar nebula value of ~1.5, unaffected by any solubility-dependent fractionation imparted during large scale melting. The apparently primitive nature of the Yellowstone plume source revealed by these analyses is particularly notable within the global plume inventory, as it is not clearly associated with any LLSVP [4]. It further implies the existence of a significant deep heterogeneity in mantle 3He/22Ne, and by extension mantle regions that preserve distinct melting and volatile degassing histories.

[1] Lowenstern et al., 2014, Nature, 506:7488; [2] Huane et al., 2015, Science, 348:6236; [3] Broadley et al., 2020, PNAS, 117:25; [4] Koppers et al., 2021, Nature Earth&Env, 2

774

Melt and bulk viscosity changes due to oxide nanolites formation in iron-bearing rhyolitic magma

Dr Francisco Cáceres[1], Kai-Uwe Hess[1], Michael Eitel[1], Mathieu Colombier[1], Bettina Scheu[1], Melanie Kaliwoda[2], Donald B. Dingwell[1]
[1]Ludwig-Maximilians-Universität München, Munich, Germany, [2]Mineralogical State Collection Munich (SNSB), Munich, Germany

Magmas ascending to shallow levels in the Earth's crust are subjected to decompression and cooling. Due to decompression, magmas lose volatiles that, added to cooling, increase melt viscosity and change the magma liquidus, processes that lead to nucleation and growth of crystals. Both viscosity and crystal content are critical properties controlling the behaviour of erupting volcanoes. The bulk viscosity of a magma is largely controlled by the viscosity of its melt phase and its suspended (or dispersed) crystal load. Yet the effects of nanolites formation on magma bulk viscosity due to chemical changes in the melt phase and the crystal load that nanolites provide remain highly unexplored. Here we conducted highly controlled magma cooling experiments at oxidising conditions and later viscosity measurements on an iron-bearing rhyolitic magma, in order to explore the effects of nanolites nucleation and growth on both melt and bulk viscosities. During cooling from superliquidus conditions, oxide nanolites nucleated in the rhyolitic melt. Both thermal and viscosity analyses show that nucleated oxide nanolites can rapidly grow when magma is re-heated. These analyses also show that the effect of nanolite growth on bulk magma viscosity can be significant, and it is mainly due to iron depletion of the melt phase. Depending on the dynamics of magma degassing and ascent, the viscosity increase due to nanolites crystallisation may hold the potential to shift a magma into explosive behaviour.

1156

Bubbles (sometimes) matter: CO2 bubbles in rhyolitic melt inclusions

Tyler Cadena[1], Dr. Chelsea Allison[2], Dr. Kenneth Befus[2], Dr. Penny Wieser[1], Dr. Michael Manga[1]
[1]University Of California, Berkeley, Berkeley, United States, [2]Baylor University, Waco, United States

In recent years, a volcanological paradigm shift has occurred recognizing the significance of the contribution of volatiles in mafic melt inclusion vapor bubbles to the total inclusion volatile budget, which had previously been regarded as trivial. To investigate this determination for rhyolitic systems, we used Raman spectroscopy to probe melt inclusion bubbles from seven high-silica rhyolite eruptions sampling a swath of geographies and tectonic settings. Here we present a new data set of CO2 densities measured in quartz- and sanidine-hosted rhyolitic melt inclusion bubbles, along with contextual data from petrographic microscopy and x-ray microtomography of bubble distributions, morphology, and vol.% (average of ~4.5 vol.% for CO2-bearing bubbles). Out of 328 bubbles scanned across all deposits, ~20% contained some amount of quantifiable CO2, with a mean value of 0.132 ± 0.076 g/cm3. In some cases the measured CO2 in the bubble can comprise up to ~90% of the total CO2 in the melt inclusion. However, these CO2 bubbles do not appear to be systematically related in terms of their density, size, or distribution inside single melt inclusions, crystals, or a single volcanic deposit. This underscores open questions of how to accurately predict which bubbles will contain appreciable CO2 and overall bubble evolution after entrapment. Although the precise factors that influence which bubbles will contain CO2 remain unclear, our findings show that, similar to their mafic counterparts, CO2-bearing bubbles in rhyolitic melt inclusions can hold a large portion of the total CO2 in the inclusion. These results emphasize the importance of analyzing any bubbles present when studying melt inclusions and their volatiles across the compositional spectrum, to better constrain pre-eruptive volatile budgets, storage depths, and calculated degassing paths.

1130

Geodetic Constraints on Mass Loss and Magmatic Recharge at Sierra Negra Caldera, Ecuador

Miss Antonina Calahorrano-Di Patre[1], Dr. Helen Gaunt[2,7], Dr. Glyn Williams-Jones[1], Dr. Mario Ruiz[2], Dr. Falk Amelung[3], Dr. Peter La Femina[4], Dr. Maurizio Battaglia[5,6]

[1]Centre for Natural Hazards Research, Department of Earth Sciences, Simon Fraser University, Burnaby, Canada, [2]Instituto Geofisico de la Escuela Politecnica Nacional, Quito, Ecuador, [3]Department of Marine Geosciences - Rosenstiel School of Marine, Atmospheric, and Earth Science, University of Miami, Coral Gables, USA, [4]Department of Geosciences, Pennsylvania State University, State College, USA, [5]Volcano Disaster Assistance Program, U.S. Geological Survey, Moffett Field , USA, [6]Department of Earth Sciences, Sapienza – Universita di Roma, Roma, Italy, [7]Earth Science Department, University College London, London, UK

Deformation and gravity monitoring at active volcanoes are routinely used to characterize sources of unrest and contribute to eruption forecasting. Despite their extensive use, there are few volcanoes in the world in which both deformation and gravity vary dramatically before eruptive activity, and even rarer where it occurs for extended periods of time. Sierra Negra volcano, a basaltic caldera in the Galapagos Islands, Ecuador, is thus remarkable both for the magnitude and timescale of its geodetic changes: more than 6.5 m of inflation and 1080 µGal gravity increase occurred between the 2005 and the 2018 eruption. Due to heightened activity detected by IG-EPN in 2017, we reoccupied and expanded the gravity monitoring network at Sierra Negra just ahead of and immediately after its most recent eruption in 2018. We detected a gravity decrease of -776 µGal in the centre of the caldera, consistent with mass loss due to the 2018 eruptive activity. Subsequent temporal gravity surveys have shown a consistent gravity increase at all measured sites, with more than 100 µGal positive change per year in the centre of the caldera. This was accompanied by consistent inflation of the caldera floor. Through inverse modelling of deformation and gravity change after the 2018 eruption, we infer the magmatic recharge of a sill-like source, located between 1 to 2 km below the surface, at an approximate rate of 3×10^{11} kg per year. Forward modelling of gravity change between 2005 and 2018 supports a similar magmatic recharge rate between the two past eruptions at Sierra Negra. By investigating past and current magma recharge, we propose an upper bound for mass increase prior to the onset of new eruptions.

1134

Bouguer Gravity Studies of Volcanic Centres in the Garibaldi Volcanic Belt, British Columbia, Canada – Characterizing Geothermal Resources

Miss Antonina Calahorrano-Di Patre[1], Dr. Glyn Williams-Jones[1], Mr. Cedar Hanneson[2], Dr. Martyn Unsworth[2]
[1]*Centre for Natural Hazards Research, Department of Earth Sciences, Simon Fraser University, Burnaby, Canada,*
[2]*Department of Physics, University of Alberta, Edmonton, Canada*

The Garibaldi Volcanic Belt (GVB), located in southwest British Columbia (BC), Canada, is the northern extent of the Cascade Volcanic Arc and consists of at least eight major volcanic centres. Due to the post-glacial volcanic activity in the GVB, geothermal energy has been considered a viable alternative resource for several decades, with one particular project (the South Meager Geothermal project) even reaching the drilling phase and producing electricity in flow tests. Despite its advantages over other renewable sources, geothermal development in BC has been delayed partially due to the inherent risk of investing in a poorly mapped or understood resource. As such, there is the need to effectively characterize the geothermal resource potential of the GVB as well as its geological context. We use spatial Bouguer gravity measurements to image the subsurface structure of two volcanic complexes, Mt. Meager and Mt. Cayley, in order to better understand the geothermal resource potential and the geohazards associated with these sites. Bouguer gravity anomaly maps provide insight into the combined density signatures of subsurface rocks and geological structures. In particular, the Bouguer gravity measurements of Mt Meager show a negative anomaly centred in the same area as the previously explored South Meager Geothermal project – this suggests the presence of lower density geothermal fluids in the area. Although Bouguer gravity modelling is a powerful tool to identify areas of interest and delineate spatial density variations, it is insufficient to uniquely determine vertical change in subsurface features. We present preliminary 3D inversions of the gravity data which provide a glimpse into the internal volcanic structures. We combine these with other information, such as Magnetotelluric imaging and geological and structural mapping, to develop comprehensive 3D models of the subsurface, enhancing exploration of potential geothermal resources in the GVB.

1275

Exchanging knowledges: what we can learn from Guatemalan Maya Tz'utujil communities and their relational ontologies with volcanic landscapes

Professor Eliza Calder[1], Mr Diego Sapulu[2], Mr Alex Petzey[2], Dr Cristina Sala[3], Dr Teresa Armijos[3], Dr Lisa MacKenzie[1], Mr Diego Vasquez Monterroso[1], Ms Carla Chun[4], Prof Jeremy Phillips[5], Dr Neil Stuart[1]
[1]University Of Edinburgh, Edinburgh, United Kingdom, [2]Santiago Atitlan, , Guatemala, [3]University of East Anglia, , UK, [4]Universidad Mariano Galvez, , Guatemala, [5]University of Bristol, , UK

We present our research with Indigenous Tz'utujil Maya communities of Chuk Muk, Cerro de Oro, Santiago Atitlán and Panabaj on the flanks of Tolimán volcano in the area of Atitlán caldera. This is part of a broader effort to re-imagine people's relationship with their landscape, in particular around Panabaj (the site of a landslide disaster in 2005), utilising practical action and participatory methods.

Within that space we have facilitated interdisciplinary conversations where geology has been important and has lead to new understanding of how these communities understand their landscape. This is evidenced through the kinds of questions community members ask themselves and that they seek to understand from others in their own community as well as beyond, as well as the knowledge they communicate. Conversations were centered on relational ontologies between the volcanic landscape and present (and recent past) communities around it, and related to the origin of rocks, meteorites, of volcanic landforms and sounds; the health of the ground and appropriate ways to use land where their dead were buried by the landside; the connection between flora and fauna and rocks; the ancient sacred places and spiritual practices connected to specific locations and types of spaces within the volcanic landforms; the "personhood" of the volcano and other natural features; and abandonment and re-inhabitation of settlements.

These are communities that have maintained their cultural, spiritual, and ritual relationships with this landscape for hundreds to thousands of years. The lessons that we geoscientists can learn from better understanding Indigenous knowledges and ways of being in these landscapes (in particular their relational ontology marked by connection, reciprocity, respect to sacred natural beings beyond religious beliefs, and wholeness ideas) can deepen our own understanding as well as our understanding of and ability to challenge the power dynamics that underlie Eurocentric hazard management approaches.

896

Cordillera de Fuego film: a collective effort centering Guatemalan Maya Tz'utujil and Kaqchikel communities in an active volcanic landscape

Professor Eliza Calder[1], Mr Alex Petzey[2], Prof Julie Cupples[1], Mr Jayro Bustamante[3], Mrs Margarita Kenefic[3], Mr Luis Pineda[3], Ms Maria Mercedes Coroy[3], Dr Alejandra Colom[4], Ms Carla Chun[5], Mr Diego Sapulu[2], Dr Charlotte Gleghorn[1], Mr Renato Serrano[4], Mr Mischa Prince[6], Mr Amilcar Roca[7], Dr Raquel Ribeiro[1], Dr Ana Cabrera Pacheco[1], Dr Rudiger Wolf[7], Dr Teresa Armijos[8]

[1]University Of Edinburgh, Edinburgh, United Kingdom, [2]Santiago Atitlan, , Guatemala, [3]Casa de Producción, , Guatemala, [4]Fundacion Ixcanul, , Guatemala, [5]Universidad Mariano Galvez, , Guatemala, [6]Xocomil Producciones, , Guatemala, [7]INSIVUMEH, , Guatemala, [8]University of Michigan Tech, , USA, [9]University of East Anglia, , UK

We are co-producing a feature film and TV series that centres Indigenous Maya Tz'utujil and Kaqchikel communities in Guatemala, whose lives are changed by a volcanic eruption. We aim to produce media that deals in a politically and culturally contextualised manner with the question of disasters in Guatemala, that brings together different knowledges, that represents key themes ethically, and that is both challenging and entertaining to watch. We hope to produce high levels of civic engagement and debate within affected communities and beyond.

An endeavour of this nature is only possible through bringing together a diverse team and with adequate financial support (UKRI Global Challenges Research Fund). Our team includes Ixchel project leaders who had the original idea and vision for the project, along with a leading Guatemalan film director, his production company and a nonprofit organisation who are producing the film. Project investigators include community-based Tz'utujil researchers, academics based in Guatemala, the UK and the US, and researchers from volcano monitoring institutions, who all fed into the script development and were consulted on various aspects. Experiences and learnings from numerous communities have been woven together to produce a narrative with which many communities affected by civil war and disasters across rural Guatemala and beyond will identify.

Filming was undertaken in the volcanic landscape of Atitlán caldera and lake. The production includes professional Indigenous actors, as well as over 140 support actors from five local communities – the Kaqchikel communities of San Andrés, and San Lucas Tolimán, and the Tz'utijil communities of Chuk Muk, Cerro de Oro and Santiago Atitlán. The support actors include many individuals previously affected by landslide disasters on the flanks of Tolimán volcano. This presentation introduces the film project and the processes employed to maximise broad involvement and impact.

1315

Disaster Risk Management in complex volcanic risk environments: a co-produced, modular scenario framework for caldera volcanoes in Taupo Volcanic Zone

Mr Rodrigo Calderon[1], Dr Thomas Wilson[1], Dr Graham Leonard[2], Dr Sarah Beaven[1], Dr Thomas Robinson[1], Dr Josh Hayes[2], Dr Colin Wilson[3], Dr Simon Barker[3], Dr Finnigan Illsley-Kemp
[1]University Of Canterbury, Chirstchurch, New Zealand, [2]GNS Science, Lower Hutt, New Zealand, [3]Victoria University of Wellington, Wellington, New Zealand

Managing risk at caldera volcanoes poses many complexities and challenges. In particular, managing episodes of volcanic unrest are highly challenging. Unrest episodes can be relatively frequent at caldera volcanoes and potentially signal the onset of an eruption, yet most unrest episodes do not result in an eruption. This contributes significant uncertainty to volcanic hazard and risk assessment, associated risk management planning, and risk communication. In this work, we present a co-produced, modular volcanic scenario framework for caldera volcanoes in Taupō Volcanic Zone. The model was co-developed with the Caldera Advisory Group (CAG), which is comprised of national and local authorities, Iwi partners, science agencies, and other stakeholders to plan for managing caldera volcanic risk, with a specific focus on caldera unrest risks. The CAG identified a need for understanding future potential volcanic hazard and risk from caldera volcanoes, which they could use to inform emergency and risk management planning. Therefore, the research development process identified a suite of scenarios that would be a useful and useable approach for illustrating the complex and broad range of potential volcanic unrest and eruption phenomena and associated impacts. It also clearly identified the need for the scenarios to be 'scientifically credible' and also 'operationally relevant', thus bridging the science-policy/practice boundary. In this presentation we present the outcome of the development process: a modular framework that provides diverse storyline pathways, addressing the variability of caldera volcanic processes and their hazards, the extended geographical extension, and the potential exposure of population and critical infrastructure assets. Finally, we will present the results of an evaluation workshop that critically analysed the framework for emergency and risk management planning.

431

Bubbles rising in complex conduits: simulating shallow plumbing system geometries and their implications for basaltic eruption explosivity.

Miss Hannah Calleja[1,2,3], Doctor Eric Breard[1,2], Professor Linda Kirstein[1], Professor Godfrey Fitton[1], Doctor Ian Butler[1]

[1]University Of Edinburgh, Edinburgh, United Kingdom, [2]NERC - UKRI, , United Kingdom, [3]E4 DTP, Edinburgh, United Kingdom

Knowledge of volcanic eruption styles and forecasting relies on our understanding of the multiphase behaviour of magmas in the near-surface. Eruption dynamics are primarily driven by the rise and burst of gas from within volcanic conduits, and low viscosity magmatic systems exhibit a variety of eruption styles. Specific gas regimes are attributed to specific eruption types, and their ascent dynamics in the upper km within the conduit are a major control for surface explosivity. Current models cannot suitably explain natural system complexity because they assume simple rise conditions (rheologically uniform media and a vertical cylindrical conduit) but kinks, flares, diameter variations, wall roughness, storage zones and obstacles are common features of shallow plumbing systems. It is thus vital to consider the effects of complex internal conduit geometries on bubble ascent parameters to improve our understanding of volcano-scale flow dynamics and their implications for basaltic eruption explosivity.

Here, we consider the combined effects of variable viscosity and conduit geometry on bubble ascent parameters using a suite of novel experiments. The current focus is to examine slug, cap and bubbly flow within inclined tubes and a storage zone to simulate complex, multi-vent, shallow plumbing systems like Stromboli, and investigate a potential mechanism for paroxysms. Dimensionless parameters are derived to describe specific flow characteristics at laboratory and volcanic scales, and demonstrate the viability of current framework for true-scale application. Preliminary results indicate that internal conduit geometry controls for eruption explosivity as a direct consequence of its influence on gas ascent dynamics independently of (and in addition to) the factors currently attributed to eruption triggering in the literature, i.e., magma viscosity, gas flux and related controlling characteristics. We aim to validate a multiphase flow model using experimental data, and later simulate true-scale behaviour within a broad range of geometries and boundary conditions.

593

High-resolution numerical modelling of rhyolite melt generation and transport induced by basalt emplacement into the crust beneath Long Valley, CA.

Dr Meredith Calogero[1], Prof. Eric Hetland[2], Prof. Rebecca Lange[2]
[1]University of Bayreuth, Bayreuth, Germany, [2]University of Michigan, Ann Arbor, United States

We present a new high-resolution numerical model of the thermal and compositional evolution of the crustal column beneath Long Valley, California, a site of voluminous rhyolitic volcanism over the past 2.2 Myr, driven by the influx of basalt. This model incorporates a set of criteria for the removal of secondary (i.e., rhyolitic) melts (i.e., partial melts of granitoid wall rock and late-stage interstitial melts in basaltic sills) from the lower crust, followed by their emplacement into the middle crust, which significantly alters crustal-scale thermal and compositional profiles. The basaltic sills are randomly emplaced within a climbing 2 km depth window (from 28-30 km to 18-20 km) at varying rates and an initial 20ºC/km geotherm. The evolving crustal-scale thermal profile is tracked and reveals the development of a quasi-steady state thermal structure through the lower crust. The amount of secondary (rhyolite) melt, which meets the criteria for transport, is derived from both partial melts of granitoid crust (~40%) and interstitial melt in basaltic sills (~60%) and is ~25% of the cumulative thickness of emplaced basalt. Furthermore, the basaltic source contributes >90% of the Sr and Nd (and thus their isotopic signatures). A second set of basalt emplacements in the middle crust is guided by exposed bimodal plutons in the Colorado River extensional corridor in Nevada. It leads to reworking of the accumulated secondary rhyolitic melts, which drives Sr concentrations down in the tertiary set of rhyolite melts that form and meet criteria for transport. Tracking thermal and compositional consequences of transporting two generations of rhyolite melt formed by the emplacement of basalt into the lower and middle crust, respectively, places constraints on the multi-stage processes that led to the origin of Long Valley rhyolites.

1219

The work to get the engagement of the government officials when volcanoes awaken: Case Colombia

Dr Marta Calvache[1], Mrs Adriana Agudelo[2], Mrs Gloria Patricia Cortes[3], Mr Diego Gomez[4], Mr Cristian Lopez[3], Mrs Maria Luisa Monsalve[3], Mrs Lina Dorado[5]
[1]Independent, Bogotá, Colombia, [2]Colombian Geological Survey, Volcano Observatory of Popayan, Popayan, Colombia, [3]Colombian Geological Survey, Volcano Observatory of Manizales, Manizales, Colombia, [4]Colombian Geological Survey, Volcano Observatory of Pasto, Pasto, Colombia, [5]National Unit of Disaster Risk Managements-UNGRD, Bogota, Colombia

Volcanic eruptions can generate different events, such as, lava flows, pyroclastic density currents, volcano slope collapses, lahars, ballistic projectiles, pyroclastic falls, shock waves, seismicity, gases by fumaroles and grounds, deformation, among others, converting volcanic eruptions into multi-hazard events. This leads to the importance of understanding the volcano behavior through volcanic hazard assessment and monitoring. This is emphasized when volcanoes, in the vicinity of cities and towns or regions located in zones of volcanic influence, show signs of new activity. All this, is especially evident for decision makers, government officials and community and the relationship that should exist between these stakeholders and the scientists who study volcanoes.

Everyone involved in volcanic disaster risk management and decision-making must handle the details of the events that can occur during a volcanic eruption and thus be able to define the measures that will be taken and where and when those measurements will be taken.

During recent years the Nevado del Ruiz volcano has had an unrest process, mainly characterized by the intrusion of a dome, which produces time to time seismic events, deformation and numerous changes in the size and the ash content of the volcanic plume.

Likewise, in the last year, the Coconucos Volcanic Chain, where the Purace volcano is one of the most active volcanoes in Colombia, has had an increase in seismic activity, evidences of deformation and the opening of cracks and the formation of fumaroles, all this in a crater located of the north-western extreme of the Coconucos Volcanic Chain.

We want to share the experience, first, of creating trust through the uninterrupted presence for more than three decades in the volcanic regions, second, to interact with local, regional and national authorities, with other institutions and the community and third, jointly build the necessary actions for volcanic risk management.

1413

Apparent, but probably false, ice-modulated volcanism at Mt. Rainier, Washington (USA)

Research Geologist Thomas Sisson[1], Dr Andrew Calvert[1]
[1]*USGS Volcano Science Center, Menlo Park, United States*

It's widely accepted that unloading by loss of ice caps during interglacials can stimulate subaerial volcanism, but most alpine glaciers are thin, so load reductions would be much less in glaciated but non-ice-cap regions, and associations with volcanism are uncertain. Nevertheless, $^{40}Ar/^{39}Ar$ eruption ages aggregated for volcanoes of the Cascade and Alaska–Aleutian arcs show a peak commencing around the strong interglacial marine isotope sub-stage (MIS) 5e and continuing into intermediate glacial/interglacial conditions of substages 5a or 5b. Mount Rainier is one such volcano with abundant glaciers, lava-ice interaction features, and a peak in numbers of dated flows in MIS 5. However, its eruptive flux reconstructed from mapped deposits shows no correlation with glacial or interglacial periods, instead defining four protracted stages of alternating greater and lesser output. Explanations for this apparent contradiction include (1) incompleteness of dating, exposure, and preservation create spurious age peaks and reconstructed volumes, (2) deeper processes determine magmatic flux, so while interglacials may facilitate eruptions, these do not correlate with changes in overall volumetric output, or (3) ice extent controls deposition or non-deposition, creating associations between numbers of dated flows and interglacial or glacial periods. Support at Mount Rainier for this latter volcano-glaciological explanation includes that lava flows defining its apparent MIS 5 peak are relatively small and crop out chiefly near the break in slope at the foot of the edifice (1500–2500 m elevation) – areas later overrun and scoured by ice during subsequent glacial advances – and that those lava flows commonly overlie glacial unconformities. These relations support that smaller glaciers during strong interglacials allow lava flows to reach and deposit on the then ice-free or ice-poor lower edifice flanks, thereby creating accessible and datable volcanic deposits. Ice abundance thus chiefly controls deposition rather than eruption on stratovolcanoes.

1244

Episodic construction of Mt. Shasta, California Cascades, USA

Dr Andrew Calvert[1], Research Geologist Emeritus Robert Christiansen[1]
[1]*USGS Volcano Science Center, Menlo Park, United States*

Eruption history studies of active volcanoes often suggest volcanism is episodic with long repose periods; however, distinguishing the character and lengths of episodes is challenging as it requires good exposure, preservation, and precise and accurate geochronology. The segment of the Cascades volcanic arc including Mt. Shasta and Medicine Lake volcanoes in northern California has produced >1000 km^3 of eruptive output over the past 1200 ka. Prior to 700 ka the most productive composite volcano in this segment was along the arc axis, then from 700 ka to present one locus of volcanism shifted 20 km west of the axis and built the steep, 350 km^3 Mt. Shasta (4322m). A sector collapse destroyed Mt. Shasta ~350 ka so time/volume relations are incomplete, but detailed mapping and comprehensive argon geochronology of the succeeding edifice indicate that eruptive behavior is episodic with eleven cone-building episodes averaging 5 kyr in duration separated by remarkably quiet intervals 5-55 kyr in duration. These eruptive episodes comprise only 20% of time since 350 ka yet include >90% of erupted volume. Holocene volcanism expelled >60 km^3 during an 8 kyr episode beginning with Shasta's only known Plinian eruption (10.9 ka) followed by flank Shastina dacite domes, lavas and pyroclastic flows (10.7 ka) coeval with rapid central vent construction (10.7 – 8 ka). Summit-derived domes and lavas continued to 3.2 ka, followed by quiescence. The Holocene Shastina flank dacite event produced over 15 km^3 in time shorter than can be resolved by radiocarbon or paleomagnetic variation (Christiansen and others, 2020, Geosphere) and may have fueled much of the extended Holocene episode. Short-lived (tens to hundreds of years) shield volcanoes are abundant along this segment's arc axis, likely fueled by similar episodic, but chemically diverse, eruption of magma batches.

222

Integrating GPS and InSAR datasets for interpreting geodetic changes surrounding the 2020-21 eruption of La Soufrière volcano, St. Vincent

Dr Michal Camejo[1], Dr. Karen Pascal[2,3], Dr. Pablo Euillades[4], Dr. Raphaël Grandin[5], Dr. Ian Hamling[6], Dr. Leonardo Euillades[4], Dr. Rodrigo Contreras-Arratia[2], Dr. Graham A. Ryan[2,3], Dr. Joan L. Latchman[2], Mr. Lloyd Lynch[2], Dr. Minjeong Jo[7]
[1]Department of Earth Sciences, University Of Oxford, , United Kingdom, [2]Seismic Research Centre, The University of the West Indies, St. Augustine, Trinidad and Tobago, [3]Montserrat Volcano Observatory, Flemmings, Montserrat, West Indies, [4]CEDIAC Institute, Universidad Nacional de Cuyo, , Argentina, [5]Université de Paris, Institut de Physique du Globe de Paris, Paris, France, [6]GNS Science, , New Zealand, [7]USRA, NASA-GSFC, , United States of America

The 2020-21 eruptive crisis at La Soufrière volcano propelled the much needed expansion of geodetic surveillance in St. Vincent. Its effusive 'dome building' start allowed for growth of the pre-existing continuous Global Positioning System (cGPS) network from 2 to 6 stations, combined with real-time integration of interferometric synthetic aperture radar (InSAR) data through external collaboration. Detailed retrospective analysis of cGPS and InSAR (ALOS-2, SAOCOM and Sentinel-1) datasets over the period 2018 to 2021 reveals six deformation periods contributing to this eruptive episode: (1) deep and (2) shallow pre-eruptive inflation, (3) dome extrusion, (4) syn-eruptive (effusive) inflation, (5) syn-eruptive (explosive) deflation and (6) post eruptive recovery. Variations in the spatial resolutions of each technique proved to be complementary for constraining the deformation field active during this event. The far-field cGPS network geometry (closest operational station 5 km from the vent) only allowed for a depth sensitivity to deformation events ≥ 6 km, while InSAR was most useful for detecting shallower deformation events otherwise imperceptible by the cGPS network. Our analytical modelling distinguishes three pressure source depths contributing to this eruptive episode: 18 km, 6 km and <1 km. Deformation data are therefore in line with a vertically extensive magmatic system being tapped pre- and syn-eruption with interaction between deep and shallow regions by ascending magma batches. Although providing first order constraints on magma storage depths, our results do not fully characterise the geometry of La Soufrière's plumbing system; this will require more sophisticated modelling approaches. Nonetheless we present the first attempt at characterising this volcano's sub-surface architecture using solely geodetic data, a feat previously hindered by a combination of prolonged inter-eruptive quiescence and a limited monitoring network. The direction of future geodetic monitoring at La Soufrière should utilise both GPS and InSAR with a view towards maximising detectability and coverage.

295

Stories of L'úx Shaa / Mt. Edgecumbe, and their influence on our volcanic knowledge

Ms Cheryl Cameron[1], Dr. Michelle Coombs[2]
[1]State Of Alaska, Alaska Volcano Observatory, Fairbanks, United States, [2]United States Geological Survey, Alaska Volcano Observatory, Anchorage, United States

Lingít people have been in southeast Alaska for more than 10,000 years. Thousands of years ago, Lingít people came via canoe to the region around what is now Sitka, Alaska. Lingít oral history describes what they saw when they arrived; ice still clogged the inside passages and the scouting party could only traverse the outer coast. Vegetation was alders and shrubs, except in ice refugia. Kaagwaantaan clan elder Herman Kitka kept the oral history of L'úx Shaa, a volcano on Kruzof Island 26 km west of Sitka, and the "volcano woman." (L'úx Shaa was named Mount Edgecumbe in 1778 by Captain James Cook.) Kitka shared and recorded these stories before his death in 2009. The oral history describes how Lingít people first encountered L'úx Shaa: a smoking volcano with ashes carried eastward with the prevailing winds, whose name translates as "blinker." A volcano goddess appeared and demanded jewelry. Even today, people sometimes leave gifts of shiny objects. While Edgecumbe was erupting, Lingít people settled on the northern end of Kruzof Island, and when it quieted, they moved across the shallow channel to the Sitka area. In Lingít knowledge, Edgecumbe was recently erupting, possibly as recently as 800 years ago, although the youngest deposits yet identified in the geologic record are ~5,000 years old. People became accustomed to thinking of Edgecumbe as "dormant" although the oral history describes likely small eruptions in the very recent past. With our new knowledge that a magmatic intrusion has been ongoing at Edgecumbe since August 2018, the Alaska Volcano Observatory has installed a monitoring station on the edifice and plans for greater monitoring, scientific study, Indigenous collaboration, and communication about Edgecumbe. Understanding the Lingít oral history of Edgecumbe can help guide our understanding of the volcano, better informing our hazard analyses and eruptive studies.

1062

Modeling ground deformation caused by magma migration using a dipole source

Dr Flavio Cannavo[1]
[1]INGV , Catania, Italy

In volcanic areas, the ground deformation field can usually be predicted by some analytical or numerical source models, which take into account forces acting in the Earth's interior, such as changes in pressure and volume.

The typical dynamics associated with volcanic deformation sources include inflation and deflation for volumetric sources, and opening and closing for dyke-type sources.
The ability to detect and track magma movement in volcanic areas, however, represents an essential component in predicting eruptions and reducing their associated risks.
An inversion of multiple time measurements is typically used to infer source location variation.
The objective of this study is to provide an analytical solution to the surface deformation caused by migration of a volumetric source. The formulation is valid for small movements of the volumetric source in an elastic half-space. The proposed model is described by an oriented axis of motion that connects the initial and the final positions of the source. In this way, the model is similar to a volumetric dipole.
As a result, ground deformation can be modeled based on source migration, and source migration can be estimated based on the measured ground deformation by means of data inversion.

To identify the peculiarities, capabilities, and applicability of the dipole solution, it is compared with the basic volumetric source.

727

Formation of steep-sided volcanic domes on Venus

Mr Ri Cao[1], Dr Lee Saper[1], Dr Geoffrey Bromiley[1], Dr Alan Hastie[1], Dr Sally Law[1]
[1]*School of GeoSciences, Grant Insititute, King's Buildings, University of Edinburgh, Edinburgh, United Kingdom*

Steep-sided domes are prominent volcanic landforms on Venus that have been postulated to require high melt viscosities in order to support their steep-sided morphologies. The SiO_2 content of silicate melts is a critical parameter that controls melt viscosity. The aim of this study is to investigate one possible mechanism for the formation of Venusian domes by constraining the silica contents of liquids formed by batch melting (BM) of Venusian crust or by fractional crystallization (FC) processes of possible Venusian liquids.

We performed FC and BM models using Rhyolite-MELTS software to determine melt compositions and then calculate viscosities. Based on X-ray fluorescence data from surface probes, two Venusian basalt compositions, Venera 13 (alkaline) and 14 (low alkali), were chosen for modelling FC and BM processes at different pressures (0.01-1GPa), temperatures (900-1400°C), water content (0-0.2 wt.%), CO_2 (0-0.2 wt.%) and oxygen fugacities (ΔFMQ=-1, 0).

For FC, the maximum viscosity is ~$7x10^7$ Pa·s for Venera 14, at anhydrous condition, 980 °C, 0.01 GPa after 90% fractionation, corresponding to a maximum SiO_2 content of 76 wt.%. Addition of 0.2 wt.% H_2O in bulk composition slightly increase the maximum SiO_2 to 77 wt.%, whereas this leads to a lower viscosity compared to anhydrous case due to 1 wt.% H_2O in the liquid. For BM, the maximum SiO_2 content is ≤ 70 wt.%, which does not yield melts for higher viscosity compared with melts for FC. Therefore, one feasible way to get very SiO_2-rich melt is by FC of alkali-poor Venusian magmas.

Despite the maximum calculated SiO_2 content of ~76 wt.% for evolved Venera 14 liquids, calculated viscosities are still one order of magnitude lower than critical viscosities proposed to fully account for dome formation. This indicates that other factors need to be considered that may dramatically increase melt viscosity (i.e., high crystal content).

437

Diffuse CO2 degassing in continental rift volcanoes: A case study of the Greater Olkaria Volcanic Complex, Kenya.

Mr Lorenzo Cappelli[1], Ms Purity Mwihaki Kamau[2], Dr Paul Anthony Wallace[1], Mr Antonio Randazzo[3,4], Ms Ruth Wanjiku Njoroge[2], Mr Victor Otieno[5], Ms Monicah Selyian Tubula[6], Prof Nicholas Obuya Mariita[2], Prof Karen Fontijn[1]

[1]Université Libre De Bruxelles (ULB), Department of Geosciences, Environment and Society, Bruxelles, Belgium, [2]Dedan Kimathi University of Technology (DeKUT), Geothermal Training and Research Institute, Nyeri, Kenya, [3]University of Florence, Department of Earth Science, Florence, Italy, [4]Institute of Geosciences and Earth Resources (IGG), National Research Council of Italy (CNR), Florence, Italy, [5]Kenya Electricity Generating Company-PLC, Naivasha, Kenya, [6]No affiliation, Naivasha, Kenya

The investigation of diffuse CO2 soil emissions is a reliable tool for volcano monitoring on many active or dormant systems worldwide. Indeed, characterising volcanic CO2 diffuse emissions not only allows evaluating the total natural CO2 budget emitted by a volcanic system, but it also permits (i) speculating the storage at depth of degassing magmatic/hydrothermal reservoirs, (ii) recognising possible changes of these systems, (iii) quantifying the thermal capacity of hydrothermal fluid flows, or (iv) locating buried tectonic structures and their influence on gas rising. Many soil CO2 investigations have been performed on subduction-related dormant volcanoes and caldera complexes, however little is still known about degassing conditions of continental rift zone volcanoes. Despite, in recent years, more attention was drawn to soil degassing in the East African Rift, the passive CO2 emissions of individual rift segments or single volcanic complexes are still largely undescribed. Accordingly, the estimates of the total amount of deep-sourced CO2 released by the entire rift system remain ambiguous.

This study aims to characterise the degassing budget and the emission setting of a dormant rift volcano. We investigated soil CO2 degassing of a large, multicentred, geothermally-exploited caldera complex in the southern portion of the Kenyan Rift: the Greater Olkaria Volcanic Complex. Approximately 1180 CO2 flux measurements were collected in two different surveys (Jul-Aug 2021 & Jul 2022). The measurements mostly focused on six large fumarolic fields lined up along specific volcanic/tectonic fractures, which seemed to promote CO2 rising solely in concomitance with hydrothermal fluids circulation. Soil CO2 fluxes measured up to 5500 g/m^2d, whereas the contribution of multiple sources of CO2 (biogenic background vs magmatic/hydrothermal) was tested using both graphical statistical analysis and the carbon isotopic signature (13C-CO2) on 56 gas samples. Altogether, we estimate a total release of 89 tCO2 per day from the surveyed areas (1.32 km^2).

569

The latest rifting episode on Reykjanes Peninsula: insights into plumbing architecture and parental melt composition

Dr Alberto Caracciolo[1], Dr Enikö Bali[1], Dr Saemundur Ari Halldórsson[1], Dr Guðmundur Heiðar Guðfinnsson[1], Mrs. Ingibjörg Þórðardóttir[1], Mrs. Guðrún Lára Pálmadóttir[1], Mr. Valerio Silvestri[2]
[1]NordVulk - Insitute of Earth Sciences, University of Iceland, 102, Reykjavik, Iceland, [2]Department of Earth and Environmental Sciences, University of Milano-Bicocca, Bicocca, 20126 , Milano, Italy

In 2021, an eruption occurred in Reykjanes Peninsula, in southwest Iceland. Judging from the past eruptive history of the peninsula, this could mark the onset of a new eruptive period. In fact, in the past 4000 years, three rifting episodes have occurred on Reykjanes Peninsula with the activation of four of the five volcanic systems: Reykjanes, Svartsengi, Krýsuvík and Brennisteinsfjöll. In this work, we focus on 16 lava units erupted across Reykjanes Peninsula during the most recent rifting period, between 800 – 1200 AD. We analysed major and minor elements of glasses, mineral phases and melt inclusions (MIs), with the goal to reconstruct plumbing system architecture and parental melt compositions. Application of cpx-melt and OPAM barometry on groundmass glasses indicates that, prior to eruption, magmas are extracted from reservoirs located at about 7-10 km depth (2-3 kbar) in the Reykjanes, Svartsengi and Krýsuvík volcanic systems, whereas in Brennisteinsfjöll magmas are tapped directly from deep reservoirs located at about 14-21 km depth (4-6 kbar), with little or no storage at shallow depth. Ratios of minor elements insensitive to fractional crystallization, such as K_2O/TiO_2, show very narrow variation in groundmass glasses, between 0.09 – 0.13, whereas K_2O/TiO_2 of MIs varies between 0.04 to 0.45. This variability collapses as melt evolution proceeds, indicating that concurrent mixing and crystallization plays an important role in the geochemistry of these lavas. However, the most enriched MIs (K_2O/TiO_2 >0.3), which are hosted in plagioclase crystals, have Mg# between 51-72, suggesting the existence of evolved, incompatible element-enriched, magma pockets at shallow depth. This suggests that enriched melts can escape the mixing process and form enriched melt pockets within the uppermost crust. Identifying these enriched melt pockets is important because it has been shown that mobilization of enriched melts can trigger mush disaggregation, hence eruption, without requiring hot recharge.

697

CO2 flushing triggers large eruptions at open conduit volcanoes: the case of Stromboli

Professor Luca Caricchi[1], Dr Chiara Montagna[1], Professor Alessandro Aiuppa[1], Dr Paolo Papale[1]
[1]*University Of Geneva, Geneva, Switzerland*

Open conduit volcanoes, of which Stromboli is an emblematic example, erupt with the highest frequency on Earth. The activity at Stromboli is characterised by frequent small explosions intercalated by larger events that pose a significant risk to local populations, tourists, and scientists. Thus, identifying the signs of an impending larger explosion is of outmost importance for the mitigation of volcanic hazard. Here we show that the interaction between CO_2-rich fluids and magma leads to the accumulation of volatile-rich, low-density magma at depth without the requirement of a permeability barrier: CO_2 -flushing forces the exsolution of water and the increase of magma viscosity, which proceeds from the bottom of the plumbing system upwards. This rheological configuration leads to the progressive thickening of a gas-rich, low density and gravitationally unstable layer at the bottom of the volcanic plumbing system. Our calculations account for gas monitoring data and provide a base to track the approach to deeply triggered large or paroxysmal eruptions and estimate their size from continuous gas monitoring data. The model we propose for Stromboli can be applied to any other open conduit volcanoes globally and offers a framework to anticipate the occurrence of unexpectedly large eruptions.

1145

High Cadence UV Observations of Volcanic Eruptions by DSCOVR/EPIC

Professor Simon Carn[1], Dr. Bradford Fisher[2,3], Dr. Nickolay Krotkov[2], Dr. Can Li[2,4]
[1]*Michigan Technological University, Houghton, United States,* [2]*NASA Goddard Space Flight Center, Greenbelt, United States,* [3]*Science Systems and Applications, Inc., Lanham, United States,* [4]*University of Maryland, College Park, United States*

Accurate and timely satellite measurements of volcanic sulfur dioxide (SO_2) emissions are critical for assessment of the potential climate impacts of eruptions and can also provide novel insight into eruption processes. Until recently, high-cadence imaging of volcanic clouds from orbit was limited to geostationary visible-infrared sensors, but since 2015 the Earth Polychromatic Imaging Camera (EPIC) aboard the Deep Space Climate Observatory (DSCOVR) has provided hourly, daytime ultraviolet (UV) observations of volcanic SO_2 and ash emissions from the first Earth-Sun Lagrange point (L1). Here, we present EPIC SO_2 and Aerosol Index data from recent volcanic eruptions, including Raikoke (Kuril Islands, Russia) in June 2019, La Soufrière (St. Vincent) in April 2021, and the major submarine eruption of Hunga volcano (Tonga) in January 2022. We emphasize the novel information on eruption processes provided by the high-cadence EPIC observations, including measurement of eruptive SO_2 fluxes, improved monitoring of multi-phase eruptions, and constraints on umbrella cloud growth rates and volume flux during explosive eruptions. The January 2022 Hunga eruptions, which produced an explosion of historic magnitude, a plume that rose to lower mesospheric altitudes, but relatively low SO_2 emissions, provides a particularly interesting case study. High cadence EPIC SO_2 imagery permits the first UV-based analysis of umbrella cloud spreading and volume flux in the January 13, 2022 Hunga eruption, and also tracks early dispersion of the stratospheric SO_2 cloud injected on January 15, whilst confirming the modest SO_2 amounts measured by polar-orbiting satellite sensors. EPIC observations of this rare submarine explosive eruption could play a key role in unraveling the dynamics of this unusually explosive event. DSCOVR/EPIC observations of volcanic eruptions demonstrate the value of high-cadence UV data for volcano science applications and pave the way for future geostationary UV measurements of volcanic SO_2 and ash emissions (e.g., by the South Korean GEMS mission).

1241

The dynamic implications of excess volatiles in volcanic systems: an interdisciplinary approach

Professor Simon Carn[1], Helge Gonnermann[2], Jong Gil Park[2], Josef Dufek[3], Paul Wallace[3], Christina Cauley[3], Valentina Aquila[4], Matteo Trolese[4], Tobias Fischer[5], Lexi Kenis[5], Peter Colarco[6], Paul Newman[6], Nickolay Krotkov[6], Can Li[6,7], Benjamin Andrews[8], Verity Flower[9], Fred Prata[10], Parker Case[6]

[1]Michigan Technological University, Houghton, United States, [2]Rice University, Houston, United States, [3]University of Oregon, Eugene, United States, [4]American University, Washington DC, United States, [5]University of New Mexico, Albuquerque, United States, [6]NASA Goddard Space Flight Center, Greenbelt, United States, [7]University of Maryland, College Park, United States, [8]Smithsonian Institution, Washington DC, United States, [9]University of Stirling, Stirling, UK, [10]AIRES Pty Ltd, Melbourne, Australia

The pre-eruptive abundance and distribution of a free (or 'excess') volatile phase in magma reservoirs may have profound consequences for eruption precursors, magma ascent, plume dynamics, eruption magnitude and duration, and the atmospheric and climate impacts of explosive eruptions. Pre-eruptive volatiles may accumulate at the top of magma reservoirs, potentially triggering eruptions and driving transients in eruptive behavior due to varying volatile abundance over time. Volatile accumulation may also be necessary to sustain very high mass discharge rates and allow eruptions to grow to exceptional magnitude (e.g., Volcanic Explosivity Index [VEI] 6+). Here, we describe our interdisciplinary approach to elucidating the dynamic consequences of excess gas in volcanic systems and present some key interim results. New petrological modeling of magmatic volatile (H_2O, CO_2, SO_2) budgets in explosive andesitic to rhyolitic eruptions, with SO_2 release measured by satellite remote sensing, provides initial constraints for coupled conduit flow and high-resolution plume models that simulate magma and volatile ascent and transfer into the atmosphere. Vertical distributions of volcanic emissions output by the plume model are used in turn to initialize simulations by NASA's Goddard Earth Observing System (GEOS) General Circulation Model (GCM), which permit investigation of the radiative interaction of the erupted gases and aerosols and its impact on volcanic plume dispersal. NASA GEOS model simulations are validated using NASA satellite observations of volcanic SO_2, ash and aerosol emissions. To benefit from optimal NASA A-Train satellite data, we focus on recent VEI 3-5 explosive eruptions (since 2006) likely to have involved a significant pre-eruptive volatile phase (based on magma compressibility inferred from ground deformation data). Our modeling framework will provide new insight into the dynamic implications of excess volatiles in volcanic systems and improve NASA's ability to simulate and respond to future, high-magnitude explosive eruptions.

1007

Multiple geochemical and morphological instrumental approaches to improve the supereruption Young Toba Tuff knowledge.

Dr Benoît Caron[1], Giulia Del Manzo[2], Benoit Villemant[1], Annachiara Bartolini[3], Eva Moreno[3], Anne Le Friant[2], Franck Bassinot[4], François Baudin[1]

[1]Sorbonne Université ISTeP, Paris, France, [2]Institut de Physique du Globe de Paris, Paris, France, [3]Muséum National d'Histoire Naturelle, Paris, France, [4]Laboratoire des Sciences du Climat et de l'Environnement, Gif-sur-Yvette, France

The recent developments of ICP-MS/MS (Agilent 8800 and 8900) technique coupled with a laser ablation of the ALIPP6 geochemical analytical laboratory allows in situ analyses of the majority of elements of Mendeleev's periodic table. The LA-ICP-MS/MS technique has many advantages compared to classical LA-ICP-MS for analyzing trace elements in geological material, as it can resolve many important isobaric interferences.

We propose here to present how we have coupled the high-resolution tephrostratigraphic marine sedimentary record study with the morphological characteristic using both numerical microscope and SEM, and the geochemical major and trace elements composition using both EPMA and LA-ICP-MS/MS facilities to improve our knowledge of supereruption history.

To illustrate our new methodology, we will present a study on the well-known Indonesian Young Toba Tuff eruption commonly accepted age of ~74 ka. Using a marine sedimentary core record 600 km far from Sumatra Island, we challenge the short-lived explosive supereruption of YTT, arguing that YTT is not a single event but composed of a multiple event volcanic activity period. Our recent findings indicate that the eruptive history at that time was complex and multifold, with numerous eruptive events. High resolution tephrostratigraphic study of BAR94-25 marine core (600 km N-W far from Toba caldera respectively) show a succession of 17 distinct tephra and cryptotephra layers between ca. 103 and 48 ka which can be grouped in three main magmatic and eruptive phases based on their textural (pumice/glass ratio) and trace element characteristics.

It suggests that only one huge eruption is not responsible of various consequences including climatic transition and human's impacts, but that over a longer period a succession of ash and gas volcanic injections should be. These new data are in themself a first big step for a better understanding of Toba's explosive activity and of its climatic impact.

1222

Vent construction and erosion observed by UASs during 2021-2022 at Fagradalsfjall, Iceland

Dr Brett Carr[1], Dr. Christopher Hamilton[1], Ms. Joana Voigt[1], Dr. William Moreland[2], Dr. Thorvaldur Thordarson[3], Dr. Ármann Höskuldsson[2], Dr. Ingibjörg Jónsdóttir[3]
[1]Lunar and Planetary Laboratory, University of Arizona, Tucson, United States, [2]Institute of Earth Sciences, University of Iceland, Reykjavik, Iceland, [3]Faculty of Earth Sciences, University of Iceland, Reykjavik, Iceland

The morphology of vents formed during effusive basaltic eruptions provides insight on the processes that created them. In this study, we quantify vent growth and erosion at Fagradalsfjall volcano (Iceland) associated with different styles of effusive activity and inactive periods during and in between the 2021 (19 March to 18 September) and 2022 (3 to 21 August) eruptions. We use digital elevation models (DEMs) and point clouds produced from surveys conducted by unoccupied aerial systems (UASs) to create a record of vent morphology over time and difference these data products to measure change. Here, we focus here on changes at the main 2021 vent (Vent 5). During a phase of episodic vent filling and draining in August 2021, we measure both widening of the vent and an increase in the cone height. Overflows of the cone increased the thickness of lava surrounding the vent. After the eruption ended in September 2021, erosion reduced the height of the cone as much as 20 meters and eroded material had infilled the vent by 30 meters by July 2022. We identify multiple locations of volume loss in the cone interior and deposition at the bottom of the vent that occurred due to rockfalls between 13 July and 19 August 2022. These rockfalls were potentially triggered by shaking during the late July earthquake swarm preceding the 2022 eruption. We also present preliminary data from the 2022 eruption, where we quantify vent morphology change that occurred during consistent but declining effusion, in contrast to the episodic style of activity in August 2021. The data used in this study are part of a larger set of UAS survey data from Fagradalsfjall archived and freely available for community use through the University of Arizona's Research Data Repository.

1137

The hazards and driving processes of lava dome collapse: insight from the eruption of Sinabung Volcano (Indonesia)

Dr Brett Carr

Effusive eruptions of more viscous intermediate-to-silicic lava often build lava domes above the vent. Lava domes are inherently unstable structures prone to collapses that form block-and-ash style pyroclastic flows. Multiple different processes can cause instabilities to develop in lava domes and affect the size and frequency of dome collapses. This can make dome collapse hazards during an eruption difficult to assess. Dome-forming eruptions can also last years or even decades, creating a persistent hazard to those living in vicinity to these volcanoes.

The recent eruption of Sinabung Volcano (Indonesia) included lava dome and flow emplacement and numerous processes driving thousands of dome collapses that occurred over more than a decade of activity. Our investigations of this eruption have provided numerous insights on the hazards and driving processes of dome collapse. While collapse frequency often correlated with the effusion rate, collapse size did not. Large collapses remained possible throughout the eruption and thus the range of the pyroclastic flow hazard never decreased even as eruption rate waned. In one case, the volcano's topography controlled the development of a large instability that collapsed and led to both a change in effusive style (endogenous to exogenous) and an increase in collapse activity, all while effusion rate continued to decline. We developed a new method using photogrammetry and a slope stability model to assess the collapse hazard of dome instabilities which develop independent of the eruption rate, including after an eruption has ended. This work helps contribute to a more complete understanding of dome stability and assessment of collapse hazards at volcanoes with lava domes.

525

High temperature SO2-gas reactions with pyroxenes

Dr Ana Casas Ramos[1], Dr. Penelope King[1]
[1]*The Australian National University, Canberra, Australia*

Sulphur is an abundant species in volcanic settings; yet the sulphur budget is challenging to constrain, in part because we do not fully understand the mechanisms of S-gas-solid reactions in the magma, volcanic plume or crust. Previous studies show that SO_2 reacts rapidly with silicate glasses and rock-forming minerals to produce sulphates, oxides (Fe, Si, Al) and reduced sulphur. However, there are no studies of the kinetics for SO_2-mineral reactions. Pyroxenes provide a useful starting point for such studies because they are common in the crust and react to form Ca-, Mg- and/or Na-sulphates dependent on their composition. Here, we aim to systematically test reactions between pyroxene (augite, diopside, enstatite) and SO_2 at various temperatures (500-900 °C) and exposure times (1-18h), under controlled gas fluxes (20 sccm SO_2 in Ar) to obtain information about the reaction kinetics and products. These parameters are essential for estimating sulphur sequestration during volcanic eruptions, interpreting the composition of gases effectively released, and understanding ore-deposit formation and planet-forming processes.

1328

Sulfur isotopes in Kīlauea Volcano's 2018 summit ash: Tracing sulfur-bearing reactions from the source to hydrothermal system and plume

P.L. King[1], J.N. Ávila[1,2], E.M. Oborski[1], D.E. Damby[3], A. Patkar[1], I.S. Williams[1], J. Labidi[4], Dr Ana Casas Ramos[1], B. Fu[1]

[1]Research School of Earth Sciences, The Australian National University, Canberra, Australia, [2]School of Earth and Environmental Sciences, The University of Queensland, Brisbane, Australia, [3]Volcano Science Center, U.S. Geological Survey, Moffett Field, Mountain View, USA, [4]Institut de Physique du Globe de Paris, Paris, France

Kīlauea Volcano emits significant SO_2 and the May 13, 15 and 28 ash eruptions from its summit – at the start of its 2018 activity – sampled the source (glass), hydrothermal system (sulfates and sulfides), and plume (sulfates). We collected ashes soon after eruption, desiccated them, and prepared mounts without water to evaluate sulfur reactions.

Small areas (15-25µm diameter) of sulfur-bearing materials were analysed with the SHRIMP-SI ion microprobe (15kV, ~2-3nA Cs+ primary beam, 10kV extraction, and an electron gun for insulators). We developed a calibration for $\delta^{34}S$ using submarine basaltic glasses, and used existing reference materials to measure $\delta^{34}S$ in minerals.

We found sulfur contents and $\delta^{34}S$ of the glasses are consistent with degassing from the source (~2500ppm, ~–5‰) to near-surface (~80ppm, ~+2.5‰). At S<300ppm, $\delta^{34}S$ has poor precision (>0.8‰, 1σ) and varies widely (most –5 to +6‰, some +16‰).

We measured $\delta^{34}S$ in rare hydrothermal pyrite (–24 to –5‰) and hydrothermal (natro)alunite (–26 to –1‰); these are typically lower than glasses. Late, hydrothermal gypsum (–9 to +5.6‰) overlaps with glass $\delta^{34}S$.

In the plume, SO_2 + glass forms sulfates. We identified increasing reaction progress and measured $\delta^{34}S$ following: i) crystal + glass fragments rimmed by anhydrite (–2.3‰, +10.6‰); ii) Pele's tear rimmed by albite + anhydrite (–1 to +9.2‰); iii) crystal + glass fragments rimmed by quartz + albite + anhydrite (+3.8‰, +11.4‰); and iv) glass fragments rimmed by quartz + albite + anhydrite (+8.8 to +12.6‰). Thus, $\delta^{34}S$ increases as the reaction proceeds.

Our microanalyses record sulfur reactions at Kīlauea Volcano. The source melt ($\delta^{34}S$ ~–5‰) degassed SO_2 to form higher $\delta^{34}S$ glasses. Relative to primary melt, the hydrothermal pyrite and (natro)alunite have lower $\delta^{34}S$ indicating changes in temperature and S-species. Plume anhydrite records increasing $\delta^{34}S$ with SO_2-glass reaction progress suggesting $\delta^{34}S$ increased in the plume SO_2.

379

Eruption dynamics during eruptive episode 2016-2019 on Poás volcano, Costa Rica

Monserrat Cascante[1,2], Thomas Giachetti[1]
[1]University Of Oregon, Eugene, United States, [2]Observatorio Vulcanológico y Sismológico de Costa Rica, OVSICORI-UNA, Universidad Nacional, Heredia, Costa Rica

Poás volcano, located in the central valley of Costa Rica, is a large stratovolcanic complex with a well-developed hydrothermal system and a main crater usually filled with an acidic crater lake. Between 2016 and 2019, Poás volcano went through an eruptive period with different eruptive styles (phreatic, phreatomagmatic, and magmatic) and several changes in its crater lake and hydrothermal system. We collected tephra fall samples consistently during many of these events and thus have a unique opportunity to better comprehend the impact of the hydrothermal system and the lake on eruption dynamics. We analyzed ash samples from 22 individual explosions and integrated the results with existing geophysical and geochemical data.

We sieved the samples every ϕ from -2 to 5 ϕ and analyzed each fraction separately for grain size, shape, density, and componentry (juvenile porous glass, lithics, hydrothermal, altered material). We combined laser diffraction and dynamic image analysis techniques to produce a high-resolution grain-size distribution (GSD) over the complete size range of the tephra samples (0.001-4 mm). We found that, for each eruption, the cumulative number distribution of particles can be fit by a power-law relationship, $N > d = \lambda d^{(-D)}$, where N is the number density of particles with a diameter greater than d, D is the fractal dimension, and λ is a scaling factor. The fractal dimension varies from 2.9 to 2.1 and we find that D is directly modulated by the componentry. Grain-size distribution for each component shows a distinct fractal dimension, with fragments of juvenile magma being characterized by a fractal dimension of 2.6, consistent with experimental fragmentation of magma by rapid decompression. Direct correlations between grain size distribution and componentry can help understand fragmentation processes, assess temporal changes in the style of eruptive activity, and aid hazard forecasting.

367

Insight into mush processes provided by 50 years of analysis of the Kīlauea Iki drill cores

Professor Katharine Cashman[1], Dr. Benjamin Andrews[2], Professor Josef Dufek[1], Dr. Claudio Contreras Hidalgo[3], Dr. Rosalind Helz[2], Dr. Johan Lissenberg[4], Professor Alison Rust[3]
[1]University Of Oregon, Eugene, United States, [2]Smithsonian Institution, Washington, USA, [3]University of Bristol, Bristol, UK, [4]Cardiff University, Cardiff, UK

Work over the past five decades has illustrated the wealth of data and resulting insight into magmatic processes provided by detailed studies of drill cores from Hawaiian lava lakes, in general, and Kīlauea Iki, specifically. Important observations include the timing and extent of olivine and melt redistribution within the lake and local controls on melt evolution as modulated by olivine-melt re-equilibration. Here we extend these studies by adding data from µCT scans and high resolution element mapping of thin sections. 3D scans allow imaging and analysis of the 3D distribution of melt and crystal phases. Initial results of a core with 34% olivine crystals (66% groundmass) show that crystals form a well-connected network, that the calculated permeability (~10-9m2) of the matrix is consistent with extrapolations from analysis of melt-bearing xenoliths with lower melt fractions and that the simulated formation factor (normalized resisitivity) of ~2 matches the lowest values (2.3-3 ohm-m) measured within the solidifying lava lake. Element maps of quenched ('snapshot') samples from the olivine accumulation zone illustrate the size-dependence of compositional re-equilibration of olivine crystals and location-dependence of re-equilibration of included chrome spinel. Chromite crystals, in particular, have re-equilibrated to various degrees depending on the olivine host Mg# and are homogeneous in Mg# but strongly zoned in Cr#, thus providing the opportunity to obtain new constraints on Cr and Al diffusion rates within both chromite and host olivine. These results illustrate the potential of using the Kīlauea drill cores to address key questions related to mush properties and processes, such as the evolution of mush permeability and electrical conductivity with increasing crystallization, controls on rates of melt-crystal-bubble re-distribution within the lava lake and the role of local conditions in controlling liquid lines of descent during cooling and solidification.

1388

What can halogen degassing at active volcanoes tell us about underlying magmatic processes? A machine learning and modelling approach

Dr Michael Cassidy[1,2], Professor Tamsin Mather[2], Professor David Pyle[2], Dr Madeleine Humphreys[3]
[1]University of Birmingham, Birmingham, United Kingdom, [2]University of Oxford, Oxford, United Kingdom, [3]University of Durham, Durham, United Kingdom

To enable better forecasting of eruptive behaviour, volcano monitoring needs to decipher the conditions and processes occurring within the underlying magmatic system in real time. This is not trivial, as commonly used approaches such as seismicity and deformation can be difficult to interpret in terms of processes occurring within the magmatic system; whilst carbon and sulfur degassing behaviour are mostly controlled by variables such as pressure and oxidation state, obscuring a range of other rapid pre-eruptive triggering processes (e.g., second boiling). Halogens such as F, Cl and Br are sometimes measured in volcanic plumes and show promising results as forecasting tools, but what controls their degassing behaviour is less well understood. In this presentation we compile experimental data on halogen fluid/melt partitioning and use various machine learning regression methods to develop a predictive tool for halogen degassing over a range of different magmatic conditions and compositions. Here we simulate a variety of pre-eruptive magmatic processes (such as cooling, heating, differentiation, decompression) via MELTS, and use our machine learning algorithms and a degassing model to demonstrate how halogens behave under these various scenarios. We find that ratios involving F, Cl, Br are more sensitive to changes in magmatic temperature, volatile saturation and differentiation, relative to degassing of C and S, and thus may provide a promising tool to decipher volcanic unrest under active volcanoes prior to sudden explosive eruptions.

236

Diffusion of halogens (F, Cl, Br, I) in silicic melt

Mr. Yves Feisel[1], Dr Jonathan Castro[1], Dr. Christoph Helo[1], Dr. Donald B. Dingwell[2]
[1]Institute of Geosciences, University of Mainz, Mainz, Germany, [2]Dept. für Geo- und Umweltwissenschaften, Ludwig-Maximillians-Universität, Munich, Germany

Chemical diffusion of the halogens F, Cl, Br, and I in silica-rich melts was experimentally investigated by the diffusion couple technique. Experiments were conducted under anhydrous conditions at atmospheric pressure and hydrous conditions (~1.5 wt.% H_2O) at 160 MPa, over a temperature range of 750–1000 °C and 1000–1200 °C, respectively. Quenched trachytic melts were analyzed using an electron microprobe and by secondary ion mass spectrometry. All halogens exhibit Arrhenian behavior in the investigated melt compositions with F always diffusing fastest. The other halogens show slower diffusion (F > Cl > Br > I) correlated to their ionic radii. In anhydrous melt a diffusivity (D) range of 3–4 orders of magnitude is covered with DF(1000 °C) ~5×10^{-13} m²/s and DI(1000 °C) ~1×10^{-16} m²/s. The diffusivities of all halogens increase in hydrous melt yielding DF(1000 °C) ~3×10^{-12} m²/s. However, the largest increase is observed for the slowest-diffusing halogens, resulting in a narrower diffusive range of only 1–2 orders of magnitude with iodine diffusivity yielding DI(1000 °C) ~9×10^{-15} m²/s. Activation energies (EA) of all halogens range from ~200–290 kJ/mol in anhydrous melts. In hydrous melt EA generally decreases, with the highest decrease determined for F (~131 kJ/mol) and only slight changes for the other halogens (~201–222 kJ/ mol).

Diffusivity data of the anhydrous series exhibit a pronounced correlation of diffusivity with the ionic radii, suggesting that halogen diffusion in silicic melt is related to the melt's ionic porosity. The correlation between diffusivity and ionic radius is weaker in the hydrous experiments. The results of this study provide the first consistent halogen diffusion dataset under relevant magmatic conditions and highlight the compositional effects of major elements and dissolved H_2O on halogen diffusion. These data also show the potential for diffusive fractionation among the halogens in silicate melts.

1199

Temporal patterns of explosive volcanic eruptions

Dr Angelo Castruccio[1]
[1]Universidad De Chile, Santiago, Chile

The classification of volcanic eruptions is of fundamental importance to understand volcanic phenomena and the hazards associated to it. Current schemes of classification are based mainly on size (magnitude), eruption rate (intensity) and style (effusive versus explosive). However, none of these classifications consider in depth, the temporal variations of eruption parameters such as the eruption rate or style of the eruption. Here a coupled conduit – magma chamber numerical model that incorporates gas exsolution and crystallization inside the chamber is presented. The model was used to analyze which parameters (conduit length and radius, magma chamber size, magma water and crystal content, injection rate of new magma into the chamber) control the evolution of an eruption. Using our model results together with an analysis of the temporal evolution of historical cases of Plinian and sub-Plinian eruptions, a new classification scheme for large explosive eruptions is proposed.

Plinian eruptions are more likely to occur when associated to shallow chambers (< 5km depth) and higher (<4% wt.) water contents compared to sub-Plinian events. Sub-Plinian eruptions are subdivided into 3 classes: Type A are characterized by an explosive, high intensity initial phase, followed by a waning stage and a transition to an effusive phase. Type B eruptions are characterized by an initial effusive phase, followed by a sudden increase in eruption rate and a transition to an explosive phase. Type C eruptions consist in discrete, multiple explosive phases, without the extrusion of lava. Model results indicate that these changes in the temporal evolution of eruptions can be caused by small variations on pre-eruptive conditions of the magma (initial crystal and water content) and magma chamber depth and size. Furthermore, our results suggest that under certain conditions, the eruption rate can be controlled by volatile exsolution rate inside the magma chamber rather than conduit conditions.

1368

Towards monitoring phreatic eruptions using seismic noise

Corentin Caudron[1], Tarsilo Girona[2], Thomas Lecocq[3], Alberto Ardid[4], David Dempsey[4], Alec Yates[5]
[1]Université Libre de Bruxelles, Brussels, Belgium, [2]University Fairbanks, Fairbanks, USA, [3]Royal Observatory of Belgium, , Belgium, [4]University of Canterbury, , New Zealand, [5]ISTerre, Grenoble, France

Phreatic and hydrothermal eruptions remain among the most difficult to forecast. The frequent absence of clear precursor signals challenges volcanologists' ability to provide timely and accurate hazard advice. They remain poorly understood and have recently caused human fatalities. It is therefore paramount to better investigate such eruptions by integrating new methodologies to fully understand the preparatory processes at play and improve our ability to forecast them.

Among the different approaches to monitor volcanoes, seismology forms the basis, and most active volcanoes are nowadays equipped with at least one seismometer. Seismology is unique amongst the Earth Science disciplines involved in volcano studies, as it provides real-time information; as such, it is the backbone of every monitoring program worldwide. With data storage capabilities expanding over the last decades, new data processing tools have emerged taking advantage of continuous seismic records. Recent advances in volcano monitoring have taken advantage of seismic noise to better understand the time evolution of the subsurface.

The well-established seismic interferometry has allowed us to detect precursory changes (dv/v or decorrelation) to phreatic eruptions at different volcanoes, thereby providing critical insights into the triggering processes. More recent approaches have provided insights into the genesis of gas-driven eruptions using seismic attenuation (DSAR: Displacement seismic amplitude ratio) and correlation with tidal stresses (LSC). Yet, puzzling observations have been made at different volcanoes requiring the use of numerical models and machine learning-based approaches, as well as complementary dataset to reach a more comprehensive understanding. This presentation will review recent insights gained into precursory processes to phreatic eruptions using seismic noise and how we could possibly forecast them. These tools are freely available to the community and have the potential to serve monitoring and aid decision-making in volcano observatories.

394

Volcanic SO2 emissions and magmatic volatile budgets

Ms Christina Cauley[1], Prof Paul Wallace[1], Prof Simon Carn[2]
[1]*University of Oregon, Eugene , United States,* [2]*Michigan Technological University, Houghton, United States*

Understanding and modeling the atmospheric and climate effects of volcanic eruptions requires knowledge of the magmatic volatile contents. The volatile budget includes the mass fraction of major volatiles dissolved in magma before eruption and the mass fraction present in a separate vapor or fluid phase. It is well demonstrated that intermediate to silicic magmas are typically vapor saturated before eruption (e.g., Scaillet & Pichavant, 2003; Shinohara, 2008). As part of a NASA Interdisciplinary Research in Earth Science (IDS) project on volatiles in volcanic systems, we are investigating the volatile budgets of explosive andesitic to rhyolitic eruptions spanning many orders of magnitude in erupted volume.

Using recent experimental results on the partitioning of oxidized sulfur between melt and vapor in arc systems (Masotta et al., 2016), together with other petrologic data and remote sensing measurements of SO_2 release, we estimate the composition and mass fraction of pre-eruptive vapor for well studied volcanic eruptions since 1982. We perform similar calculations for pre-1982 eruptions using SO_2 releases constrained by other methods such as ice core analysis. Our results allow us also to predict the masses of magmatic H_2O and CO_2 released. Our database allows us to examine potential relationships of exsolved vapor mass fraction to magma temperature, composition, crystallinity, and oxygen fugacity.

Bulk sulfur contents for erupted magma can be calculated from measured or estimated SO_2 release and erupted magma mass. The resulting values are at the upper limit or higher than the range of S contents in silicate melts based on melt inclusion data. This comparison shows that pre-eruption, open-system vapor enrichment or accumulation in erupted magma reservoirs is common. This vapor enrichment is likely supplied by crystallization and vapor exsolution from subjacent cumulates and/or mafic magma recharge.

1010

Volcano-tectonic setting of Mt. Etna offshore areas

Dr Danilo Cavallaro[1], Dr Marco Firetto Carlino[1], Dr Mauro Coltelli[1], Dr Luca Cocchi[2], Dr Domenico Patanè[1]
[1]Ingv, Catania, Italy, [2]Ingv, Rome, Italy

Mt. Etna is located in eastern Sicily (Italy) and its volcanism takes place in a complex geodynamic setting, where the front of the African vs European plates' collisional belt overlaps the Hyblean continental foreland crustal block. Therefore, the geological setting of Etna results from the interaction between different processes occurring at different temporal and spatial scales: regional tectonics (foreland-related extensional, Tyrrhenian-related strike-slip and collisional processes), local neotectonics, gravitational instability and quaternary volcanism.

Since Etna volcano lies along the Ionian coast, a multidisciplinary study of its offshore areas is fundamental for a full understanding of the relationship between tectonics and magmatism.
The available dataset used for this work consists of a plentiful set of high-resolution single- and multi-channel seismic reflection, seismic refraction, bathymetric, magnetic and gravity data, ROV images and sea-floor samples, collected during the last two decades.

The volcano basement, which locally crops out in the coastal and offshore areas, is characterized by horsts and grabens, bounded by NNW-SSE and NE-SW oriented fault systems pertaining to the Hyblean foreland domain. This structural arrangement strongly influenced the emplacement and distribution of the external nappes of the Apenninic fold-and-thrust belt.

Wrench tectonics affecting this region locally reactivated some Hyblean extensional faults, and favoured volcanism in the Etna region. Here, strike-slip tectonics led to the formation of local transtensive zones, which promoted the fissure-type volcanism of the Timpe Plateau and Riposto Ridge during Plio-Quaternary. The ongoing strike-slip tectonics led to the migration of the transtensive regions and the positive inversion of the former ones, where new magma ascent was hampered. This process caused the temporal and spatial shifting of the Etna volcanic centres up to the present-day stratovolcano.

This structural setting locally controls neotectonics of Etna, characterized by intense seismicity and gravitational instability, whose understanding is of great interest for hazard assessment.

487

Seafloor Geodetic Observations, Modeling, and Eruption Forecasting at Axial Seamount, NE Pacific

Dr Bill Chadwick[1], Dr. Scott Nooner[2], Dr. Jeffrey Beeson[1], Dr. David Caress[3], Ms Jennifer Paduan[3], Dr. David Clague[3], Dr. William Wilcock[4]

[1]Oregon State University, Newport, United States, [2]University of North Carolina at Wilmington, Wilmington, United States, [3]Monterey Bay Aquarium Research Institute, Moss Landing, United States, [4]University of Washington, Seattle, United States

Axial Seamount is a basaltic hotspot volcano superimposed on the Juan de Fuca spreading ridge in the NE Pacific, with a summit caldera at ~1500 meters depth. It erupted in 1998, 2011, and 2015. Since 1997, continuous monitoring of vertical deformation has been accomplished with precise bottom-pressure recorders. Since 2011, repeat high-resolution bathymetry collected by Autonomous Underwater Vehicles (AUVs) has also been used for measuring vertical movements of the seafloor. The pressure measurements are more precise (± 1 cm) but are only made at a limited number of stations (10-15) and are time-consuming to collect. The AUV repeat bathymetry is less precise (± 20 cm), but is spatially more extensive and continuous along tracklines that cover the entire volcano summit. Together, these complementary methods show that vertical displacements amount to 2-4 m over an eruption cycle, maximum displacements are consistently at the center of the caldera, and most of the deformation is within the caldera. Minor fault slip may also be accommodated across the caldera faults, along which most of the seismicity occurs. Modeling of the observed vertical displacements can be best-fit by either a steeply-dipping, conduit-like, prolate spheroid centered at 3-4 km depth, or a horizontal rectangular sill at ~1 km depth beneath the caldera. We favor the latter since it is more consistent with multi-channel seismic results showing an extensive magma reservoir beneath the caldera with a roof at 1-2 km depth. The pattern of inflation and deflation appears to be repeatable and useful for eruption forecasting. Monitoring since the 2015 eruption shows that Axial has re-inflated to 90-95% of its pre-eruption level. However, the rate of inflation has decreased by an order of magnitude since 2015 and the rate of seismicity is relatively low so the next eruption still appears to be at least several years away.

1452

Elucidating transport mechanisms of distal, deep sea ash deposits from the 15 January 2022 eruption of Hunga volcano, Tonga.

marcus chaknova[1,2], Dr Thomas Giachetti[1], Dr Alexa Van Eaton[3], Dr Joali Paredes-Mariño[4], Dr Shane Cronin[4], Dr Adam Soule[5], Dr Katherine Kelley[5], Mr Taaniela Kula[6], Dr Roxanne Beinart[5], Dr Shawn Arellano[7], Dr Craig Young[2], Mr Daniel Tran[2]

[1]Department of Earth Sciences, University Of Oregon, , United States, [2]Oregon Institute of Marine Biology, University of Oregon, , United States, [3]U.S. Geological Survey, Cascades Volcano Observatory, , United States, [4]School of Environment, University of Auckland, , New Zealand, [5]Graduate School of Oceanography, University of Rhode Island, , United States, [6]Tonga Geological Services, Government of the Kingdom of Tonga, , Tonga, [7]Department of Biology, Western Washington University, , United States

The large-scale eruption of Hunga volcano in Tonga on January 15th deposited several centimeters of ash and lapilli on proximal islands. However, up to 6 km3 of erupted mass entered the ocean as from ash fall and pyroclastic density currents (PDCs). Voyage TN401 to the Lau Basin back-arc spreading center 80-100 km away from the HT-HH caldera discovered voluminous ash deposits. A dominantly North to South sampling campaign along the Lau Basin spreading ridge took place less than 4 months after the eruption. Sampling and observations of ash deposits was conducted with the Remotely Operated Vehicle Jason and Autonomous Underwater Vehicle Sentry (Woods Hole Oceanographic Institution). Over 25 kg of ash was recovered by scoop and three push cores were collected at water depths of 2,200-2,800 m. At these locations, estimated thickness of the deposit ranges from 7-150cm. The material collected is extremely fine-grained volcanic ash (89–99 wt.% <63um) at all seven sites. The deposits are rich in juvenile glass (>80% of point-counted grains) ranging from dense to pumiceous, with a lithic content of 1–8%. Glass chemistry ranges to a lower Silica content than on-land samples (50-66 vs. 55-66 wt.% SiO2), but is otherwise consistent with the main sample suite. Biological componentry shows site-specific abundances of phytoplankton (foraminifera, coccolithophores, diatoms and radiolarians) providing potential insight into transport. Two theories are under investigation to determine whether these distal deposits represent primarily: (1) ashfall from the Western plume, or (2) PDC-generated turbidity currents and associated re-suspended ash. Our preliminary analyses support a combination of the two—suspension settling derived from submarine density currents and vertical settling derived from ashfall. Ongoing work requires multidisciplinary expertise to determine the mass proportions involved in these long-range transport processes and implications for the eruption dynamics at source.

984

Numerical simulations of propagating analogue dykes

Dr Caitlin Chalk[1], Dr Adrià Quintanas-Corominas[2,4], Dr Janine Kavanagh[1], Dr Guillaume Houzeaux[2], Prof Antonio Costa[3], Dr Arnau Folch[2,5]

[1]University Of Liverpool, Liverpool, United Kingdom, [2]Barcelona Supercomputing Centre (BSC), Barcelona, Spain, [3]Istituto Nazionale di Geofisica e Vulcanologia (INGV), Bologna, Italy, [4]Imperial College London, London, United Kingdom, [5]Geociencias Barcelona, Consejo Superior Investigaciones Científicas (CSIC), Barcelona, Spain

Numerical models of dyke propagation are vital for predicting the pathways of ascending magma in the lead up to volcanic eruptions. They're developed with the aim of assisting volcano observatories in interpreting subsurface signals as dykes ascend, and predicting whether or not the magma will reach the surface. Dyke propagation is naturally hidden from view, and we can only compare model results with outcrops representing the final stage in a dyke's journey. However, in order to interpret signals in real-time as they occur, numerical models must be capable of capturing the dynamic processes of dyke propagation at different stages of ascent, which can't be observed in nature. Instead, numerical models can be validated with analogue experiments, that are scaled to represent physical processes. Numerical models can also enhance experimental data sets by simulating a much wider parameter space than is possible with physical experiments. Combining these two approaches therefore has the potential for major developments in our understanding of subsurface processes, yet simulating analogue dyke experiments remains a key challenge. Most numerical models are based on simplifying assumptions (such as ignoring magma flow, or assuming a pre-defined vertical dyke pathway), that do not accurately represent physical models. We propose a new approach for modelling dyke propagation, based on the concept of a phase field – a continuous variable that denotes the presence or absence of a fracture. Our model couples phase-field evolution, fluid dynamics, and the solid deformation of the host-rock in a Finite Element Model framework. We apply our model to real-time simulations of analogue dyke experiments, where a fluid, magma analogue is injected into an elastic host rock analogue. These simulations show promising results, and suggest that our numerical model has the potential to simulate the dynamic behaviour of dykes in nature.

978

Shedding (laser) light on the coupled solid-fluid processes of propagating dykes

Dr Caitlin Chalk[1], Dr Janine Kavanagh[1], Dr Alex Charogiannis[2]
[1]University Of Liverpool, Liverpool, United Kingdom, [2]LaVision UK Ltd., Oxford, United Kingdom

Dyke propagation is a solid-fluid (rock-magma) interaction problem controlled by multiphysical processes involving fluid dynamics and the mechanics of fractured solids. Understanding these processes is vital for interpreting subsurface signals of magma movement in real time, yet dyke propagation is complex and naturally hidden from view. Laboratory experiments of fluid being injected into an elastic solid are analogous to dyke propagation in the upper crust, and have been used to shed valuable light on the mysteries of subsurface magma transport. For example, Kavanagh et al. (2018) showed that, contrary to a common assumption of many theoretical and numerical intrusion models, fluid flow in analogue dykes does not always resemble the profile of a unidirectional channel flow. I will present new experiments of a fluid, magma analogue being injected into a solid host rock analogue (gelatine), where a state-of-the-art laser imaging system was used to quantify material behaviour from injection to eruption. Seeder particles – which fluoresce in laser light – were suspended either in the fluid or the gelatine in order to track material movements and measure the analogue magma velocity and host rock deformation, respectively. Temporal velocities and displacements were calculated in a two-dimensional plane – both in the plane of fracture opening (parallel to the strike), and in the plane of lateral dyke growth. The experimental set up allowed for the measurement of the third, out-of-plane component of velocity or displacement, providing a quasi-three-dimensional view of dyke behaviour. These analogue experiments provide new insights on the coupled behaviour of magma flow and surrounding host-rock deformation of propagating dykes. I will also present ongoing work on numerical simulations of the analogue dykes, and how a combined experimental and numerical approach can be utilised to improve our understanding of dyke propagation.

1186

Geothermal: The Next Generation - Advancing the Understanding of the New Zealand's Supercritical Resources

Dr Isabelle Chambefort[1], Geothermal: The Next Generation Team
[1]Gns Science, Taupo, New Zealand

New Zealand is endowed with generous geothermal resources. NZ's deeper, currently untapped, supercritical geothermal resources have the potential to provide a source of renewable energy. New Zealand's unique tectonic setting, with its active rifting arc, producing voluminous magma and outstanding heat flow, delivers exceptional opportunities for geothermal development. This New Zealand's geothermal project skills places New Zealand as a leader in geothermal energy technology. This is demonstrated since the initiation of geothermal energy utilisation over 70 years ago.

Early supercritical projects are expected to have long lead times, thus additional research and inquiry should be embarked upon now in order to ensure future supercritical geothermal developments can align with New Zealand's low carbon economy and energy sector aspirations. Sector-wide roll out of supercritical geothermal operations ideally needs to occur before 2050. Working backwards, pilot and scale up demonstration of supercritical energy production would be needed by about 2040, and thus, the first exploration wells need to be drilled by 2030 or soon after.

Started in October 2019, the Geothermal: the Next Generation research programme aims to resolve the critical, underpinning, geological, geochemical, and technological challenges of establishing supercritical geothermal as part of the solution for New Zealand carbon neutral energy future.

The research team is composed of New Zealand and overseas geophysicists, geologists, experimental geochemists, modellers, as well as, economic and Māori strategic investment advisors.

Here we present an update on the main objectives, relevance, future linkages and the initial results, three years into this challenging and strategic scientific endeavour. Aotearoa New Zealand's supercritical journey is underway.

271

Petrological monitoring as a tool for forecasting changing eruptive activity: Insights from the 2021 Tajogaite eruption, La Palma, Canary Islands

Dr Katy Chamberlain[1], Dr Olivia Barbee[2,4], Dr Jane Scarrow[3], Dr Matthew Pankhurst[4,5], Dr David Neave[6], Dr Dan Morgan[7], Dr James Hickey[8], Dr Penny Wieser[9], Dr Beverley Coldwell[4,5], Dr Gavyn Rollinson[8], Alba Martín-Lorenzo[4,5], Dr Fatima Rodríguez[4], William Hernández[4], Dr Pablo Hernández[4,5], Dr Nemesio Pérez[4,5]
[1]Teesside University, Middlesbrough, United Kingdom, [2]Geology Department, Whitman College, Walla Walla, U.S.A., [3]Department of Mineralogy and Petrology, University of Granada, Granada, Spain, [4] Instituto Volcanológico de Canarias, San Cristobal de La Laguna, Canary Islands, Spain, [5] Instituto Tecnológico y de Energías Renovables, Granadilla de Abona, Canary Islands, Spain, [6]Department of Earth and Environmental Sciences, The University of Manchester, Manchester, U.K., [7]School of Earth and Environment, University of Leeds, Leeds, U.K., [8]Camborne School of Mines, University of Exeter, Penryn, U.K., [9]Earth & Planetary Science, University of California, Berkeley, , U.S.A.

Forecasting when and how volcanoes will erupt is the pivotal question in volcanology. While this can be done using geophysical and gas geochemical tools with varying effectiveness, forecasting how eruptions will evolve, and ultimately cease, remains challenging, and has important implications for hazard management. The 85-day eruption of Tajogaite volcano in 2021, part of the Cumbre Vieja volcanic complex on La Palma in the Canary Islands, presents an invaluable opportunity to develop and refine volcano monitoring methods, which will allow more effective forecasting of eruption evolution and cessation in the future. Combined with established volcano monitoring methods, petrological data has the ability to see through shallow crustal activity and reveal changes in magmatic processes that drive eruptions. Advancements in (1) the use of precise and automated sample preparation techniques, (2) rapid and high-resolution textural and compositional characterisations, and (3) increasing computing capacity allow samples to be collected, analysed and interpreted within days rather than months. To assess the value of information accessible through petrological data, we have utilised time-resolved samples from INVOLCAN's litoteca, which contains more than 400 tephra and 100 lava samples that span the entire eruptive sequence.

In this contribution, we present textural and chemical data from samples of lavas and tephras that span the initiation, duration and cessation of volcanism. These data are used to constrain temperature(s) and pressure(s) of mineral growth and magma storage, mineral-melt equilibrium dynamics, and timescales of magmatic processes. The alkali basalts erupted throughout the Tajogaite eruption show changes in mineral populations that link to different magma storage regions, highlighting the complex dynamics of the magmatic plumbing system. This petrological study highlights the importance of real-time sampling and shows how both rapid qualitative observations and in situ quantitative characterisation can be used to couple volcanic behaviour with subsurface magma dynamics.

796

Tales from twin eruptions: New dual ID-TIMS and ID-ICPMS U-230Th-Pb zircon geochronology for the Mamaku and Ohakuri ignimbrites, New Zealand

Mrs Christine Chan[1], Dr. Noah McLean[1], Dr. Kari Cooper[2], Dr. Darren Gravley[3]
[1]University of Kansas, Lawrence, United States, [2]University of California-Davis , Davis, United States, [3]University of Canterbury, Christchurch, New Zealand

Paired volcanic eruptions occur closely in time and space and may be evidence for effective volcano-tectonic feedback. Therefore, examining paired eruptions provides an opportunity to understand how rapidly syneruptive volcano-tectonic faulting can trigger subsequent eruptions. One of the best examples of paired caldera-forming eruptions is the ca. 240 ka Mamaku and Ohakuri ignimbrites that co-erupted from two separate calderas ≃30 km apart in the central Taupo Volcanic Zone, New Zealand. The Mamaku and Ohakuri share similar eruptive volumes (100 km^3) and crystal content (< 10 %), and are both characterized by hot-dry reducing magma types (Gravley et al., 2007; Deering et al., 2010). Despite their similarities, the Mamaku crystallized at deeper magma storage depths compared to the Ohakuri (Gualda et al., 2018). These observations raise some interesting questions about the magma reservoirs that fed the paired eruptions, including: (1) when did the Mamaku and Ohakuri magma reservoirs form, (2) do they share similar crystallization histories, and (3) what are the similarities and/or differences in the magmatic evolution of the Mamaku and Ohakuri magmas?

To answer these questions, we apply a new dual ID-TIMS and ID-ICPMS U-^{230}Th-Pb zircon dating technique to significantly improve the precision for zircon ages near secular equilibrium (≃100-350 ka). Our technique can produce U-Th-Pb ages with precision of <5% whereas SIMS U-^{230}Th ages for the same age range have an age precision of 15-30% (2σ uncertainty). If we combine our higher-precision zircon ages with time-resolved trace element data via TIMS-TEA, we can document the pre-eruptive conditions and magmatic evolution for both Mamaku and Ohakuri ignimbrites to better understand how paired, or closely paired eruptions can occur. And although paired eruptions are rare, determining the absolute timing of initiation can help us better understand the potential frequency of large-magnitude eruptions and improve our forecasting tools for future eruptions.

971

A Study on Volcano Alert Level System of Other Countries for Establishing the System for Korea

Dr Cheolwoo Chang[1], Ms. Hyeri Kim[2], Prof. Sung-Hyo Yun[1,3], Dr. Jeonghyun Lee[1]
[1]Volcano Specialized Research Center, Busan, South Korea, [2]Graduate School of Education, Pusan National University, Busan, South Korea, [3]Department of Earth Science Education, Pusan National University, Busan, South Korea

This Study aimed to establish volcano alert level system(VALS) for Mt. Baekdu, Jeju Island and Ulleung Island which are volcanoes located Korean Peninsula. These volcanoes have many geological and historical eruption records and the last eruption of each volcanoes occurred within 5,000 years, so these volcanoes can be distinguished active volcano. The Global Volcanism Program of Smithsonian Institute also categorized them to active volcano. But these volcanoes did not erupt at least a hundred years to thousands years, so there is no volcano alert level system for each volcanoes, there are only basic watch and warning system against ashfall. However, from 2002 to 2006, there are many eruption precursors such as increased volcanic earthquakes, ground deformation, rising temperature of hot spring water and changing of gas components. Resent study using seismography shows evidences of partial melting or magma reservior beneath of Jeju and Ulleung Island. We selected six countries that have well established the volcano alert levels system for their active volcanoes, using literature survey and collected data then compared each systems. By the data and results of comparison, we choose applicable points were selected to fit the characteristics of our volcanoes. We designed diffrent systems for each volcanoes, due to different tectonic setting and eruption type of the volcanoes. This VALS may insufficient because of the lack of field data but can be used when the emergency situation occurred.

893

CO CREATING A VOLCANIC HAZARD MAPPING FRAMEWORK FOR AOTEAROA NEW ZEALAND

Dr Danielle Charlton[1]
[1]Te Pū Ao/GNS Science, 1 Fairway Drive, Avalon 5010, PO Box 30-368, , New Zealand

Volcanic hazard maps are critical tools for communicating hazard and risk information and when developed, communicated, and used appropriately they can represent a central point for communication and mitigation of volcanic hazards and discussions about risk.

There is no consistent approach to volcanic hazard mapping in Aotearoa New Zealand. Mapping has to-date been ad hoc with differing degrees of collaboration between map makers, stakeholders and with map users. Existing maps have been produced by different groups using a variety of approaches and designs. This diversity stems from differences in map purpose; the methodology used; prevailing scientific and cartographic practices at the time; and local standards or policy requirements.
Since 2019, we have been combining communications research, expert experiences, and user needs in order to co-develop and test a new operational framework for volcanic hazard map development in Aotearoa. The framework includes workflows and guidelines for the development of different types of maps that are commonly used (e.g. long-term preparedness and event-specific maps).

We will present the current status of this framework, how it has been co-developed to date and next steps. In addition, we have used this approach to assist in the development of new long term maps for Tongariro National Park, event-specific risk-to-life maps for Whakaari, a VAL 2 specific map for Ruapehu, and for a new map-based communication product for Taranaki Maunga. These case studies have led to iterative and reflexive enhancements in the framework in order to better capture the range of unique volcanic environments in Aotearoa. For example, in the recreational Ruapehu setting, we found that hazard information should supplement a more comprehensive communication product that also addresses risk.

956

Gravity Data and Heat flow density using to determine the Crustal Configuration associated with volcanic activity in Tunisia Pelagian Platform

Mrs Badiaa Chelli[1]
[1]*Carthage University, CERTE, Tunis, Tunisia*

A description of the crustal and lithospheric structure is coupled with a synthesis of the available geophysical data sets, namely: Bouguer gravity anomalies, heat flow data through Pelagian Platform in Tunisia to southern Sicily in Italy.

The Pelagian Platform, which extends from Tunisia to southern Sicily, has been affected by tectonic activity producing a series of basins and structural highs, from the Miocene onwards to the recent extension of the Pantelleria rift (Reuther, 1987). The most recent basaltic volcanic eruption dates from October, 1981 (Baratta, 1981).

This recent Pantelleria rift is characterized by positive Bouguer anomaly and is thought to be caused by crustal thinning from Pelagian Platform (in Tunisia) towards the Sicily (in Italy).
The heat-flow density (HFD) values on the Pelagian Platform are generally higher than 80 mW. m-2, reaching 130 mW.m-2 or more in the younger part of the rift (Pantelleria and Linosa basins). These basins have both been affected, in the Quaternary, by prominent magmatic episodes which led to the formation of volcanic islands.

636

Near real time lava flow Hazard assessment in support to eruptive crises management at Piton de la Fournaise, La Réunion

Dr Oryaëlle Chevrel[1], Dr Andrew Harris[1], Dr Aline Peltier[2,3], Dr Nicolas Villeneuve[2,4], Dr. Diego Coppola[5], Dr. Mathieu Gouhier[1], Mr. Stéphane Drenne[6]

[1]Université Clermont Auvergne, CNRS, IRD, OPGC, Laboratoire Magmas et Volcans, Clermont-Ferrand, France, [2]Université de Paris, Institut de Physique du Globe de Paris, CNRS, Paris, France, [3]Observatoire Volcanologique du Piton de la Fournaise, Institut de Physique du Globe de Paris, La Plaine des Cafres, France, [4]Université de La Réunion, Laboratoire GéoSciences Réunion, Saint Denis, France, [5]Dipartimento di Scienze della Terra, Università degli Studi di Torino, Torino , Italy, [6]EMPZCOI, Préfecture de la Réunion, Saint Denis, France

Near real-time lava flow forecasting and monitoring is a necessary step in mitigating the impact to communities on the flanks of effusive volcanoes. We present here an operational protocol that has become an indispensable tool for crisis management at Piton de la Fournaise since its first full implementation in 2019.

Since 1979, Piton de la Fournaise (La Réunion) has erupted two times per year, with 95% of these eruptions occurring within an uninhabited caldera. This high eruption frequency often threatens the hundred thousand tourists hiking the volcano every year, the national road belt linking the north to the south of the island and the observatory's monitoring stations. Eruptive fissures and associated lava flows may also occur outside the main caldera and invade villages as it was the case in 1977 and 1986.
Since 2014, an integrated satellite-data-driven multinational response to effusive crises has been developed to rapidly assess lava inundation area and flow runout distance. This protocol was later implemented as a standalone software to provide a lava flow hazard map showing the probability of flow coverage and runouts, as a function of discharge rate. Since 2019, the produced short-term hazard map is shared with local civil protection in the first few hours following the start of an eruption to aid in mitigation actions. Here we present and discuss how the multiple exchanges between scientists, the observatory and civil protection has improved the delivered hazard map, ensuring a common understanding, a product which is of use and usable, and helping to build effective mitigation strategies at Piton de la Fournaise.

769

Measuring the viscosity of lava in the field using a portable rotational rheometer

Dr Oryaëlle Chevrel[1], Ing. Thierry Latchimy[2], Lionel Batier[3], Dr. Romain Delpoux[4], Dr. Stephan Kolzenburg[5], Martin Harris[5], Dr. Ingo Sonder[5], Travis Parsons[5], Claude Berlie-Caillat[6]

[1]Université Clermont Auvergne, CNRS, IRD, OPGC, Laboratoire Magmas et Volcans, Clermont-Ferrand, France, [2]CNRS, Observatoire Physique du Globe de Clermont, Université Clermont Auvergne, Clermont-Ferrand, France, [3]Université Clermont Auvergne, Polytech Clermont, Clermont-Ferrand, France, [4]Univ Lyon, INSA Lyon, Université Claude Bernard Lyon 1, Ecole Centrale de Lyon, CNRS, Ampère, UMR5005, Villeurbanne, France, [5]Department of Geology University at Buffalo, 126 Cooke Hall , Buffalo, USA, [6]ART SUD, Centre des arts du feu, Saint-Joseph, France

Viscosity is one of the most fundamental parameters that needs to be well constrained to fully describe lava flow emplacement dynamics. Using re-melted lava, viscometry in the laboratory allows for some parameters (temperature, shear rate, oxygen fugacity) to be controlled precisely and accurate measurements to be made. However, these experiments are typically constrained to two phase suspensions (liquid + crystals) and thus unable to completely replicate natural lava conditions where content and type of crystals, presence and size of bubbles, amount of dissolved volatiles, and oxygen fugacity vary. Therefore, one promising approach for quantifying lava rheology in its natural state is to carry out direct field measurements by inserting a viscometer into the lava while it is flowing. Such syn-eruptive in-situ experiments are notoriously difficult to perform due to the lack of appropriate instrumentation and the difficulty of working on or near active lava flows. The last time rotational viscometry was conducted in the field was during the 2016 Kilauea's Pu'u 'O 'o eruption. Although these measurements were successful, this work highlighted the need for a lighter and more versatile instrument capable of recording more precise viscosity data and with synchronous temperature measurements.

Here we present a new prototype field rheometer that was developed at the Université Clermont Auvergne. This new prototype is light (<15 kg), easy-to-deploy and can be handled and operated by only one person. The device simultaneously measures the three fundamental parameters to determine the viscosity of the lava: rotation speed, torque, and temperature. We performed calibration using standard oils in the laboratory as well as first measurements in large volumes of re-melted natural lavas at high temperatures. This preliminary work shows how the new device performs well under near-natural conditions and is ready for deployment to real lava flows.

1151

Modelling alkali-exchange alteration with rhyolite-MELTS to obtain melt compositions and magma storage pressures of fiamme from the Ora Ignimbrite, Italy

Ms Genna Chiaro[1], Dr. Guilherme Gualda[1], Dr. Calvin Miller[1]
[1]*Vanderbilt University, Nashville, United States*

Fiamme glass contains a wealth of information about the magma reservoirs that feed eruptions; however, glass is highly susceptible to secondary processes (e.g., fluid alteration) that modify original glass compositions. We investigate the Ora Ignimbrite (~275 Ma), a crystal-rich (~40%), supereruption-sized (~1,300 km^3) rhyolite in northern Italy, that has two vitrophyre units, an intracaldera vitrophyre and an outflow vitrophyre, that contain well-preserved, glass-bearing fiamme. Glass compositions from very coarse-grained crystal-rich (VCCR) intracaldera fiamme and coarse-grained (CG) outflow fiamme present a paradox: average K_2O concentrations are too low to crystallize sanidine (2.34-3.60 K_2O wt.%); yet, each fiamma contains euhedral sanidine.

Here we test if 1:1 alkali exchange is a viable mechanism of alteration for rhyolitic glass from the Ora Ignimbrite. We demonstrate that rhyolitic glass can experience "reverse" alkali-exchange alteration in which Na is replaced by K on a 1:1 atomic basis. By iteratively modelling alkali-exchange alteration and running the resulting glass compositions in the thermodynamic software rhyolite-MELTS, we obtain the original compositions of Permian rhyolitic glass from the Ora Ignimbrite. We show through animations that by progressively replacing Na for K in glass, we find compositions saturated in quartz + sanidine + plagioclase, consistent with the mineralogy observed in the fiamme. We also obtain Q2F (quartz + two feldspar) pressure estimates for the Ora magma bodies using our models. Overall, we present a new application of rhyolite-MELTS that returns original glass compositions and pressure estimates from altered, Q2F-bearing, rhyolitic fiamme.

Our results show that Q2F saturation for Ora Ignimbrite fiamme is attained with modelled original melt compositions with 4.85-5.60 K_2O wt.% and 3.05-3.80 Na_2O wt.%. Rhyolite-MELTS barometry returns pressures for modelled original glass compositions ranging from 100-165 MPa (CG) and 130-150 MPa (VCCR). Our results demonstrate that altered fiamme glasses can still provide meaningful information about their magmatic origins.

1166

Mush architecture and processes in the reservoirs of a supereruption-scale magma system inferred from fiamme glass: Ora Ignimbrite (Italy)

Ms Genna Chiaro[1], Dr. Guilherme Gualda[1], Dr. Guido Giordano[2], Dr. Corrado Morelli[3], Dr. Calvin Miller[1]
[1]Vanderbilt University, Nashville, United States, [2]Universitá Roma TRE, Roma, Italy, [3]Ufficio Geologia e Prove Materiali, Cardano, Italy

The Ora Ignimbrite (~275 Ma) is a crystal-rich (~40%), supereruption-sized (~1,300 km³) rhyolite in northern Italy and the final eruptive product of the Athesian Volcanic Group (289-274 Ma), the largest Permian volcanic region in Europe. Glacial and fluvial incision have exposed a >1,300 m thick intracaldera sequence, allowing us to observe how the eruption progressed through time.

Two key outcrops, an intracaldera vitrophyre and an outflow vitrophyre, provide well-preserved, glass-bearing juvenile material. Geochemical and petrological investigations of crystal-rich and crystal-poor fiamme from the Ora Ignimbrite vitrophyres allow us to reconstruct critical aspects of its magmatic architecture and pre-eruptive history, granting us further insight into the storage and magmatic processes that occur in large, silicic, crystal-rich systems.

Textural analysis of fiamme reveals four fiamma types: the intracaldera vitrophyre has very coarse-grained crystal-rich (VCCR) and fine-grained (FG) fiamme while the outflow vitrophyre has coarse-grained (CG) and fine-grained crystal-poor (FGCP) fiamme. Differences in glass trace-element compositions between the intracaldera and outflow fiamme suggest that two separate magma reservoirs fed the Ora Ignimbrite.

High crystal contents (VCCR: 40-50%; CG: 20-40%), large crystals (max crystal size for VCCR: >5 mm; CG: 1-3 mm), high-silica rhyolite major-element glass compositions (77.2-78.3 wt. % SiO_2), and depleted Sr (VCCR: < 20; CG: < 5 ppm) and Ba (VCCR: < 70; CG: < 20 ppm) glass concentrations suggest that the crystal-rich fiamme (VCCR + CG) represent erupted magma mush bodies that underwent extensive feldspar fractionation. The diversity of crystal-poor (FG + FGCP) fiamme glass compositions and presence of multiple glass types in single fiamme imply that there were various, small, melt-rich magma bodies that mingled prior to eruption. Overall, we propose that the magmatic system that fed the Ora Ignimbrite included two complex magma reservoirs, primarily composed of magma mushes with small, melt-rich bodies dispersed throughout.

733

Climate projections underestimate future volcanic forcing and its climatic impacts

Miss Man Mei Chim[1], Dr. Thomas J. Aubry[2], Dr. Nathan Luke Abraham[1,3], Prof. Anja Schmidt[1,4,5]
[1]Centre for Atmospheric Science, Yusuf Hamied Department of Chemistry, University of Cambridge, Cambridge, United Kingdom, [2]Department of Earth and Environmental Sciences, University of Exeter , Penryn, United Kingdom, [3]National Centre for Atmospheric Science, , United Kingdom, [4]German Aerospace Center (DLR), Institute of Atmospheric Physics (IPA), Oberpfaffenhofen, Germany, [5]Ludwig-Maximilians University Munich, Meteorological Institute, Munich, Germany

Explosive volcanic eruptions are one of the most important drivers of natural climate variability. In current climate modelling studies (i.e. CMIP6 ScenarioMIP), volcanic eruptions are represented by a constant volcanic forcing inferred from the mean forcing exerted by volcanic eruptions over the period 1850 to 2014. This approach does not account for the sporadic and thus time-variable nature of volcanic forcing. Ice-core measurements of volcanic sulfate deposition throughout the Holocene suggests that the total volcanic sulfur flux can vary by a factor of 25 between centuries. To understand how uncertainty in volcanic forcing affects climate variability up to the year 2100, we generate stochastic future volcanic eruption scenarios by resampling state-of-the-art ice-core, satellite, and geological records of volcanic activity in the Holocene. We then perform simulations for the period 2015 to 2100 using the future eruption scenarios in combination with a new plume-aerosol-chemistry-climate modelling framework ("UKESM-VPLUME") that integrates a 1-D eruptive plume model (Plumeria) into a fully-coupled Earth System Model (UKESM). Using this framework, we find that CMIP6-based climate projection underestimate volcanic forcing by at least a factor of two in a median future eruption scenario. This in turn leads to underestimation of the climate response as a whole including global radiative forcing, surface temperature, ocean circulation, sea level, and sea ice extent. We find that small-magnitude eruptions (emitting < 3 Tg of SO_2), contribute between about 30% and 50% of the volcanic impacts on climate in a median future scenario. Our results highlight the importance of improving the current representation of volcanic forcing in climate projections.

1466

Volc2clim: A webtool for fast estimation of the climate response to volcanic sulfur emissions from explosive eruptions

Prof. Anja Schmidt[1,2,3], Dr. Thomas J. Aubry[4], Miss Man Mei Chim[1]
[1]Centre for Atmospheric Science, Yusuf Hamied Department of Chemistry, University of Cambridge, Cambridge, United Kingdom, [2]German Aerospace Center (DLR), Institute of Atmospheric Physics (IPA) , Oberpfaffenhofen, Germany, [3]Ludwig-Maximilians University Munich, Meteorological Institute, Munich, Germany, [4]Department of Earth and Environmental Sciences, University of Exeter, Penryn, United Kingdom

During eruptive crises, direct hazards posed by volcanic ash or tsunamis are the top priority in terms of scientific response and communication with authorities and agencies in charge of managing volcanic hazards. However, questions on the potential climate response to an eruption rapidly emerge within scientific communities, stakeholders, and the public. Rapid prediction of the climatic response to an eruption immediately after an eruptive crisis is challenging because of: i) the uncertainties associated with near-realtime satellite estimates of volcanic emissions; ii) the fact that most climate model simulations require detailed aerosol optical properties for; and iii) the significant computational costs of and uncertainties associated with climate models with interactive stratospheric aerosol capabilities, which only require estimates of the initial volcanic sulfur emissions.

To address this challenge, we developed Volc2clim, a webtool predicting volcanic radiative forcing and climate response from volcanic sulfur emissions. Volc2clim combines three simple published models:

1. EVA_H, which predicts perturbations in aerosol optical properties, such as the stratospheric aerosol optical depth (SAOD) for a given mass of sulfur dioxide (SO_2), injection altitude and injection latitude.

2. A scaling factor that links the global-mean SAOD perturbation (at 550 nm) and the global-mean effective volcanic radiative forcing at the top of the atmosphere.

3. FaIR, a simple climate response model that calculates the global-mean surface temperature response based on the global-mean effective volcanic radiative forcing.

Volc2clim is computationally inexpensive and outputs both simple metrics and figures characterizing the radiative forcing and climate response, as well as full 4-dimensionnal fields of aerosol optical properties required to run climate models. We will showcase Volc2clim's main functionalities and discuss how well it performs for recent eruptions such as that of Raikoke in 2019.

1483

On processes leading to sudden explosive eruptions from wet volcanic systems: Constraints and models from Whakaari, Ruapehu and Raoul (NZ)

Dr Bruce Christenson[1], Dr Ben Kennedy[2], Dr Agnes Reyes[3], Mr Aaron Farquahr[4], Dr Mike Heap[5], Dr Richard Henley[6], Ms Sarah Spencer[7]

[1]National Isotope Centre, GNS Science , Lower Hutt , New Zealand, [2]Geological Sciences, University of Canterbury, Christchurch , New Zealand, [3]GNS Science, , Lower Hutt , New Zealand, [4]Department of Geology, Colorado College, , Colorado Springs , USA, [5]Géophysique Expérimentale, Institut de Physique de Globe de Strasbourg, Strasbourg , France, [6]Department of Applied Mathematics, Research School of Physics, The Australian National University, Canberra, Australia, [7]Robinson Research Institute, Victoria University of Wellington, Wellington, New Zealand

Evidence shows that permeability reduction through interaction between magmatic volatiles and meteoric fluids (principally crater lakes) is a key factor behind gas-driven eruptions from Whakaari (2016), Ruapehu (2007) and Raoul (2006). In the cases of Whakaari and Ruapehu, ejecta analysis shows that degassing of proximal underlying melts leads to the formation of hyper-acidic fluids which aggressively interact with host rocks to form mineral assemblages comprised principally of elemental sulfur, sulfate minerals and cation-stripped silicates. Fluid inclusion analysis of anhydrite from hydraulically fractured ejecta from the Whakaari eruption reveal vapor-dominant aquifer conditions and CO_2 pressures exceeding 40 bars at times in the vent.

TOUGH2 heat & mass transport modelling of fumaroles in the Whakaari vent environment reveal convective counter-flows of water and gas, with down-flowing surface fluids being drawn inward toward the up-flowing hot conduit gases. X1t reactive transport modelling of this aqueous flow shows that conductive heating of crater lake water becomes strongly supersaturated with respect to natroalunite between 180-200 °C. Equating and mapping this field of natroalunite precipitation onto the 180-200 °C temperature interval in the TOUGH2 topology prescribes a vertical pipe, bound by low permeability walls. X1t modelling of magmatic vapor condensation into the surface water forms the capping seals at both Ruapehu and Whakaari vents. Collectively, the sealed pipes provide the means for generating extraordinarily high pore pressures against shallow seal(s), with maximum pressures limited by column height and hydrostatic boundary conditions.

A very different sealing regime exists on Raoul Island, where seals of $CaCO_3$ and $CaSO_4$ form from boiling CO_2-saturated altered seawater rising from the deep magmatic heat source which has been depleted of its acidic gaseous components enroute to the surface. Here the gas-driven eruption of 2006 produced abundant blocks/fragments of clathrate-bearing carbonate vein material, testament to elevated CO_2 pressures in the seal forming environment.

1153

Exploring continuous Bayesian Network modelling for eruption forecasting

Dr Annemarie Christophersen[1], Dr Anca M Hanea[2], Dr Yannik Behr[3], Dr Craig Miller[3]
[1]GNS Science, Lower Hutt, New Zealand, [2]Centre of Excellence for Biosecurity Risk Analysis, University of Melbourne, Melbourne, Australia, [3]GNS Science, Wairakei Research Centre, New Zealand

Best practice recommendations for volcano observatories propose using probabilistic methods with uncertainties to forecast eruptions. Bayesian networks (BNs) are probabilistic graphical models that have been promoted in the literature for more than a decade as a framework for combining different volcano monitoring data and linking them to the underlying driving processes when forecasting eruptions. However, applications of BNs in real-time volcano monitoring are rare. The graphical part of BNs represents the modelled variables as nodes that are connected by arrows pointing from a parent to a child node. The probabilistic part of BNs describes the joint probability distribution of all variables. Most commonly, the random variables are modelled as discrete with a finite number of states (e.g. low, medium, high , or increasing, unchanged, decreasing) that are mutually exclusive, and must exhaustively describe the possible node states. The dependencies between discrete variables are captured in Conditional Probability Tables (CPTs). The CPT size increases with the number of parent nodes and the number of (parents and child) nodes' states. Some of the conditions might be very rare, making it impossible to populate the CPT robustly.

Volcano monitoring data are often continuous and it can be challenging to define boundaries between states. We recently developed a discrete BN to forecast volcanic eruption on Mt Ruapehu, Aotearoa New Zealand. The model structure was defined by experts, and the CPTs were estimated from the long monitoring records, supplemented by expert elicitation. Here we use the same model structure and data to explore continuous methods of model parameterisation. We model the probability distribution of each variable separately from the dependence and parametrise the dependence using (conditional) rank correlations. This approach is implemented in the Uninet software, which has great features for data analysis that help us present the data in novel ways.

1155

Bayesian Networks to forecast eruptions at frequently active volcanoes from monitoring data and expert elicitation: Application to Mt Ruapehu

Dr Annemarie Christophersen[1], Dr Yannik Behr[2], Dr Craig Miller[2]
[1]GNS Science, Lower Hutt, New Zealand, [2]GNS Science, Wairakei Research Centre, New Zealand

Bayesian networks (BNs) are probabilistic graphical models that have been applied to model complex systems and their uncertainties in many different domains. They provide a flexible framework to incorporate conceptual understanding of a system, learn from data when available and incorporate expert knowledge when data are sparse. The graphical component of the BN visually represents the input variables and helps users to gain a clear understanding of the modelled system; robust statistics describe the joint probability distribution of all variables. Applications include modelling multiple data streams for eruption forecasting and volcanic hazard and risk assessments. Despite offering many benefits, BNs are not widely used for volcano monitoring or eruption forecasting yet. We have developed a method, based on the process flow of risk management by the International Organization for Standardization, to build a BN model to support decision-making. We have worked with the New Zealand Volcano Monitoring Team (VMG) to apply this method to develop an eruption forecast model for Mt Ruapehu, Aotearoa New Zealand. The model structure was built with expert elicitation, based on the conceptual understanding of Mt Ruapehu, and with reliance on the long eruption catalogue and long record of monitoring data. The model was parameterised partly by data learning, complemented by expert elicitation. The model forecasts the probability of volcanic eruptions that impact beyond the crater rim within the next 28 or 91 days. The VMG has regularly estimated this probability since 2014. The retrospective BN model forecasts agree well with the VMG elicitations. The BN model is now implemented as a software tool to automatically calculate daily forecast updates.

381

The electrification of geyser eruptions: Strokkur Geysir, Iceland

Dr Corrado Cimarelli[1], Dr Caron JE Vossen[1], Dr Markus Schmid[1], Dr Julia Gestrich[1,2], Dr Alec J Bennett[3,4]
[1]Department of Earth and Environmental Sciences, LMU University of Munich, München, Germany, [2]Geophysical Institute, University of Alaska Fairbanks, Fairbanks,, USA, [3]Bristol Industrial and Research Associates Ltd (Biral), Portished, Bristol, UK, [4]Department of Electronic and Electrical Engineering, University of Bath, Bath, UK

Geysers are often investigated in relation to their analogy with volcanic explosive eruptions as they can shed light into the two-phase fluid dynamics of low viscosity magmatic systems and associated geophysical signals. While geyser studies have so far focused on the triggering mechanisms and intermittence of the eruptions as well as their precursory signal, very limited research has been done on the electrical signals produced by water jets above the ground surface. Here we present electrical measurements of water jets produced by Strokkur geyser in Iceland as an analog to magmatic explosive eruptions.

We used an electrostatic lightning detector to record electrical signals within the extremely low frequency range (1-45 Hz, sample rate 100 Hz), and a microphone (PCB Piezotronics 1/2" free field acoustic sensor, 3.15 Hz-20 kHz) co-located with the detector, recording acoustic signals at a sample rate of 5 kHz. In addition, high-speed videos, focused on the growing bubble preceding the water burst, were recorded at 1000 fps, while HD videos recorded at 250 fps were used to estimate the maximum height of the water jets. During the deployment, a total of 163 events were recorded. We found that the fountain height ranged between 0.4-20 meters above the water pool surface and correlates positively with the velocity of bubble growth before bursting. Likewise, the highest acoustic pressures were measured for events with faster bubble growth and greater maximum bubble height. The ejection of water produced a sinusoidal electrostatic signal, whose magnitude generally increased with increasing fountain height.

Our multiparametric measurements of geyser eruptions provide new insight into the mechanism of water electrification (e.g. waterfall effect) and contribute valuable information to the interpretation of electrical signals produced by their magmatic analogs.

382

The electrical signatures of a basaltic explosive eruption: the 2021 Tajogaite eruption of Cumbre Vieja (La Palma, Canary Islands)

Dr Corrado Cimarelli[1], Dr Caron Vossen[1], Dr Valeria Cigala[1], Dr Ulrich Kueppers[1], Dr José Barrancos[2,3], Ms Isabella Haarer[1], Mr Wolfgang Stoiber[1], Dr Markus Schmid[1], Dr Luca D'Auria[2,3], Dr Alec Bennett[3,4]

[1]Department of Earth and Environmental Sciences, LMU University of Munich, München, Germany, [2]Instituto Volcanológico de Canarias (INVOLCAN) , San Cristóbal de La Laguna, Tenerife , Spain, [3]Instituto Tecnológico y de Energías Renovables (ITER), Granadilla de Abona, Santa Cruz de Tenerife, Spain, [4]Bristol Industrial and Research Associates Ltd (Biral), Portishead, Bristol, UK, [5]Department of Electronic and Electrical Engineering, University of Bath, Bath, UK

The 2021 Tajogaite eruption represents the longest-lived (86 days) recorded eruption of Cumbre Vieja volcanic complex. Besides generating a vast compound lava flow field and widespread tephra fall deposits of basanite-tephrite composition, this eruption produced frequent lightning activity throughout its duration, creating a rare opportunity of continuous electrical volcano monitoring over two months. We measured the electrical activity using a lightning detector operating in the extremely low frequency range at 100 Hz sampling rate, installed ~2 km away from the vents. The detector was deployed on 11 October 2021 and recorded continuously until the end of the eruption on 13 December 2021, thus providing a unique dataset of its kind. Frequent volcanic lightning events reached peak electrical discharge rates >5,000 discharges/hour with fluctuations likely determined by mass eruption rate variations and changes in explosive style. Contrasting our time-series with meteorological (AEMET) and ash cloud elevation data (Toulouse VAAC), it can be concluded that plume electrification was mainly caused by silicate particle charging.

In addition to spatial charge movement and ash fall impact transients, four types of electrical activity linked to different explosive eruption styles were observed, as determined by TIR and visible range videos. The different electrical signatures are caused by differences in the fragmentation mechanism, eruption dynamics and source parameters. Strong ash emissions, producing high plumes, generated hours-long high-intensity volcanic lightning, while weak ash emissions produced faint electrical discharges. Bursts of low-intensity continuous discharges were detected during phases of gas jetting, Strombolian activity and lava fountaining, all characterised by small ash emissions. Burst duration increases with increasing particle kinetic energy, ejection height and explosion duration as well as erupted mass temperature.
We show here for the first time how distinct electrical signatures mark varying explosion styles, thus bearing great potential for near real-time electrical monitoring of low-intensity explosive eruptions.

1254

UAS-based multitemporal remote sensing of the 2021 eruption of Tajogaite volcano (La Palma, Canary Islands, Spain)

Dr Riccardo Civico[1], Dr Tullio Ricci[1], Dr Ulrich Kueppers[2], Dr Markus Schmid[2], Dr Piergiorgio Scarlato[1], Dr Luca D'Auria[3,4]

[1]Istituto Nazionale di Geofisica e Vulcanologia, Roma, Italy, [2]Department of Earth and Environmental Sciences, Ludwig-Maximilians-Universität (LMU), Munich, Germany, [3]Instituto Volcanológico de Canarias (INVOLCAN), San Cristóbal de La Laguna, Spain, [4]Instituto Tecnológico y de Energías Renovables (ITER), Granadilla de Abona, Spain

The 2021 eruption of Tajogaite cone (Cumbre Vieja ridge) is the largest historical eruption on La Palma Island. Over the course of almost 3 months, the volcano produced profound morphological changes in the landscape affecting pristine landscapes as well as human settlements and infrastructures over an area of tens of km².

Here we present the results of three UASs surveys (September 2021, January, and March 2022) coupled with Structure-from-Motion (SfM) photogrammetry that allowed us to produce very high resolution (up to 0.2 m/pixel) Digital Surface Models (DSMs) and orthophotomosaics (up to 0.1 m/pixel). We characterised the topography of the newly formed volcanic cone and of the lava flow field and documented their morphological evolution through time. Topographic change detection was performed by differencing our surveys and a pre-eruption surface, in order to detect elevation, volumetric, and areal variations. Among major morphological changes, we documented the growth of the new volcanic edifice including episodes of major gravitational collapse, as well as the emplacement of lava flows.

The repeated topographic surveys allowed us to calculate lava effusion rates and erupted volumes and contributed to the assessment of the state of volcanic activity during the eruption supporting dynamic hazard assessment and risk mitigation actions.

1105

Hide and seek: Cryptotephra studies applied to a deep marine core

Miss Madison Clarke[1], Doctor Jenni Hopkins[1], Doctor Monica Handler[1], Doctor Lorna Strachan[2], Doctor Steffen Kutterolf[3], Ms Katharina Pank[3]
[1]Victoria University Of Wellington, Wellington, New Zealand, [2]University of Auckland, Auckland, New Zealand, [3]GEOMAR Helmholtz Centre for Ocean Research, Kiel , Germany

The record of volcanic activity in Aotearoa New Zealand has previously been limited to terrestrial records and macrotephra marine and lacustrine deposits. The use of cryptotephra deposits to expand the record of volcanic activity has had a high success rate in the northern hemisphere, particularly with Icelandic deposits, but its use in Aotearoa New Zealand has mostly been limited to lakes within the Auckland region.

The aim of this project is to use the International Ocean Drilling Program Site U1520 Hole D core drilled during Expedition 375 (2017) to investigate the primary vs reworked cryptotephra deposits within the upper 11 m of core. The project focuses on developing non-destructive techniques, including XRF and magnetic susceptibility data to identify cryptotephra within the deep marine sediment cores. These data were run through machine learning and statistical techniques to pinpoint sampling sites of interest within long cores to be targeted for cryptotephra investigation. Once the cryptotephra were identified, the glass shards were extracted and concentrated and, where possible, the shards were analysed for major element compositions. This permits information to be combined with the existing macroscopic tephra framework to reconstruct a more detailed record of the volcanic eruptions from the TVZ.

Here we present the initial findings from this project, including shard count profiles and geochemical data. We discuss the correlation of crypto- and macrotephra deposits within the core, and whether they represent primary or reworked deposits. We use the results to expand the current tephrochronological record.

611

Complex eruption processes during the most intense phase of the 2018 eruption of Kīlauea

Ms Wendy Cockshell[1], Bruce Houghton
[1]University of Hawai'i at Mānoa, Honolulu, United States

The 2018 lower East Rift Zone (LERZ) of Kīlauea displayed diverse styles and rates of eruption over 90 days. We investigate the controls on the eruption dynamics for the most powerful, stable, and last phase of the eruption. This phase had two products: a 20-45 m high scoria cone, Ahuʻailaʻau, and a surrounding blanket of much lighter golden pumice. We examined the contrasting textures of the scoria and golden pumice to infer two contrasting histories of formation and growth of gas bubbles in the magma leading up until final fragmentation and quenching. This is the first time that the cone-forming scoria has been examined; Namiki et al. (2021) proposed that the golden pumice was formed by a very late stage fragmentation, which produced highly vesicular and therefore light particles that could escape from the Ahuʻailaʻau fountains. However, they did not look or model at the cone-forming scoria, which could not escape from the top of the fountains. We propose that the cone-forming scoria only experienced an earlier and less rapid vesiculation producing particles with lower numbers of often larger bubbles. This suggestion that VERY complex processes (occurring only seconds before eruption) can control the final fate of the erupted magma has very important implications for both eruption process but also anticipating the hazards associated with Hawaiian fountaining eruptions.

492

Using RhyoliteMelts and petrological methods to elucidate the magma storage conditions at Corbetti Caldera in the Main Ethiopian Rift

Mr David Colby[1], Prof. David M. Pyle[1], Dr Karen Fontijn[2], Prof Tamsin A. Mather[1], Mr Abate A. Melaku[3], Mr Million A. Mengesha[4], Prof Gezahegn Yirgu[4]

[1]Department of Earth Science, University Of Oxford, Oxford, United Kingdom, [2]Laboratoire G-Time, Department of Geosciences, Environment, and Society, Université libre de Bruxelles, Bruxelles, Belgium , [3]School of Earth and Environmental Sciences, University of St. Andrews, St. Andrews, United Kingdom, [4]School of Earth Sciences, Addis Ababa University, Addis Ababa, Ethiopia

Peralkaline magmas account for around 90% of the erupted products in the Main Ethiopian Rift (MER). Understanding the conditions under which these magmas evolve is critical to our wider understanding of rift related volcanism. Corbetti caldera, in the MER, has an extensive record of predominantly aphyric, large-scale, peralkaline rhyolite eruptions; however, very little is known about the basaltic magmas from which these highly evolved melts have developed. Here we present data from the only recorded basaltic deposit found within the caldera, coupled with whole rock, glass and mineral analysis of the peralkaline products, to investigate magma storage conditions at Corbetti. RhyoliteMelts modelling using the most primitive recorded basaltic composition established that Corbetti's peralkaline magmas likely evolved between 100-250 MPa, had an initial water content of 0.5 – 1 wt.% and evolved at or below the QFM buffer. However, it is well known that RhyoliteMelts underperforms when investigating peralkaline systems. Therefore, we undertook thermometry and hygrometry on the sparse crystal populations in the basaltic tuff and on a peralkaline welded ignimbrite to evaluate the accuracy of the modelling specifically looking at H2O contents.

This analysis established that the basaltic magmas had between 0.1-1.2 ± 0.32 wt.% H2O and the peralkaline magmas between ~3-7.9 ± 0.75 wt.% H2O (outliers ~1 wt.%). These results broadly match the estimations from RhyoliteMelts (~ 5 wt.% H2O) and with melt inclusion estimates for Corbetti and other peralkaline systems. Significantly the upper H2O estimate is within the range of H2O solubility for the calculated temperature at 250 MPa.

These results add to our understanding of the storage conditions of peralkaline magmas within a continental rift setting and highlights the hydrous nature of Corbetti's magmas and the roll that H2O plays during explosive eruptions.

1028

A novel experimental apparatus to investigate flow localisation and thermal feedbacks during volcanic fissure eruptions

Dr Rosie Cole[1,2], Professor James White[1], Ms Rachael Baxter[1], Mr Hamish Bowman[1], Dr Tobias Dürig[2], Ms Madi Fleming[1], Mr Brent Pooley[1], Farra Engineering[3], Ms Javiera Ruz-Ginouves[1], Professor Magnús Tumi Gudmundsson[2], Professor Shane Cronin[4], Dr Graham Leonard[5], Professor Greg Valentine[6]
[1]University of Otago, Dunedin, New Zealand, [2]University of Iceland, Reykjavík, Iceland, [3]Farra Engineering Ltd, Dunedin, New Zealand, [4]University of Auckland, Auckland, New Zealand, [5]GNS Science, Lower Hutt, New Zealand, [6]University at Buffalo, Buffalo, USA

Volcanic fissure eruptions transition from magma extrusion along long cracks to discrete vents within hours or days. Flow localisation is facilitated by variations in fissure geometry and host rock temperature along the crack. Variable cooling and blockages along the fissure direct flow into areas that remain open. We present a new experimental program aimed at investigating the thermal feedbacks that occur during cooling and flow localisation once a fissure eruption is underway, and the sensitivity of the system to changes in fissure shape and wall temperature. We have built a model volcanic fissure with adjustable shape, width, and wall temperature. We use Polyethylene Glycol (PEG) 600, a type of wax, as a low-temperature analogue fluid, which is injected into the slot from a pump with variable speed drives. This allows fluid flux to also be changed or paused during an experiment. Understanding how wall-rock properties influence conduit initiation will assist hazard modellers in determining future eruption evolution and likely vent locations.

Initial tests prove the function of the device, showing that the key variables can be changed and that localisation in various conditions can be achieved. Video is used to record the physical changes in the PEG as it flows, cools and solidifies, while continuous wall temperature data show initial high rates of heat transfer into the wall before an insulating solid wax layer forms. The wax also carries particle tracers from which flow patterns and rates can be determined as the fluid moves around obstacles, is channelled into a conduit, and flow rate decreases during solidification. The apparatus is housed at the University of Otago, New Zealand. The device is the focus of an experimental program running over several years, but it may be adapted for other experiments on fluid flow behaviour in non-planar slots and variable temperature conditions.

644

Late Pleistocene volcanism and environments at Katla volcano, south Iceland

Dr Rosie Cole[1], Professor Magnús Gudmundsson[1], Dr Birgir Óskarsson[2], Dr Catherine Gallagher[1], Professor Guðrún Larsen[1], Professor James White[3]
[1]University of Iceland, Reykjavík, Iceland, [2]Náttúrufræðistofnun Íslands, Garðabær, Iceland, [3]University of Otago, Dunedin, New Zealand

Volcanic landscapes, edifice morphologies, and environmental conditions influence the styles of eruptions at ice-capped and subglacial volcanoes, making glaciovolcanic products useful in reconstructing past environments and glacier characteristics. We use geological mapping and physical volcanology to determine eruption styles and emplacement processes of three glaciovolcanic formations on the flanks of the ice capped Katla volcano. We determine the volume of ice melted and thickness and extent of the glacier at each eruption, and we integrate these results with 40Ar/39Ar dating of lava to provide onshore constraints on the size of the glacier in the late Pleistocene.

One sequence, situated between Katla and Eyjafjallajökull volcanoes, is basaltic. Deposits of subaqueous pyroclastic currents adjoin a pile of pillow lavas and pillow breccia, indicating eruptions into a meltwater lake. Overlying lobate entablature-jointed to massive pahoehoe lava record a drying-up sequence as the formation emerged above lake level ~ 790 m above present-day sea level. Meltwater accumulation was facilitated by the setting between two volcanoes at the ancient confluence of three major glaciers. The interaction between glaciers and the subglacial topography directly influenced eruption style and volcanic products.

Two rhyolitic formations on the northwestern and eastern flanks of Katla comprise silicic fragmental material intruded or capped, respectively, by ice-confined rhyolitic lava. The glacier had a minimum surface elevation above present-day sea level of 1160 m in the northwest and 900 m in the east, at the times of eruption. These formations show no evidence for meltwater accumulation; meltwater probably drained from the eruption site as it was formed, indicating a leaky glacier and/or that glacial hydrology was controlled by subglacial topography rather than ice thickness.

Understanding the interplay among volcanic eruption styles, glacial hydrology, glacial characteristics and edifice morphology is becoming increasingly important as the climate and glacial-edifice configurations change at ice capped volcanoes.

505

Developing major and trace element analysis of volcanic matrix for petrological monitoring. Insights from Mt Etna.

Ms Emily Conn[1], Dr Teresa Ubide[1], Dr Ruadhán Magee[1,2], Ms Alice MacDonald[1]
[1]School of Earth and Environmental Sciences, The University of Queensland, St. Lucia, Australia, [2]University College Dublin, Dublin, Ireland

Volcanic risk to human settlement is increasing, from growing populations, proximity of major cities to active volcanoes, and escalating societal vulnerability.

To mitigate hazards, observatories regularly monitor volcano's seismicity, deformation, and gas chemistry to track magma movement to the surface. In addition, petrological monitoring is emerging to track variations in the properties of the magma through eruption, providing insight into the magma's sources, storage, temperature, and transport.

Syn-eruptive, "rapid-response petrology" requires access to eruptive products, specialised equipment, and development of rapid analytical approaches. While scanning electron microscopy (SEM) and electron microprobe produce reliable major element data for volcanic ash, fast analysis of trace elements remains under-developed.

Here we optimise fast, high-resolution major and trace element analysis of volcanic matrix via Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS). We use ash from recent eruptions at Mount Etna (2015-21) of differing crystallinities. Volcanic ash is advantageous due to its wide dispersal and accessibility, and it can be sampled with the help of local communities. High-resolution analysis of major and trace elements can provide valuable information on magma source, evolution through plumbing systems, and the magmatic processes linked to the evolution of eruptions.

Comparison of the new data to results from past eruptions allows assessment of magmatic system evolutions. Our project aims to assist future volcano monitoring efforts and better understand volcanic development on human to geological timescales.

799

Rapid eruption run-up & magma ascent at flank vents of Nyiragongo & Nyamulagira: perspectives from diffusion in olivine

Lissie Connors[1], Dr. David Matthew Sublett[2], Dr. Paul Wallace[3], Dr. Kenneth Sims[1], Dr. Robert Bodnar[2]
[1]University Of Oregon Department of Earth Sciences, Eugene, United States, [2]Virginia Tech Department of Geosciences, Blacksburg, United States, [3]University of Wyoming Department of Geology and Geophysics, Laramie, United States

Distributed along the flanks of Nyiragongo and Nyamulagira are hundreds of scoria cones and tuff rings, many of which erupted during the Holocene. Despite their prevalence, eruptive frequency, and proximity to the city of Goma and communities along Lake Kivu, the magmatic plumbing systems fueling these eruptions are poorly constrained. We are studying compositionally zoned olivine phenocrysts from both primitive (Fo84-91) and more-evolved (Fo74-85) scoria cones and tuff rings to characterize magma storage conditions and potential timescales of unrest. As the durations of storage and ascent can vary by orders of magnitude, variable diffusion rates for a range of elements in olivine are utilized to estimate timescales of various magmatic processes.

Olivine crystals most commonly exhibit broad, homogeneous cores and thin, normally zoned rims. We measured major (Mg, Fe) and trace (Ni, Cr, Al, Mn) elements in oriented crystals using electron microprobe analysis. Steep gradients between high-Mg cores and thin low-Mg rims yield model timescales of days to weeks between magma mixing and eruption. In contrast, lower-Mg olivine has more gradational profiles yielding timescales of months to ~1.5 years. These results suggest primitive flank eruptions are preceded by days to months of unrest following magma mixing, whereas eruptions of more evolved compositions experience prolonged pre-eruptive storage.

Hydrogen in olivine and clinopyroxene phenocrysts was measured using FTIR spectroscopy to investigate magma ascent rates. Concentration profiles show H depletion along the outer rims of crystals, consistent with diffusive loss during H2O degassing in the ascending melt. The results of these analyses will be used in conjunction with a 1D diffusion-conduit ascent model (Newcombe et al., 2020) to estimate ascent rates for flank eruptions.

As monitoring infrastructure grows in the region, crystal chronometers of past eruptions can better contextualize the magmatic processes generating modern signals of volcanic unrest.

414

Tephra2 and a Jupyter Notebook suite for tephra sedimentation from umbrella clouds

Dr ROBERT CONSTANTINESCU[1], Aurelian Hopulele-Gligor[2], Dr. Jeremy T. White[3], Dr. Charles B. Connor[4]
[1]Université Libre de Bruxelles, Bruxelles, Belgium, [2]Independent Software Engineer, Cluj Napoca, Romania, [3]INTERA Inc., Boulder, United States of America, [4]University of South Florida, Tampa, United States of America

Large explosive eruptions form laterally spreading umbrella clouds that transport tephra to great distances, making tephra fallout the most impactful volcanic hazard. Here we present a Jupyter Notebook suite, an interactive and graphical forward and inverse modeling tool for tephra sedimentation from umbrella clouds, including several fully worked examples, on the VICTOR volcanology hub. We use a forward advection - diffusion model to calculate the mass accumulation of tephra on the ground as it is released from an umbrella cloud. The model assumes tephra particles fall from a disk-shaped source (i.e., the base of the umbrella cloud), are diffused through a layered atmosphere and are advected by a layered wind field. For simplicity, the model assumes particle settling velocities depending on Reynold's number. The output is in the form of isomass maps (contour lines of equal tephra mass loading) and the grain size distribution at a point of interest. A separate tool uses Monte-Carlo simulations by randomly sampling the total erupted mass, the umbrella height and radius and the wind field. The output is an exceedance plot of tephra accumulation at a point of interest on the ground, given a prior range of input parameters. Lastly, the forward umbrella cloud model is combined with a Bayesian inversion and uncertainty quantification algorithm to estimate the eruption source parameters of past or unobserved eruptions. We hope the Jupyter Notebook suite will help improve future tephra hazard assessment by providing volcanologists with an accessible tool to model tephra fallout.

1351

Carbon fluxes from the Upper mantle: subducted carbonates vs. carbonatite metasomatism

Prof. Riccardo Avanzinelli[1,2], Dr. Alessandro Bragagni[1,3], Dr. Martina Casalini[1,2], Dr. Filippo Mastroianni[1,3], Prof. Tim Elliott[2], Prof. Carsten Münker[3], Professor Sandro Conticelli[1,4]
[1]Dipartimento di Scienze della Terra, Università degli Studi di Firenze, Firenze, Italy, [2]Bristol Isotope Group, School of Earth Sciences, University of Bristol, Bristol, United Kingdom, [3]Institut für Geologie und Mineralogie, Universität zu Köln, Köln, Germany, [4]Istituto di Geologia Ambientale e Geoingegneria, CNR, Montelibretti (Roma), Italy

Recent and active volcanoes in Southern Italy are characterized by large CO2 emissions. The exceptional amount of carbon and other volatiles released by volcanoes such as Vesuvius and Etna requires a continuous flux from the mantle. The fate of carbonate-rich sediments recycled at destructive plate margins is a key issue for constraining the budget of deep CO2 supplied to the atmosphere by volcanism. Experimental studies have demonstrated that metasomatic melts can be generated by partial melting of subducted carbonate-pelitic sediments, but signatures of the involvement of such components in erupted magmas are more elusive. We combine U-Th disequilibria, Sr-Nd-Pb isotope, and high-precision delta 238U analyses on lavas from Mount Vesuvius (Italy) to suggest that the 238U-excesses require a mantle source affected by the addition of U-rich carbonated melts, generated by partial melting of subducted calcareous sediments in the presence of residual epidote. Our quantitative enrichment model, combined with published experimental results, allows us to estimate a resulting flux of 0.15–0.8 Mt/yr CO2 from the subducted carbonates to the mantle source of Vesuvius. We argue that the occurrence of 238U-excesses in 'sediment-dominated' arc magmas represent diagnostic evidence of addition of carbonate sediments via subduction, hence providing constraints on the deep carbon cycling within Earth. On the other hand, Etna volcano releases 3.3 Mt/yr CO2, representing about 10% of the global volcanic emission. Its unusually high Nb/Ta (up to 26) and low Zr/Nb testify a mantle source that was enriched in carbon by carbonatite-like metasomatism. Indeed, the low K/K* and Rb/Th of Etna lavas point towards a lithospheric contribution. These findings indicate that the degassing CO2 derives mostly from a subcontinental lithospheric mantle affected by carbonatite-like metasomatism as also supported by carbon-rich mantle xenoliths in the nearby Hyblean plateau.

398

GEOCHEMISTRY: WHAT CAN IT TELL US ABOUT ERUPTION EXPLOSIVITY?

Ms Brenda Contla Hernandez[1], Melody Whitehead[2], Mark Bebbington[1,2], Michael Rowe[3]
[1]School of Mathematical and Computational Sciences, Massey University, Palmerston North, New Zealand, [2]Volcanic Risk Solutions, Massey University, Palmerston North, New Zeland, [3]School of Environment, University of Auckland, Auckland, New Zealand

Magma composition has been qualitatively linked to eruption explosivity. However, quantitative linkages between geochemical data and eruption style remain ambiguous. In an attempt to explore this we conducted statistical analyses of whole-rock geochemical data. Data from eruptive products in the GEOROC database is matched against eruption style (VEI) from the GVP catalogue for 459 Holocene eruptions from 155 volcanoes. The aim is to identify possible relationships between key parameters of the two datasets, and quantify the strength of any correlations, along with the limit of their applicability.
Several methods from a variety of machine learning techniques (including Naïve Bayes, Random Forest, Support Vector Machines, among others) were used to identify statistically plausible relationships between geochemical composition(s) and VEI. Preliminary results indicate that moderate-sized eruptions (VEI 1-4) cannot be robustly classified by whole-rock compositions, but those on the more extreme ends of the eruption scale (VEI 0,5,6 and 7) can be more reliably identified.
We hope to build on these results by incorporating other processes such as magma ascent rates, temperatures, and pressure. Developing a forecasting procedure for the composition and other parameters of the next eruption would then statistically inform robust future eruption scenarios.

1455

Tracking extrusive activity during the (2016 –present) Nevados de Chillán Volcanic Complex (NChVC) eruption, Southern Andes, using remote sensing techniques

Miss Maria Contreras[1], Miss Gabriela Pedreros[1], Miss Angela Diefenbach[3,4], Dr. Angelo Castruccio[2], Miss Lizette Bertin[1], Miss Claudia Bucarey[1]

[1]National Geology And Mining Service - Soutern Andean Volcano Observatory, Temuco, Chile, [2]University of Chile, Santiago, Chile, [3]United States Geological Survey, , United States, [4]Volcano Disaster Assistance Program, , United States

The paucity of contemporary high-silica lava flows explains the poor current knowledge about the complexity of their emplacement. However, the current eruption of NChVC has produced a complex eruptive cycle, which involves the extrusion of 8 dacitic blocky lava flows and 4 domes, being a valuable opportunity to study the emplacement of dacitic lavas through remote sensing and a robust monitoring network.

Between September 2019 and December 2021, 11 Digital Elevation Models were produced from stereo collections of aerial photographs and both Pleiades and WorldView satellite imagery to constrain lava flow volume, effusion rate and thickness. The study of flow front velocity and morphological changes was carried out by mapping a set of 21 high spatial resolution satellite images, complemented with field and overflight observations, as well as Internet Protocol (IP) and thermal cameras.

This work is focused on the longest-lived lava flow: L5. Most lava flows were active fewer than 100 days, reaching distances less than 800 m. However, L5 extruded for 14 months, reaching 1.4 km from the vent. Additionally, L5 emplacement was accompanied by the growth of a lava dome, generating a complex morphology inside the crater.

The highest velocity was achieved 30 days after the start of the extrusion, followed by a sudden decrease at rates one or two orders of magnitude lower during the next months. Finally, an increase in the flow front velocity was observed one month before the stop of the extrusion. Effusion rate values were in the range of 0.01 m3/s to 0.5 m3/s, showing a fluctuating behavior. L5 bulk volume is 6.5x106m3 and measured surface temperatures varied between 70 and 308°C.

Our work shows that a combination of careful and detailed observations together with theoretical approaches is key to improve current models of lava emplacement and volcanic crisis management plans.

1221

An assessment of potential causal links between deglaciation and volcanism at arc stratovolcanoes

Dr Chris Conway[1], Leo Pure[2], Osamu Ishizuka[1]
[1]*Geological Survey Of Japan, Tsukuba, Japan,* [2]*Department of Climate Change, Energy, the Environment and Water, Canberra, Australia*

To better understand connections between volcanism and the cryosphere, it is critical to determine whether the decompression of crustal magma systems via deglaciation has resulted in enhanced eruption rates along volcanic arcs in the middle to high latitudes. Preserved erupted materials at Pleistocene-Holocene stratovolcanoes provide archives of eruption frequency, size, and style that can be used to test whether magma generation and eruption rates have been affected by ice volume fluctuations.

We have assessed the growth histories of 36 stratovolcanoes in arc settings affected by glaciation by reviewing published radiometric ages and erupted volumes and/or compositions of edifice-forming products in the context of climate proxy records. Increased apparent eruption rates during more than one post-glacial period were shown by 4 out of 20 reviewed stratovolcanoes with available high-resolution time-volume data. For all 36 volcanoes examined, however, available evidence was unable to show that deglaciation caused increases in eruptive rates or in magma chemistry, which is partly due to limitations in those datasets.

Four common caveats were identified that hinder investigations of causality between deglaciation and increased volcanism. These are: (1) the potential for biased preservation of eruptive materials within certain periods of a volcano's lifespan; (2) the relative imprecision of geochronological constraints for volcanic products when compared with high-resolution climate proxy records; (3) the reliance on data only from immediately before and after the Last Glacial Termination (ca. 18 ka), which are rarely compared with trends throughout the Pleistocene to test the reproducibility of eruptive patterns; and (4) the lack of consideration that eruption rates and magma compositions may be influenced by mantle and crustal processes that operate independently of glacial advance/retreat. Addressing these limitations will lead to significant advances in the fields of geochronology, paleoclimatology, and eruption forecasting, and a better understanding of volcano-climate feedbacks.

258

The effect of sector collapse on the magmatic plumbing system of Oshima-Oshima volcano, NW Japan

Dr Osamu Ishizuka[1], Hajime Katayama[1], Jun Arimoto[1], Hiroaki Koge[1], Gen Shimoda[1], Yumiko Harigane[1], Ayanori Misawa[1], Kyoko S. Kataoka[2], Fukashi Maeno[3], Izumi Sakamoto[4], Yuka Yokoyama[4], Dr Chris Conway[1], Seishiro Furuyama[5]
[1]Geological Survey Of Japan, Tsukuba, Japan, [2]Niigata University, Niigata, Japan, [3]University of Tokyo, Tokyo, Japan, [4]Tokai University, Shizuoka, Japan, [5]Tokyo University of Marine Science and Technology, Tokyo, Japan

Loading and unloading of the lithosphere in volcanic settings affects the dynamics of magma generation, storage and eruption. It is critical to improve our understanding of the feedback mechanisms between changes in external forces and eruptive activity in order to interpret past volcanic histories and prepare for future hazards at active volcanoes. We conducted a multi-disciplinary study to investigate how the behaviour of magmatic systems is affected by sector collapse, using Oshima-Oshima volcano, off the western coast of NW Japan, as a case study. This volcano experienced a major sector collapse event during an eruption in 1741, which triggered a tsunami that killed about 1500 people. We studied the submarine part of the volcano and offshore sedimentary sequences by seismic reflection survey, bathymetric survey, three component magnetic survey, dredging and gravity coring. Samples were also collected during field surveys on the island, in order to integrate terrestrial and submarine volcanic records. Seismic reflection data revealed lateral variations in the thickness and structure of the deposit associated with the sector collapse. New bathymetric data has revealed the distribution and morphology of collapsed blocks in detail. Gravity core samples were successfully recovered at 12 stations. Preliminary observations indicate that tephra layers occurred frequently during and following the collapse event. Chemical and petrographical analyses of the basaltic tephra layers in these cores as well as those from subaerial exposures in the summit area of the volcano indicate that the cores record tephras erupted before and after the flank collapse event. As such, we have detected geochemical changes within a high-resolution record that can be used to investigate the evolution of the Oshima-Oshima magma system and causal mechanisms between sector collapse and volcanism during this event.

1289

Early Holocene explosive Kamchatkan volcanism cooled climate in the Northern Hemisphere

Dr Eliza Cook, Dr Johannes Lohmann[1], Dr Vera Ponomareva[2], Dr Maxim Portnyagin[3], Jiamai Lin[1], Anders Svensson[1], Michael Sigl[4], Elliott Street[5], Joseph Harrison[5]

[1]University Of Copenhagen, Niels Bohr Institute, Copenhagen , Denmark, [2]Institute of Volcanology and Seismology , , Russia, [3]GEOMAR Helmholtz Centre for Ocean Research Kiel, Kiel, Germany, [4]Climate and Environmental Physics & Oeschger Centre for Climate Change Research, University of Bern, , Switzerland, [5]Royal Holloway, University of London, , UK

The early Holocene marked a return to violent explosive volcanism across the Kamchatkan Peninsula following 15 kyrs of moderate volcanic activity and we report that the largest eruption cooled the Northern Hemisphere climate for a decade by about 1.3-1.6 oC. This inference was made through assessment of a significant negative anomaly found in multiple oxygen isotope records from Greenland. It also left its signature in the chemistry of both Arctic and Antarctic ice cores, where sulfate records show it to be among one of the largest Holocene events, surpassing the Okmok (43 BCE) and Krakatoa (1883 CE) events, both of which had an impact on human civilisations and global climate. Between 7 and 9.5 ka BP we find layers of volcanic ash (tephra) from 7 explosive eruptions in Greenland ice cores with a typical Kamchatkan geochemical composition as well as others from the northern Pacific region, including two from Japan and two from North America. Kamchatka is one of the world's most active centres of Pleistocene volcanism, yet this study reveals the regular appearance Kamchatkan tephra in Greenland ice-core records only occurred after 9.5 kyr BP. This is despite extensive screening over the Last Glacial for known Kamchatkan events during this period (e.g. Bourne et al., 2014), and alludes to a potential change in the ash deposition pathway to Greenland during the Holocene.

680

“Our volcano is active?”—Communicating volcanic hazards during ongoing unrest at Mount Edgecumbe volcanic field, Alaska

Dr Michelle Coombs[1], Cheryl Cameron[2], Ronni Grapenthin[3]
[1]USGS Alaska Volcano Observatory, Anchorage, United States, [2]Alaska Division of Geological and Geophysical Surveys / Alaska Volcano Observatory, Fairbanks, United States, [3]University of Alaska Fairbanks Geophysical Institute / Alaska Volcano Observatory, Fairbanks, United States

In April 2022, the Alaska Volcano Observatory (AVO) detected an earthquake swarm at Mount Edgecumbe volcanic field (Lingit name: L'úx Shaa). Rapid retrospective analysis showed that seismicity, as recorded on distant stations, began in 2019, and InSAR data revealed that uplift began in August 2018 and is ongoing. These signs of unrest suggest that magma is accumulating at about 10 km below the volcano. Long described as “dormant,” Mount Edgecumbe now meets AVO’s definition of an historically “active” volcano due to this unrest. This poses hazard implications for the community of Sitka, 26 km east of Mount Edgecumbe across a shallow sea channel. Sitka is accessible only by boat or plane and has about 8000 year-round residents and over 100,00 summer visitors.

When first faced with this unrest, AVO encountered multiple communication challenges: assessing and communicating the current activity at an unmonitored volcano; putting low-probability, high-hazard past events, such as early Holocene eruptions that deposited 1 m of tephra on Sitka, in the appropriate context; establishing AVO as the authority for information to a population unused to considering active volcanism; and correcting misinformation. Communication strategies included timely information statements, numerous interviews with local media outlets, and community question-and-answer sessions organized in collaboration with local partner organizations. To calm fears, AVO appealed to individuals’ experiences with previous eruptions elsewhere, reminded people that they are already taking mitigation measures for other hazards, such as landslides and tsunami, and implemented and communicated plans to increase monitoring. AVO continues to communicate about Mount Edgecumbe monitoring and activity through personal connections in the community, social and traditional media platforms, and partnerships with other agencies and institutions, including the US Forest Service and the Sitka Sound Science Center.

1064

Data management at the Alaska Volcano Observatory

Dr Michelle Coombs[1], Cheryl Cameron[2], David Fee[3]
[1]USGS Alaska Volcano Observatory, Anchorage, United States, [2]Alaska Division of Geological and Geophysical Surveys / Alaska Volcano Observatory, Fairbanks, United States, [3]University of Alaska Fairbanks Geophysical Institute / Alaska Volcano Observatory, Fairbanks, United States

The Alaska Volcano Observatory (AVO) has three primary objectives: conduct monitoring and other scientific investigations to assess the nature, timing, and likelihood of volcanic activity in Alaska; assess volcanic hazards associated with anticipated activity; and provide timely and accurate information on volcanic hazards and warnings of impending dangerous activity to local, state, and federal officials. In support of these goals, AVO builds and maintains extensive networks of geophysical monitoring equipment, has a robust satellite data monitoring effort, and has also curated a broad geologic database for Alaska volcanoes. AVO is a joint program of three agencies: the US Geological Survey, the University of Alaska Fairbanks Geophysical Institute, and the State of Alaska Division of Geological & Geophysical Surveys. Our data management solutions must be available and usable by each partner agency, and we are also making progress in rapidly exposing both raw and interpreted data to the public and other researchers. In 2022 AVO completed a multi-year effort to convert all of our field monitoring stations and telemetry from analog to digital data (A2D). AVO now maintains more than 220 fully digital, remote monitoring stations that transmit a host of geophysical data in real-time—primarily seismic, but increasingly also including infrasound, geodetic, webcam, and gas data. This presentation covers the production, transmission, archiving, querying, and accessibility of AVO's data. We begin with collection and telemetry of geophysical, satellite, and geologic data, continue to analysis and interpretation at AVO's offices (located hundreds to thousands of kilometers from Alaska volcanoes), and finish with where and how data are aggregated on AVO's internal platforms and swiftly stored in publicly accessible databases. We also discuss challenges and opportunities with emerging data-management solutions.

488

Magma Reservoir Response to Ice Unloading: Applications to Volcanism in the West Antarctic Rift System

Ms Allie Coonin[1,2], Dr. Christian Huber[2], Dr. Juliana Troch[3,4], Dr. Meredith Townsend[5], Kathryn Scholz[5]
[1]University of California-Berkeley Department of Earth and Planetary Science, Berkeley, United States, [2]Brown University Department of Earth, Environmental, and Planetary Sciences, Providence, United States, [3]Department of Mineral Sciences, Smithsonian National Museum of Natural History, , United States, [4]Division of Earth Sciences and Geography, RWTH Aachen University, Aachen, Germany, [5]University of Oregon Department of Earth Sciences, Eugene, United States

While effects of volcanism on Earth's short- and long-term climate conditions are fairly well understood, the volcano-ice system is a two-way feedback. Magmatic activity contributes to glacial retreat, which in turn affects the internal dynamics of the magma chamber below. In the age of anthropogenic climate change, accurate forecasts of sea level rise require taking into consideration subglacial volcanoes and their role in this feedback loop. The West Antarctic Ice Sheet is particularly vulnerable to collapse as the bedrock is situated below sea level, but its position atop an active volcanic rift is seldom considered. Ice unloading above a volcanic system raises the geotherm and alters the crustal stress field, impacting dike propagation. However, impacts of ice unloading on internal magma chamber dynamics and thus long-term eruption behavior remain unclear. Given the potential for unloading-triggered volcanism in the West Antarctic Rift System to further expedite global sea level rise, we reparametrized the thermo-mechanical magma chamber model from Degruyter and Huber (2014) for West Antarctic Rift basalts and simulate a shrinking ice load at the surface with a prescribed decrease of lithostatic pressure over time. We investigate the effect of different rates and magnitudes of lithostatic pressure decrease on volatile partitioning within the magma and eruptive trajectory across a wide range of magma chamber conditions. Pressurization of a magma chamber beyond a critical threshold results in eruption to the surface, rapidly introducing enthalpy to the ice sheet base. We model several scenarios of ice unloading to determine the regimes in which magma chambers are most sensitive to unloading-induced perturbations and find that the rate of unloading serves as the primary control on the cumulative mass erupted and thus the enthalpy released to the ice-rock interface. These findings provide insights into complex volcano-ice interactions in West Antarctica and other subglacial volcanic settings.

806

When do caldera systems produce large eruptions? Insights from the geochemistry of volcanic crystals

Professor Kari Cooper[1], Ms Elizabeth Grant[1], Dr. Tyler Schlieder[1], Professor Adam Kent[2], Professor Darren Gravley[3], Professor Chad Deering[4]

[1]University Of California Davis, Davis, United States, [2]Oregon State University, Corvallis, United States, [3]University of Canterbury, Christchurch, New Zealand, [4]Michigan Technological University, Houghton, United States

Caldera-forming eruptions are rare events but can represent a global catastrophe. The volume of eruptions may be influenced by many factors including triggering mechanisms, magma supply changes, tectonic influences, and the architecture of the subvolcanic reservoir. Caldera systems often produce many smaller intracaldera eruptions between caldera-forming events, raising the question of what controls whether a caldera system will produce a large eruption or a smaller eruption at any given time: do large eruptions require more time to develop a large magma body? Do they sample a broader region of the subsurface? Here we examine differences in the compositional heterogeneity and the thermal storage conditions of magmas feeding intracaldera vs. caldera-forming eruptions over the most recent caldera cycles at the Taupō Volcanic Center and the Okataina Volcanic Center, New Zealand.

We find that: 1. The majority of time scales of high-temperature storage of individual plagioclase crystals derived from modeling intracrystalline diffusion of Sr are not significantly different for eruptions of different size; 2. Zircon and plagioclase trace-element compositions of grain interiors show varying degrees of heterogeneity, but the caldera-forming eruptions do not show systematically more compositional diversity; and 3. Independent of eruptive volume, analyses of zircon and plagioclase crystal rims are more restricted in composition than the corresponding interiors, in some cases showing multiple compositional groups. These data suggest that the accumulation of large bodies of magma in the subsurface does not require sampling systematically more diverse material from a crystal mush, and that they accumulate and are stored prior to eruption for similar time scales as smaller eruptions. This in turn requires a model for generation of caldera-forming eruptions that relies on other factors, and that subsurface processes that mix crystals of different origins lead to similarly heterogeneous crystals over a wide range of volumes sampled.

529

Subduction erosion and arc magmatism: new insights from the Taupo Volcanic Zone and Hikurangi forearc from Sr-Pb-Nd-Hf isotopic systematics

Mr Carlos Corella Santa Cruz[1], Dr Georg F. Zellmer[1], Dr Susanne M. Straub[2], Dr Claudine H. Stirling[3,4], Dr Malcolm Reid[3,4], Dr Candace Martin[4], Dr Marco Brenna[4], David Barr[3,4], Dr Károly Németh[1,5,6]
[1]Volcanic Risk Solutions, Massey University, Palmerston North, New Zealand, [2]Lamont-Doherty Earth Observatory of Columbia University, Palisades, NY , United States of America, [3]Centre for Trace Element Analysis, University of Otago, Dunedin, New Zealand, [4]Department of Geology, University of Otago, Dunedin, New Zealand, [5]Saudi Geological Survey, Jeddah, Kingdom of Saudi Arabia, [6]Institute of Earth Physics and Space Science, Sopron, Hungary

Forearc crust removed by 'subduction erosion' from the underside of the upper plate has been recognized as an important and potentially dominant contributor to the recycled flux in global arc magmas. While not all arcs are equally influenced by subduction erosion, a flux of recycled eroded crust to arc is likely for settings where asperities like plateaus, ridges or seamounts are subducted at the trench. This is the case for the Hikurangi portion of the Tonga-Kermadec-Hikurangi trench system, where the 120 Ma oceanic Hikurangi Plateau has been subducting since ~10 Ma.

Geophysical data provide evidence for forearc erosion in the Hikurangi segment east of the North Island of New Zealand, such as strike-slip and compressional faulting from seamount collisions followed by collapse of the upper plate. The 2 Ma old Taupo Volcanic Zone (TVZ), where arc volcanism is linked to the subduction of the Hikurangi Plateau, has a high proportion of rhyolites (>95% total erupted volume) compared to mafic members (<1%). Moreover, the TVZ is constructed on relatively thin (16-30 km) basement composed of Permian-Cretaceous accretionary clastic terranes.

Results from mass- and energy-constrained MCS modelling show that the evolution of TVZ basalts to rhyolites is inconsistent with extensive AFC processes. Therefore, we tested the hypothesis that the silicic TVZ magmas may be linked to the tectonic erosion of the forearc crust at the Hikurangi margin. A new set of high-quality Sr-Pb-Nd-Hf isotope data of the TVZ mafic to silicic volcanic rocks as well as forearc and trench lithologies reveal the existence strong compositional links, whereby the tight TVZ isotopic array is best explained by binary mixing between the mantle wedge and tectonically eroded forearc. Thus, our data indicate crustal recycling via subduction erosion emerges as a viable alternative to AFC processes to explain the silicic TVZ volcanic rocks.

1281

Pyroclastic Density Currents overcoming obstacles: Insights from experimental simulations

Mr Lucas Corna[1], Prof. Gert Lube[1], Dr. Ermanno Brosch[1], Mr. Daniel Uhle[1], Prof. Jim Jones[2], Mr James Ardo[1]
[1]School of Agriculture and Environment, Massey University, Palmerston North, New Zealand, [2]School of Food and Advanced Technology, Massey University, Palmerston North, New Zealand

The interactions of Pyroclastic Density Currents (PDCs) with topography remain an enduring uncertainty in volcanic hazard models. We simulated the propagation of dilute PDCs over hill-shaped obstacles in large-scale experiments and measured the spatiotemporal variation in flow velocity, density, temperature and deposition across flow runout lengths of up to 30 m. We varied the size of obstacles relative to the boundary layer thickness of the PDCs, while keeping their shape and the experimental input conditions unchanged.

We observe four phases of PDC-obstacle interaction linked to the flow structure comprising a head, proximal body, distal body and tail: (1) compression and acceleration on the stoss side, with flow detachment, expansion and deceleration occurring on the crest and lee side; (2) formation of a turbulent jet above the lee side separating a hot, dense, fast flow above a cold, dilute, slow wake; (3) increasing flow density destabilizing the boundary layer separation above the lee side; (4) flow deceleration and rotation of the velocity field, leading to the disappearance of the wake.

Downstream of the obstacles, the flows have lost up to c. 74 % or their initial momentum due to partial blocking of the dense underflow (which accounts for nearly half of the total momentum). The dilute turbulent parts of the PDCs have also lost between c. 25 and c. 50 % or their initial momentum with increasing obstacle size. These results suggest that dilute PDCs cannot cross obstacles that are c. 5.5 time higher than the thickness of their boundary layer (c. 1.5 times higher than the body height).
Computing ballistic trajectories produces comparable reattachment distances than those measured for the largest obstacle. However, we observe further reattachment than calculated for smaller obstacles, suggesting that some processes occur inside the wake allowing it to stay stable for longer distances.

353

Volcanic ash, ice and SO2 real time retrievals using MSG-SEVIRI during the 2020-2022 lava fountains sequence at Mt. Etna

Dr Stefano Corradini[1], Dr. Lorenzo Guerrieri[1], Dr. Luca Merucci[1], Dr. Dario Stelitano[1]
[1]*Ingv, Rome, Italy*

Mt. Etna is one the most active volcano of the world and one of the strongest sources of SO2 during and between eruptions. On 13 December 2020, after about 18 months of eruptive pause, the volcano entered in a new phase characterized by several lava fountain episodes all produced from the New Southeast Crater (NSEC). In this phase, which lasted until 21 February 2022, 60 episodes of lava fountains occurred. This persistent activity had a strong impact on population (health, viability and roof stability), environment (agriculture and water contamination) and air traffic (the Catania airport is a major international hub).
In this work the 2020-2022 Etna lava fountains sequence have been monitored in real time with the Spinning Enhanced Visible and InfraRed Imager (SEVIRI) instrument on board Meteosat Second Generation (MSG-4, Meteosat-11) geostationary satellite. The SEVIRI images have been processed in order to compute plume and volcanic cloud height, total mass and fluxes of ash, ice and SO2. In particular for the high altitude clouds, a strong formation of volcanic ice particles has been observed. The SEVIRI products are then been cross-compared with those obtained by MODIS and TROPOMI on board the polar NASA-Terra/Aqua and ESA-Sentinel 5p satellites respectively.

Results confirm the high variability of phenomena with volcanic cloud emissions height that varies between 4 and 14 km, ash/SO2 between 0.5 and 100 kt and strong ice formation that reach values greater than 100 kt. The results confirm also the ability of geostationary satellite systems to characterize eruptive events from the source to the atmosphere, in near real time during day and night, thus offering a powerful tool to mitigate volcanic risk on both local population and airspace and to give insight on volcanic processes.

548

The 2021 paroxysmal activity of the South–East Crater (Mt. Etna) as revealed by geochemical data and Sr-Nd isotopes

Dr Ilenia Arienzo[1], Dr Rosa Anna Corsaro[2], Dr. Valeria Di Renzo[3], Dr Lucia Miraglia[2]
[1]Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Vesuviano, Napoli, Italy, [2]Istituto Nazionale di Geofisica e Vulcanologia, sezione di Catania, Osservatorio Etneo , Catania, Italy, [3]Dipartimento di Scienze della Terra, dell'Ambiente e delle Risorse, Università degli Studi di Napoli Federico II, Napoli, Italy

The South-East Crater of Etna (SEC) is the most active summit crater over the last 20 years, showing periods of lava effusion interspersed with Strombolian explosions up to lava fountains. The volcanic activity of the SEC showed increasing intensity throughout 2020 and, starting from December to the end of January 2021, four paroxysmal episodes took place. A sequence of 17 episodes started on 16 February and concluded on 1 April; a new sequence began on 19 May and, up to 23 October, produced 36 new episodes, whose frequency has decreased since August 2021.

The 2020-21 eruptive activity has been monitored by the INGV-OE with instrumental networks, field surveys and laboratory analyses. In particular, the petrological monitoring has focused on lapilli and ash erupted during all the episodes, by measuring the major elements composition of the volcanic glass containing less than 15% microlites, assuming that it is representative of the pre-eruptive magma composition.
In order to strength the findings of syn-eruptive petrologic monitoring, we also analyzed the mineral chemistry, the whole rock composition (major and trace elements), as well the Sr-Nd isotopes of selected paroxysms and carried out petrologic modelling to constrain the chemical–physical environment of the pre-eruptive magmatic processes. Such detailed data allowed us to track the evolution of magma, episode by episode, and to hypothesize the subsurface magmatic processes responsible for the observed compositional variations.

Our results integrated with the findings of ground deformation, seismicity, as well as gas composition, allowed us to get insights into the magmatic processes responsible for the compositional variations. Once the subsurface processes have been recognized, a stimulating future challenge is to understand how subsurface magma dynamics affect the volcanological features and the timing of the periodic lava fountains at Etna.

549

The Cyclopean Islands (Acitrezza, Catania): a key point to interpreter the early stage of Mt. Etna volcanism.

Dr Rosa Anna Corsaro[1], Dr Stefano Branca[1], Dr. Gianfranco Di Vincenzo[2], Dr Lucia Miraglia[1]
[1]Istituto Nazionale di Geofisica e Vulcanologia, sezione di Catania, Osservatorio Etneo, Catania, Italy, [2]Istituto di Geoscienze e Georisorse, CNR, Pisa, Italy

The small archipelago of the Cyclopean Islands is located a few kilometres north of Catania and consists in two main islands (Lachea and S. Maria) and a few smaller stacks. Lachea and Faraglione Grande consist of columnar basalts that have previously been interpreted as the remnants of a subvolcanic sill intruded into the Pleistocene marly claystone of the old sea bottom. The sill is currently located at the sea level due to the regional uplift of East Sicily, but widely extends also underwaterater (Chiocci et al., 2011). Following the 'Geological map of Etna volcano' (Branca et al., 2011), the Cyclopean Islands and the outcrops of the surroundings (Acitrezza-Acicastello-Ficarazzi area) belong to the Basal Tholeiitic phase (~600-320 ka), the oldest of Etna stratigraphic succession.

Although the Cyclopean Islands have been fairly well-studied, a few intriguing scientific issues are still open because. Indeed, they have not been dated until now and are not tholeiitic, but mostly transitional towards terms of Na-alkaline serie (Corsaro and Cristofolini, 1997), probably more akin to the products of the subsequent Timpe phase (220-110 ka) of Etna.

To better constrain the stratigraphic position and role of Cyclopean Islands in the evolution of Etna magmatism, we have: i) carried out a geological survey of Lachea Island and its surroundings; ii) collected 25 samples of the most significant outcrops; iii) dated with 40Ar/39Ar selected samples of Lachea Island; iv) analysed major and trace elements of bulk rock and the mineral chemistry of selected samples belonging to the Timpe phase too.

The results have allowed us to refine the position of the Cyclopean Islands into the stratigraphic succession of Etna and to deepen the transition from tholeiitic to alkaline magmatism at Etna, occurring in a period of the volcano's history that is scarcely studied if compared to the present.

772

A simple two-state model interpreting temporal modulations in eruptive activity and enhancing multi-volcano hazard quantification

Dr Jacopo Selva[1], Dr Laura Sandri[1], Dr Matteo Taroni[2], Prof. Roberto Sulpizio[3], Dr Pablo Tierz[4], Dr Antonio Costa[1]

[1]Istituto Nazionale di Geofisica e Vulcanologia, Bologna, Italy, [2]Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy, [3]Università di Bari, Bari, Italy, [4]British Geological Survey, Edinburgh, United Kingdom

Volcanic activity tends to switch between high-activity states with many eruptions, and low-activity states with few or no eruptions. We present a simple two-regime physics-informed statistical model that allows interpreting temporal modulations in eruptive activity, enhancing the comprehension and comparison of different volcanic systems. The model satisfactorily fits the eruptive history of the three active volcanoes in the Neapolitan area, Italy (Mt. Vesuvius, Campi Flegrei, and Ischia), which encompass a wide range of volcanic behaviors. This also enables the homogeneous integration of multiple volcanoes into multi-volcano hazard assessments, accounting for potential changes in volcanic regimes. The results show that the three volcanoes have significantly different processes for triggering and ending high-activity periods, with different characteristic times and activity rates (expressed as number of eruptions per time interval) connected to different dominant volcanic processes controlling their eruptive activity. Presently, all three volcanoes are judged to be in a low-activity state, with decreasing probability of eruptions for Mt. Vesuvius, Ischia and Campi Flegrei, respectively.

1329

Insights into volcanic processes through satellite based measured sulphur dioxide and thermal emissions: Manam Volcano, Papua New Guinea

Mr Adam Cotterill[1], Dr Emma Liu[1], Professor Christopher Kilburn[1], Dr Catherine Hayer[2], Mr Kila Mulina[3], Ima Itikarai[3]
[1]University College London, London, United Kingdom, [2]EUMETSAT, , Germany, [3]Rabaul Volcanological Observatory, Rabaul, Papua New Guinea

Manam is one of the most frequently active volcanoes in Papua New Guinea. Volcanic activity ranges from lava effusions to explosive ash-rich eruptions (up to VEI 4), with strong outgassing from both summit craters persisting throughout inter-eruptive periods. In recent years, this activity has produced multiple volcanic hazards including pyroclastic density currents, tephra fall, lava flows and lahars. Since the 2004-05 sub-Plinian eruption, a further 24 major eruptions (>10 km eruption column), 128 minor explosive episodes and 7 effusive phases have occurred.

Manam is monitored continuously by a local observer and the national seismometer network, through the Rabaul Volcanological Observatory, but challenging terrain and elevated volcanic activity have so far precluded the widespread installation of multi-parametric monitoring equipment. Here we analyse spaceborne remote sensing datasets to derive SO_2 mass loading (Sentinel-5P/TROPOMI) and thermal emissions (MODVOLC). Four phases of SO_2 degassing have been identified with total emissions of 668 kt during phases 2 and 3 (March to July 2019), comprising 47% of the total SO_2 mass emission during the study period (2018 – 2021). We calculate a time-averaged emission rate of 4.7 kt day-1 in the 3 months prior to the 28th June 2019 major eruption, compared to ~0.6 kt day-1 outside of this period. Using these timeseries, we constrain the gas and magma budgets to understand the conduit processes that modulate open-vent behaviour at Manam. The average ratio between SO_2 and radiant flux is 124.2, much greater than the estimated range representing “balanced” SO_2 and thermal emissions of 3.2-21.6. This indicates that the volume of magma required to produce the observed SO_2 emissions exceeds that reaching the near-surface and contributing to the thermal radiance. This suggests a requirement for conduit convection, decoupled ascent of deep-derived fluids, or both, to sustain persistent outgassing at Manam and fuel explosive activity.

1327

Probabilistic Tephra Dispersal Modelling at Manam Volcano, Papua New Guinea

Mr Adam Cotterill[1], Dr Emma Liu[1], Professor Christopher Kilburn[1]
[1]*University College London, London, United Kingdom*

Tephra fall during volcanic eruptions have large hazard footprints and can affect populations many hundreds of kilometres away from the volcanic source. While small thicknesses of pyroclastic material (0.1-10 mm) can damage crops and agricultural land, obstruct transportation networks and contaminate water sources, greater thicknesses (10-1000 mm) can cause structural damage to buildings and roofs, and impair communication infrastructure. Manam is one of the most frequently active volcanoes in Papua New Guinea and since the 2004-05 sub-Plinian eruption, 24 major eruptions (>10 km eruption column) and 128 minor explosive episodes have occurred. Tephra fall, and post-eruptive remobilisation, therefore represents a frequent and far-reaching hazard at Manam, causing disruption to both local and regional communities. Here, we use the open-source TephraProb software to simulate tephra dispersal and deposition for a range of eruptive scenarios during both dry and wet seasons (April-October and November-March, respectively). These scenarios are based on historical activity at Manam; from short-lived (0.5-3 hours) ash-venting events with low plume altitudes to more protracted (10-15 hours) sub-Plinian eruptions with injection heights up to 25 km. We relate probabilistic mass accumulation estimates to thickness-defined impact factors to quantify the potential impacts on buildings, infrastructure and agriculture for each scenario. Preliminary results suggest that the northern coast of Manam Island has a reduced probability of ash accumulation compared to the rest of the island during low intensity (most frequent) scenarios. However, larger eruptions appear to produce more radially symmetrical footprints on Manam. We also find evidence for a seasonal influence: during the dry season the potential tephra footprint extends further towards the west than during the wet season, where the footprint is relatively symmetrical, consistent with seasonal variations in prevailing wind speeds and directions. It is therefore more probable that major eruptions occurring between April and October may impact mainland infrastructure.

1200

A global volcanic vulnerability model stocktake to inform future volcanic risk research

Dr Rebecca Fitzgerald[1,2,3], Professor Thomas Wilson[1], Dr Joshua Hayes[2], Dr Alana Weir[1], Dr James Williams[1], Miss Emma Coultas[1]

[1]School of Earth and Environment, University Of Canterbury, Christchurch, New Zealand, [2]GNS Science, Avalon, New Zealand, [3]Massey University, Palmerston North, New Zealand

Vulnerability models are being increasingly utilised by the volcano community to assess how susceptible societal elements are to volcanic hazards. Vulnerability models now cover many different societal elements and hazards, however, to date no assessment of existing models has been undertaken to identify where research has been focussed and where gaps and limitations may lie. We summarise a stocktake of available volcanic vulnerability models globally.

We identified 210 volcanic vulnerability models, covering buildings, critical infrastructure, transport, three waters, electricity, telecommunications, agriculture, humans, forestry, non-water pipelines, clean-up and society. Of these sectors and elements, buildings have the most available volcanic vulnerability models (26%). The vulnerability models covered many volcanic hazards including ashfall, volcanic ballistic projectiles, lahar, gas, lava flow, pyroclastic density currents, edifice formation, hydrothermal eruptions, volcanic earthquakes, volcanic hazards (in general), and volcanic-induced tsunamis. Ashfall has the most dedicated vulnerability models with 52%. The majority of models identified are threshold and function-type models, though ratios, indexes, percentages and qualitative indicators are also used. We identified 21 different risk metrics, with damage and loss of service overwhelmingly utilised. Hazard intensity metrics also varied across the reviewed models, with many hazards having multiple metrics - fifteen different HIMs were identified for ashfall.

This stocktake also highlighted that volcanic vulnerability models do not exist for many hazards, societal elements and types of vulnerability. There is also an absence of multi-hazard and multi-phase vulnerability models and a general lack of consideration of element quality in models. We provide some commentary to guide future research directions and prioritisation. Whilst there has been considerable advances in the volcano vulnerability model development space over the last few decades, challenges still remain. It is important that the momentum built in this field continues.

1239

Enhancing volcanic evacuation resilience in the Taranaki region

Miss Emma Coultas[1], Professor Thomas Wilson[1], Dr Alana Weir[1], Dr Thomas Robinson[1], Ms Teresa Gordon[2,3], Dr Sarah Gauden-Ing[2]

[1]School of Earth and Environment, University of Canterbury, Christchurch, New Zealand, [2]Taranaki Emergency Management Office, Taranaki, New Zealand, [3]Ministry for Primary Industries, , New Zealand

A volcanic eruption from Taranaki Mounga is a potential risk to life, well-being, and several nationally significant economic sectors. There is a 33-42% likelihood of a volcanic eruption at Taranaki Mounga within the next 50 years. Evacuation is a key volcanic risk management strategy to protect life. Effective evacuations are typically underpinned by robust and inclusive planning. However, many existing evacuation plans are informed solely by volcanic hazard assessments, consider only static population models, and lack community involvement/take a ‘top down’ approach. A large body of research and practice findings suggest it is better to take a risk-based, participatory approach, which considers the dynamic evolution of an evacuation.

This research looks to address several of these aspects. It aims to 1) develop a dynamic population model for the Taranaki region to inform more realistic evacuation planning in the event of a volcanic crises at Taranaki Mounga; 2) explore evacuation dynamics through long-duration volcanic crises, including considering social, cultural and economic well-being, as well as life-safety; and 3) develop a methodology to identify areas within the Taranaki region that are vulnerable to physical isolation due to direct volcanic- and indirect evacuation-impacts. This research will hopefully contribute to informing more effective evacuation planning. The research is being undertaken in partnership with Taranaki Emergency Management Office, as part of the He Mounga Puia | Transitioning Taranaki to a Volcanic Future research programme.

966

Geochemistry and volatile contents of volcanic glass from the offshore TVZ – southern Havre Trough

Robert Coulter[1], Dr Alex Nichols[1], Dr Richard Wysoczanski[2]
[1]University Of Canterbury, Christchurch, New Zealand, [2]National Institute of Water and Atmospheric Research (NIWA), Wellington, New Zealand

The Taupō Volcanic Zone (TVZ) and Kermadec Arc-Havre Trough, stretching north from Te Ika-a-Māui/North Island of Aotearoa/New Zealand, are expressions of subduction-generated magmatism. Volatiles (H2O, CO2, S, Cl, and F) are well-known to be one of the main drivers behind volcanic eruptions, especially in subduction-related melts. Thus, understanding how volatiles behave in the melt can help us understand processes occurring within volcanic systems. However, little to no data are available on the geochemistry and volatile contents of the volcanic features found in the offshore TVZ – Havre Trough region.
To determine volatile contents in this system we have analysed glassy samples collected from dredges undertaken during the 2015 TAN1315 voyage of R/V Tangaroa. Samples were collected from the Tūhua/Mayor Island knolls, Matatara Knoll and surroundings, and Māhina Knoll and surroundings in the offshore TVZ in addition to a basin in the southern Havre Trough. The dredging returned an array of material, but of interest to this study was glass from pumice from the offshore TVZ and pillow lavas from the Havre Trough.

Volatile contents of erupted material may not reflect the original magmatic contents with pre- and post-eruption processes altering the volatile concentrations. Degassing, secondary hydration, brine assimilation and fractional crystallisation processes can significantly alter volatile contents. H2O and CO2 were measured in these samples using Fourier-transform infrared spectroscopy, and major elements, S, Cl, and F were measured by electron microprobe. These processes will be evaluated and, if necessary, volatiles corrected to be used in solubility models (e.g., TBD) to assess degassing and volatile saturation in the samples. These will be some of the first volatile and major element data from these sites, enabling post-eruption and magmatic processes that affect the volatiles to be assessed.

1232

Trace element compositions of orthopyroxene antecrysts sampled during the proto-arc phase of magmatism along the Izu-Bonin-Mariana arc

Dr Daniel Coulthard Jr[1], Professor Georg F. Zellmer[2], Dr Raimundo Brahm[3], Professor Takeshi Kuritani[4], Professor Mark K. Reagan[5], Dr Naoya Sakamoto[6], Dr Takashi Sano[7], Dr Kenichiro Tani[7], Professor Hisayoshi Yurimoto[4,6]

[1]Volcano Science Center, US Geological Survey, Menlo Park, United States, [2]Volcanic Risk Solutions, Massey University, Palmerston North, New Zealand, [3]School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand, [4]Department of Earth and Planetary Sciences, Graduate School of Science, Hokkaido University, Sapporo, Japan, [5]Department of Earth and Environmental Sciences, University of Iowa, Iowa City, United States, [6]Creative Research Institution, Hokkaido University, Sapporo, Japan, [7]Department of Geology and Paleontology, National Museum of Nature and Science, Tsukuba, Japan

The Izu-Bonin-Mariana intraoceanic arc system was generated following subduction initiation along the proto-Philippine Plate - Pacific Plate boundary beginning c. 52 Ma. During the subsequent 2 Myr, abundant crust was generated at a suprasubduction zone ridge, a majority of which is preserved in the modern forearc including both fore-arc basalt and boninite extrusives. Boninite volcanism persisted along the margin until c. 45 Ma, constituting the proto-arc phase of magmatism. Primitive boninite products sampled by on-land surveys, oceanic dredging/diving, and DSDP/ODP/IODP drilling are similar; dominated by orthopyroxene macrocrysts (± olivine) set in a glassy matrix. Boninites are subdivided into low silica- (LS-) and high silica boninites (HSBs). LSB erupted before 51.3 Ma and were followed by HSB eruptions along the entirety of the tectonic margin lasting from 51.3 to c. 46-43 Ma. As volcanism migrated away from the trench, extrusive rocks became dominated by "normal" arc volcanics.

Here we detail the compositions of orthopyroxene macrocrysts separated from HSBs and derivative high-magnesium andesite rocks recovered from the Mariana fore-arc (near Guam), Chichi-jima, Ani-jima, the submarine portion of the Bonin Ridge and the nearby trench slope (sampled by Shinkai 6500 diving and IODP Expedition 352, respectively), and the Izu fore-arc (sampled during ODP Leg 125). Orthopyroxene H concentrations for these samples are similar, ranging from 83-151 µg/g H2O. Major element and trace transition metal (Sc, V, Ni, Cr, Co) concentrations in orthopyroxene were used to delineate relationships between the sub-volcanic reservoirs sampled at each locality and across time during the proto-arc phase of magmatism. Orthopyroxene macrocrysts were last equilibrated with trace element rich melts with similar carrier melt compositions, establishing a laterally continuous geochemical reservoir. This reservoir was consistently hydrous and produced HSB volcanism for c. 7 Myr during proto-arc magmatism owing to the consistent migration of hydrous melts to the nascent arc.

540

Modelling ashfall impacts to agriculture, buildings and health for Tanna: a comparison of published vulnerability models and field survey thresholds

Heather Craig[1], ShengLin Lin[2], Juli Ungaro[3], Johnny Tarry Nimau[4], Alec Wild[5], George Williams[6]
[1]NIWA, Riccarton, New Zealand, [2]GNS Science, Lower Hutt, New Zealand, [3]NIWA, Evans Bay, New Zealand, [4]Department of Climate Change, Government of Vanuatu, Port Vila, Vanuatu, [5]Aon New Zealand, Auckland, New Zealand, [6]Verisk, , Singapore

The population and infrastructure of Tanna Island (Vanuatu) receives frequent volcanic ashfall deposits from Yasur volcano, located in the islands southeast. This impacts the island in several ways, namely through respiratory and health effects for humans, crop yield losses, and building componentry damage.

Community workshops with village leaders and local authorities, and individual questionnaires were used to develop impact thresholds linking ashfall thickness to a qualitative description of the impacts to agriculture, buildings, and human health. These were then compared using four eruption scenarios to published vulnerability models for agriculture and buildings, and previous event and experimental data for human health. This showed that the field survey derived impact thresholds underestimated the severity of impacts for agriculture and overestimated impacts for buildings. This result demonstrates the influence of local factors in determining impacts, where it is likely that buildings have become more resilient over successive ashfall events as components easily damaged by ash are not replaced and more resistant materials are selected. Conversely, published agricultural vulnerability models have been developed with a focus on larger scale commercial farming operations as opposed to the more vulnerable small holdings that typify farming on Tanna.

Case studies such as this demonstrate that whilst generalised vulnerability and impact models have some utility in risk communication, emergency management, and insurance modelling; for high-risk areas, location-specific approaches are needed. These need to consider detailed environmental differences, volcanological characteristics, building construction types, and farming methods to allow for better emergency planning and targeted, cost-effective mitigation methods to be employed.

1205

Probabilistic Volcanic Ash Forecasting for Aviation

Dr Alice Crawford[1], Dr. Tiafeng Chai[1,2], Dr. Michael Pavolonis[3], Dr Justin Sieglaff[4], Jamie Kibler[5], Dr. Binyu Wang[6,7]

[1]NOAA Air Resources Laboratory, College Park, United States, [2]Cooperative Institute for Satellite and Earth System Studies (CISESS), College Park, United States, [3]NOAA National Environmental Satellite, Data and Information Service (NESDIS), Madison, United States, [4]Cooperative Institute for Meteorological Satellite Studies (CIMSS), Madison, United States, [5]NOAA National Environmental Satellite, Data and Information Service (NESDIS), College Park, United States, [6]IM Systems Group, Rockville, United States, [7]NOAA National Centers for Environmental Prediction, Environmental Modeling Center, College Park, United States

We present highlights of recent efforts to design an operational workflow to produce probabilistic and quantitative volcanic ash forecasts for aviation. The work utilizes the HYSPLIT atmospheric transport and dispersion model for, NOAA's global ensemble forecast system (GEFS), and observations from the VOLcanic Cloud Analysis Toolkit (VOLCAT). It includes source determination using an inversion algorithm, data insertion methods, and forecast verification of the probabilistic forecasts.

1414

Extreme explosivity of the 15 January 2022 Hunga eruption, Tonga, driven by magma-mixing, caldera collapse and magma-water interaction

Professor Shane Cronin[1], Taaniela Kula[2], Ingrid Ukstins[1], Frank Ramos[3], Joali Paredes-Marino[1], Sung-Hyun Park[4], James White[5], Rachel Baxter[5], Marco Brenna[5], Alexa van Eaton[6], Jose Borrero[7], Sam Purkis[8], Steven Ward[9], David Adams[1], Folauhola Helina Latu'ila[2], Pupunu Tukafu[2], Geoff Kilgour[10], Simon Barker[11], Larry Mastin[6], Michael Pavolonis[6]

[1]The University Of Auckland, Auckland, New Zealand, [2]Tonga Geology Services, Nukualofa, Tonga, [3]New Mexico State University, Las Cruces, USA, [4]Korean Polar Research Institute, Incheon, Republic of South Korea, [5]Otago University, Dunedin, New Zealand, [6]The United States Geological Survey, Vancouver, USA, [7]East Coast Lab, Gisborne, New Zealand, [8]University of Miami, Miami, USA, [9]UC Santa Cruz, Santa Cruz, USA, [10]GNS Science, Wairakei, New Zealand, [11]Victoria University of Wellington, Wellington, USA

Hunga Volcano (Tonga) is a ~6 km-diameter caldera up to 140-150 m below sea level. Surtseyan eruptions in the last 40 years occurred along caldera ring faults. The latest eruption sequence began on 20 Dec 2021, near the 2014-15 vent. On 14 January 2022 a >20 km-high plume formed and was followed by 18 hours of harmonic sea-level disturbance. The climactic event on 15 Jan had a peak eruption rate of ~109 kg/s, producing global air-pressure waves, tsunami and a >55 km-high eruption column. The bulk pumice composition was similar to past events: 56-57 wt% SiO2 andesite. Mingled, phenocryst- and microlite-poor glass spans 50-66 wt% SiO2 over scales of microns to millimeters. Up to ~10% volcanic/hydrothermal xenoliths are present. The roughly concentric fall deposit 65-100 km on land and sea is poorly sorted and fine-grained (4-7 wt% >1 mm). Juvenile clasts are dense (>2.7 g/cm3), with isolated and collapsed vesicles. A sparse basal layer of scoria lapilli (up to 50 mm) fell first (densities of 0.8-2.0 g/cm3). Over 70% of fine particles show hackle lines, stepped fractures, and conchoidal fractures. Geochemical and isotopic data suggests that the eruption was triggered by immiscible magma mixing between two andesitic melts. The mixing likely drove intense gas pressurization of the magmatic and hydrothermal system. As the hydrothermal seal catastrophically failed, rapid decompression and fracturing led to runaway magma rise and interaction with seawater infiltrating the edifice. Intense magma-water and magmatic-gas driven explosions generated tsunami within 35 min of the climactic eruption, but sudden caldera collapse possibly triggered another tsunami, ~1 20 min later, with a final tsunami and eruptive pulse ~4 hours later. The total caldera collapse during involved at least 6.5 km3 of volume change.

1417

Changes to the summit of Hunga volcano during the 15 January 2022 eruption

Professor Shane Cronin[1], Marta Ribo-Gene[2], Soenke Stern[1], Sung-Hyun Park[3], James Garvin[4], Taaniela Kula[5], Folauhola Helina Latu'ila[5], Pupunu Tukafu[5], Nikolasi Heni[5]

[1]The University Of Auckland, Auckland, New Zealand, [2]Auckland University of Technology, Auckland, New Zealand, [3]Korean Polar Research Institute, Incheon, Republic of South Korea, [4]NASA Goddard Space Flight Center, Greenbelt, USA, [5]Tongan Geology Services, Nukualofa, Tonga

Caldera systems are rarely observed collapsing, with the exception of effusive-dominated systems such as Kilauea or Ambrym, where “quiet” stepwise piston collapse occurs. During and/or following the catastrophic and hugely explosive 15 January 2022 eruption of Hunga volcano a major, sudden caldera collapse was witnessed. The scale and form of this caldera change was quantified by comparing 2015/2016 collected bathymetry and satellite+drone altimetry, with that collected in two post-eruption multibeam surveys, by the RV Araon, (Korean Polar Research Institute) in April 2022 and the MV Pacific Horizon (University of Auckland and Tonga Geology Services) in May 2022. The pre-eruption edifice of Hunga is ~1400 m high and ~30 km at its base. It had a broad summit plateau of ~6 km in diameter, containing a broadly E-W oriented rectangular basin ~3 km across and ~1 km wide reaching depths of ~150 m. Following the eruption, a 4 km-diameter concentric circular basin formed with steep inner flanks and a measured depth of ~870 m. Seismic data suggests an infill of >100 m of sediment, so that the caldera drop was on the order of 800 m in total. The caldera rim/edge of the summit plateau was largely unchanged in form, with a ~30 m overall drop, especially in the south. The rim, which had several volcanic cones and irregular topography has been smoothed by deposition of pyroclastic debris. Around the inner caldera wall are located ~50 active vents releasing gas plumes. The inner walls have collapsed in several places with 0.5-1 km-wide landslide scarps and fans of debris entering the basin. Based on analysis of eruption sequence/events, tsunami generation, and core/dredge samples, the caldera collapse likely occurred suddenly within 60 min of the onset of the eruption.

511

Outgassing through magmatic fractures enables effusive eruption of silicic magma

Dr Josh Crozier[1], Samantha Tramontano[2], Pablo Forte[3], Sarah Jaye Oliva[4], Helge Gonnermann[5], Einat Lev[6], Michael Manga[7], Madison Myers[8], Erika Rader[9], Philipp Ruprecht[10], Hugh Tuffen[11], Rebecca Paisley[12], Bruce Houghton[13], Thomas Shea[13], C Ian Schipper[14], Jonathan Castro[15]

[1]Us Geological Survey California Volcano Observatory, Moffett Field, United States, [2]City University of New York, , United States, [3]Instituto de Estudios Andinos, , Argentina, [4]University of Victoria, , Canada, [5]Rice University, , United States, [6]Colombia Lamont-Doherty, , United States, [7]University of California Berkeley, , United States, [8]Montana State University, , United States, [9]University of Idaho, , United States, [10]University of Nevada Reno, , United States, [11]Lancaster University, , United Kingdom, [12]Cornish Lithium Ltd, , United Kingdom, [13]University of Hawaii Manoa, , United States, [14]Victoria University of Wellington, , New Zealand, [15]Johannes Gutenberg Universitat Mainz, , Germany

Several mechanisms have been proposed to allow highly viscous silicic magma to outgas efficiently enough to erupt effusively. There is increasing evidence that challenges the classic foam-collapse model in which gas escapes through permeable bubble networks, and instead suggests that magmatic fracturing and/or accompanying localized fragmentation and welding within the conduit play an important role in outgassing. The 2011–2012 eruption at Cordón Caulle volcano, Chile, provides direct observations of the role of magmatic fractures. This eruption exhibited a months-long hybrid phase, in which rhyolitic lava extrusion was accompanied by vigorous gas-and-tephra venting through fractures in the lava dome surface. Some of these fractures were preserved as tuffisites (tephra-filled veins) in erupted lava and bombs. We integrate constraints from petrologic analyses of erupted products and video analyses of gas-and-tephra venting to construct a model for magma ascent in a conduit. The one-dimensional, two-phase, steady-state model considers outgassing through deforming permeable bubble networks, magmatic fractures, and adjacent wall rock. Simulations for a range of plausible magma ascent conditions indicate that the eruption of low-porosity lava observed at Cordón Caulle volcano occurs because of significant gas flux through fracture networks in the upper conduit. This modeling emphasizes the important role that outgassing through magmatic fractures plays in sustaining effusive or hybrid eruptions of silicic magma and in facilitating explosive-effusive transitions.

(Abstract from Crozier et al. 2022 JVGR)

509

Modeling episodic caldera collapse with earthquake rupture and magma dynamics

Dr Josh Crozier[1], Kyle Anderson[1], Eric Dunham[2]
[1]Us Geological Survey California Volcano Observatory, Moffett Field, United States, [2]Stanford University, Stanford, United States

Many basaltic caldera collapse eruptions involve episodic collapse, wherein the crustal rock overlying a magma reservoir drops downward along ring faults in sequences analogous to tectonic earthquake cycles. Collapse pressurizes the magma reservoir, and so can sustain eruptions. Understanding collapse sequences is thus important for both hazard forecasting and understanding the eruption record. Basaltic eruptions at Kīlauea, Piton de la Fournaise, Miyakejima, and Bárdarbunga have provided direct observations of episodic collapse. These eruptions show that collapse block subsidence is often asymmetric (e.g., trapdoor motion, and that collapse intervals and amplitudes can vary both between volcanoes and over the course of a single eruption. Previous lumped parameter models have provided a very general framework for exploring episodic caldera collapse mechanics, but they do not capture several important aspects of the systems such as fundamentally heterogeneous fault stresses and earthquake rupture processes. To better understand collapse mechanics and eruptive sequences, we develop a 3D numerical model for sequences of earthquakes and aseismic slip along ring faults overlying a fluid magma reservoir. We consider quasi-static elastic deformation of the rock with an approximate treatment of inertia and with rate and state friction governing fault slip. We treat magma as a compressible fluid undergoing Stokes flow with a pressure-dependent magma outflow rate. We explore a range of parameters that influence collapse interval, collapse amplitude, and collapse asymmetry, then compare these results to observed caldera collapses.

999

Development of a data model for the collection of pre- and post- disaster data in multi-hazard volcanic environments

Dr Julia Crummy[1], Dr Susan Loughlin[1], Dr Roxana Ciurean[1], Mrs Nichola Smith[1], Mr Kenneth Lawrie[1], Dr Melanie Duncan[1]

[1]British Geological Survey, Edinburgh, United Kingdom

Numerous data collection tools exist primarily for single hazards such as earthquakes, floods, and landslides. Some tools can be applied to multiple, individual hazards; however, given the complex nature of volcanic environments, where multiple concurrent, cascading, and dynamic hazards occur, very few are designed with volcanoes in mind. Moreover, data reflecting the interaction and interdependency between different volcanic hazards, their impacts on the built environment and existent mitigation actions are rarely captured and must be considered for effective response to and prevention of future risks. We present a data model and associated dictionaries for the collection of pre- (exposure) and post- disaster (damage and impact) data on buildings located in multi-hazard volcanic environments. The data model is developed using a tiered approach for data collection depending on the level of detail required and the amount of time available to the user. We anticipate the data model and dictionaries can provide stakeholders with a flexible approach for data collection which can be used and adapted either in digital or analogue format, and integrated in existing or new data collection tools. Future work will focus on testing the model in different environments and adopting and adapting the approach to different stakeholder needs.

997

Towards understanding volcanic risk in low data environments: Integration of tephra fall hazard and exposure data at Corbetti Volcano, Ethiopia

Dr Julia Crummy[1], Mrs Yewub Bekele[2], Dr Samantha Engwell[1], Dr Charlotte Vye-Brown[1], Dr Gezahegn Yirgu[3], Dr Elias Lewi[3], Dr Susan Loughlin[1]
[1]British Geological Survey, Edinburgh, United Kingdom, [2]Geological Institute of Ethiopia, Addis Ababa, Ethiopia, [3]Addis Ababa University, Addis Ababa, Ethiopia

Corbetti volcano lies in the central to southern Main Ethiopian Rift with approximately 1.7 million people living within 30 km, and over 9 million people live within 100 km of the volcano. The towns of Hawassa and Shashemene, located within 20 km of Corbetti are home to over 300,000 people each, and are popular tourist destinations. A major east-west road crossing Ethiopia passes within 20 km of the volcano, and the north-south Trans-African Highway passes through Hawassa and Shashemene. New geological and geophysical data acquired in recent years have increased our understanding of past volcanism and present-day magmatism at Corbetti; however, the data and knowledge needed to assess hazards are still limited, constrained by poor deposit preservation, lack of dateable material and resources to map and correlate volcanic deposits. We present new probabilistic tephra-fall footprints integrated with exposure data to discuss possible impacts of potential future explosive volcanic activity at Corbetti. Tephra is dispersed towards the west following the prevailing wind direction, where there are numerous settlements within 100 km of the vent, with population densities of just over 4,000 to almost 10,000 people per square kilometre. Even a low-magnitude event could result in significant localised impacts (<10 km from the vent), with high probabilities of exceeding tephra thicknesses of 160 mm which can cause damage to buildings and prolonged exposure to volcanic ash. At distances of up to 30 km downwind, a moderate-large volume explosive event could result in tephra thickness exceeding 16 mm, potentially resulting in infiltration to interiors and collapse of some roofs. This work is a step towards understanding volcanic risk in low data environments and will be part of the evidence base to enable discussion of the possible impacts of potential future volcanic activity at Corbetti volcano with national and local stakeholders.

815

Simulations of rain-triggered lahars in the micro-watersheds of Misti Volcano, Arequipa, Peru

Juan Jose Cuno[1], Kevin Cueva[1], Jersy Mariño[1], Carla Arias[1], Christopher Harpel[2], Andy Ancalle[1]
[1]Instituto Geológico, Minero Y Metalúrgico Del Perú, Observatorio Vulcanológico del INGEMMET, Yanahuara, Peru, [2]U.S. Geological Survey Volcano Disaster Assistance Program, Vancouver, U.S.A.

Misti volcano, in southern Peru, is proximal to Arequipa the country's second most populated city. Misti's main channels that produce lahars descend its southwest and southeast flanks with some transecting Arequipa's urban area.

Lahar deposits are present in the channels on the volcano's flanks and within the city of Arequipa. Deposits from hyperconcentrated flows and debris flows are present with both representing eruption- and rain-triggered events. Lahars are most frequently generated during heavy rains and are triggered by accumulated precipitation between 30 mm and 124.5 mm. To simulate lahars with VolcFlow, we use a 4-m/pixel digital elevation model and input rheological parameters such as density, viscosity, volume, and cohesion.

Considering rainfall recurrence, we apply 30 mm as the most frequent triggering rainfall event (highest hazard zone), with 50 mm considered a moderate frequency event (moderate hazard zone), and 124.5 mm a low frequency event (lowest hazard zone). Surficial water is lost through infiltration, so all the rainfall captured by the micro-watersheds is not used to generate lahars. To better account for infiltration, the Soil Conservation Service Curve Number model is applied to reduce the water volume available to generate lahars (runoff). Our data suggest that potential lahar volumes vary from 1.0 x 10^5–1.6 x 10^6 m^3.

The simulations show that flows in channels descending Misti's southwest flank can enter urban areas and are a danger. Channels descending Misti's southeast flank are 20–60 meters deep and 10–30 meters wide. Flows in these southeastern channels would enter the Andamayo River and would not transect urban areas. Such flows, nonetheless, would sever the critical road connecting the outlying Chiguata district with Arequipa in multiple locations, leaving Chiguata isolated. Our modeling results are being applied to update the lahar hazard map for Misti volcano.

507

“Cordillera de fuego: Dramatising Indigenous engagements with volcanic landscapes in the wake of the colonial state”

Professor Julie Cupples[1], Dr Charlotte Gleghorn, Associate Professor Kevin Glynn, Dr Raquel Ribeiro
[1]*University Of Edinburgh, Edinburgh, United Kingdom*

In 2021 we began to work with a Guatemalan film company to produce a feature film and TV series about Indigenous (Tz’utujil, Kaqchikel and K’iche) communities facing a volcanic eruption while also negotiating the political and cultural risks that are produced through their interactions with a racist and colonial state apparatus. The media text draws on our research with communities at risk and traverses multiple modes of articulation between hazardous volcanic activity and various forms of coloniality, including Eurocentric knowledge, patriarchal racism, uneven land tenure, volunteerism, corruption and the legacies of the armed conflict (1960-1996) in which hundreds of thousands of Indigenous and poor ladino people were massacred or forced to flee the country.

The process is the outcome of a collaboration between Ixchel researchers (a large interdisciplinary and inter-epistemic research project involving researchers in the physical sciences, social sciences and humanities), the Fundación Ixcanul, the Casa de Producción and Indigenous communities that has involved treating Indigenous and scientific knowledges horizontally, and which builds on our long-term research with survivors of major disasters and Indigenous film and mediamakers in Abiayala and Aotearoa. The production engages the intersecting and often conflicting knowledge systems and priorities of Indigenous communities and the state, and accords space for Indigenous cultural practices and livelihoods within a process of disaster risk reduction. The active participation of Indigenous authorities and many community members at both the diegetic and extra-diegetic levels articulates aspects of Indigenous relationships to volcanic landscapes audiovisually. In this paper we discuss our ambitions for this media project, the modes of civic engagement we hope to facilitate, and the ethical and logistical challenges that it has entailed thus far, including complex Indigenous engagements with the production team and with various modes of coloniality and decoloniality.

335

Simulation of channelised basaltic lava flow
through topological bends

Mr Dale Cusack[1], Dr James Hewett[2], Mr David Muchiri[2], Professor Mathieu Sellier[2], Professor Ben Kennedy[1]
[1]School of Earth and Environment, University of Canterbury, Christchurch, New Zealand, [2]Department of Mechanical Engineering, University of Canterbury, Christchurch, New Zealand

Lava flows are well-studied volcanic phenomena that can become natural hazards when they encounter populated areas. To understand and model how lava flows, it is useful to determine its rheology. This is a notoriously difficult undertaking because lava flows are often inaccessible due to terrain and unapproachable in the field due to radiant heat. In this study, we asked what we could learn about the rheology from the free surface of lava as it traverses through a bend in a lava flow channel.

How does the rheology of the lava affect the development of the wetted line on the channel wall in the lead-up to maximum vertical inertial displacement? We performed computational fluid dynamics simulations of the free surface of iso-thermal lava using the Naiver Stokes equations. We further investigated the impact on flow behaviour through changes in rheological parameters, specifically, we used the shallow water equations with a Herschel Bulkley rheology to investigate the effect of changes to the yield stress, consistency index and power law coefficient on the development of the wetted line and maximum displacement of the free surface. Preliminary results indicate that a minimum sector angle is required to develop the displacement predicted by the inertial equation. Furthermore, we found that the gradient of the wetted line is affected by changes to the simulated rheology in the simulations. Finally, we used field data collected from Heslop et al. [1989] to model the 1974 Kilauea gully flow to compare and validate our results.

Our results provide another method of probing the rheology of lava in an active channel during an eruption and may help in the forecasting of run-out distances and over-topping of levees. These methods also give new tools to planetary scientists in their efforts to determine basaltic lava rheologies from satellite images.

924

Mantle sources and geodynamic triggers of kimberlite and related magmatism in Finland

Dr Hayden Dalton[1], Dr Andrea Giuliani[1,2], Professor Janet Hergt[1], Professor David Phillips[1], Dr Hugh O'Brien[3], Dr Roland Maas[1], Professor Jon Woodhead[1]

[1]School of Geography, Earth and Atmospheric Sciences, The University of Melbourne, Parkville, Australia, [2]Institute of Geochemistry and Petrology, Department of Earth Sciences, ETH Zurich, Zurich, Switzerland, [3]Geological Survey of Finland, Espoo, Finland, [4]Department of Earth Sciences, University College London, London, United Kingdom

Despite their considerable scientific and economic importance, the origin of kimberlites remains unclear, with significant questions surrounding the nature of their source region and the geodynamic factors that promote their apparently rare eruption to surface. Here, we present new whole-rock and perovskite-derived Sr-Nd-Hf isotopic data in conjunction with new emplacement ages, for each episode of kimberlite and related magmatism in Finland to yield insights into their petrogenesis.

The ~750 Ma Kuusamo kimberlites exhibit 'archetypal' kimberlite source signatures, whereas the ~600 Ma Kaavi-Kuopio kimberlites have a marked spread in Hf isotopic compositions for samples emplaced across a ~35 Myr period. It is particularly noteworthy that the isotopic compositions of these kimberlites become increasingly enriched (more negative εHf) with time. The compositional variations in the Kaavi-Kuopio kimberlites are best explained by the progressive enrichment of their mantle source region, with modelling suggesting that progressively increasing entrainment of ancient, subducted material into the 'primitive' kimberlite source region can cause the requisite shifts in isotopic compositions. These results lend support to an increasing body of work which suggests that subducted material is a critical 'contaminant' in the source of kimberlites and may account for much of the spatiotemporal variations observed in the isotopic compositions of these rocks.

The eruption of kimberlites on the Karelian craton appears to precisely bookend the onset and completion of supercontinent (Rodinia) break-up, with potential links to mantle plumes that may emanate from thermochemically anomalous lower mantle structures (i.e., LLSVPs–Large Low Shear-wave Velocity Provinces). While it may not be possible to provide a model for triggers of kimberlite magmatism that is applicable for all occurrences in Earth's history, the outcomes presented here support arguments for an important petrogenetic link with supercontinent cycles and/or the large mantle upwellings that are often thought to disrupt the stability of such continental amalgamations.

686

Health research during volcanic eruptions: Lessons from the 2018 Kīlauea multiagency response

Dr David Damby[1], Dr Alvin Bronstein[2], Dr Ben Castellana[3], Tamar Elias[1], Dr Diana Felton[2]
[1]U.S. Geological Survey, , United States, [2]Hawaii State Department of Health, , United States, [3]U.S. Environmental Protection Agency, , United States

The May-Sept 2018 eruption of Kīlauea Volcano (Hawai'i, USA) produced diverse eruptive phenomena that resulted in a multitude of health hazards with corresponding differences in mitigation and communication needs. Three geographic regions were impacted in distinct ways: (1) the lower East Rift Zone (LERZ) erupted 1.1-2.3 km3 dense-rock equivalent as lava fountains and flows, destroying over 700 structures and releasing abundant SO2 as the magma neared the surface and degassed. (2) The summit area experienced near-daily collapse-explosion events, each producing M5.2–5.4 earthquakes. Ash from the summit plumes fell on neighboring communities and deposited downwind. (3) The Ka'ū district and Kona coast experienced prevalent vog (volcanic smog) from the 7.1–13.6 Mt SO2 emitted from both the LERZ and summit, in addition to ashfall. While some communities had lived with vog, albeit at far lower levels, the presence of volcanic ash was a comparatively novel hazard in Kīlauea's recent effusive history

The eruption prompted a large multiagency, geology-health response in support of community and first-responder protection, and comprised efforts by local, state and federal organizations along with many academic partners. Throughout the eruption, these efforts included: ash and emissions measurement, sampling, and characterization; air quality sensor deployment and real-time air quality monitoring; water quality impacts modelling and direct testing; operational dispersion and fallout modelling; information production and dissemination; and monitoring and evaluating community health outcomes. Here we present an overview of public health-focused actions and health research conducted before, during and after the eruption. The knowledge generated through research during eruption crises is essential to achieving the goals of preparedness and timely response, but this is particularly challenging when data are transient or inaccessible in real-time. Integrating the lessons learned from each eruption response with global experiences helps to improve our capacity to conduct critical research during future eruptions.

428

Isotopic composition of volcanic plume CO2 prior the July 3rd, 2019 paroxysm at Stromboli volcano, Italy

Ms Fiona D'Arcy[1], Dr Fausto Grassa[2], Dr Alessandro Aiuppa[3], Dr Andrea Rizzo[2], Dr John Stix[1]
[1]*McGill University, Montreal, Canada,* [2]*INGV , Palermo, Italy,* [3] *DiSTeM, Università degli Studi di Palermo, Palermo, Italy*

The July 3rd, 2019 paroxysm at Stromboli volcano was a sudden, fatal eruption which was preceded by less than 10 minutes of geophysical precursors. Later geochemical analysis indicated that there was an increased CO_2 flux in the days and weeks leading up to the eruption. This highlights the need to better constrain the geochemical variations, especially $\delta^{13}C$, of volcanic carbon during both quiescent and active periods to improve detection of precursory signals. In this work, we present carbon isotopic variations as measured from plume samples collected by Uncrewed Aerial System (UAS). We conducted 25 sampling flights in May 2018 and June 2019 at the summit of Stromboli volcano, coupled with ground and background measurements during the same time period. Samples were analyzed within 12 hours by Cavity Ring-down Spectrometry (CRDS) and Isotope Ratio Infrared Spectrometry (IRIS). The concentration of CO_2 collected during 14 flights in May 2018 ranged from 405 to 490 ppm and between -7.0 and -8.7 ‰. During 11 flights in June 2019, we measured CO_2 concentrations ranging from 403 to 555 ppm and between -8.5 and -10.0 ‰. Linear regression and weighted means estimate the volcanic source $\delta^{13}C$ falls between -0.2 and -3.2 ‰ in 2018 and between -3.1 and -5.6 ‰ in 2019. These results reveal stark differences in the isotopic signature of quiescent (May 2018) versus pre-paroxysmal (June 2019) carbon dioxide emissions from Stromboli as well as daily differences within the summit crater. Interestingly, both the CRDS and IRIS results confirm that there are indisputable variations of up to 2‰ in the daily composition of CO_2 in the measurements taken three weeks before the July 3rd, 2019 paroxysmal event, possibly indicating a mixture of shallow magma-derived gas and deeper CO_2 bubbles. This warrants further investigations into isotopic geochemical monitoring at summits as an eruption precursor.

1269

Seismology of the 2021 Tajogaite eruption (La Palma, Canary Islands).

Dr Luca D'auria[1,2], Dr Ivan Koulakov[3,4], Dr Jesús M. Ibáñez[5,6], Dr Jose Barrancos[1,2], Mr. Iván Cabrera-Pérez[1], Mr Rubén García-Hernández[1], Mr David Martínez van Dorth[2], Dr Germán D. Padilla[1,2], Dr. Janire Prudencio[5,6], Mrs Monika Przeor[2], Mr Victor Ortega[1], Dr. Pedro Hernández[1,2], Dr Nemesio M. Pérez[1,2]
[1]Instituto Volcanológico de Canarias (INVOLCAN), San Cristóbal de La Laguna, Spain, [2]Instituto Tecnológico y de Energías Renovables (ITER) , Granadilla de Abona, Spain, [3]Trofimuk Institute of Petroleum Geology and Geophysics SB RAS, Novosibirsk, Russia, [4]Institute of the Earth's Crust SB RAS, Irkutsk, Russia, [5]Department of Theoretical Physics and Cosmos. Science Faculty. University of Granada. , Granada, Spain, [6]Andalusian Institute of Geophysics. University of Granada., Granada, Spain

The 2021 Tajogaite eruption on the Cumbre Vieja volcano (La Palma, Canary Islands) has been one of the most studied eruptions in recent years. The first earthquake swarms were recorded in Oct. 2017, with hypocenter depths generally ranging between 15 and 20 km. Other similar earthquakes were recorded in the following years. On Sep. 12nd, a renewed intense seismicity with rapidly shallowing hypocenters marked the pre-eruptive phase lasting about eight days. On Sep. 19th, the hypocenters reached the surface comminating with an M=4.1 earthquake followed a few hours later by the opening of the eruptive fissures. Conversely, the syn-eruptive seismicity showed the persistence of hypocenters at two specific depths: 10 km and 25 km.

Local earthquake tomography revealed the presence of a vast subcrustal reservoir located right beneath the Moho. We interpret the 10 km cluster as the result of reservoir readjustment because of the magma withdrawal. The deeper cluster seems to be associated with an upper mantle reservoir, which is also supported by independent geochemical and petrological data.

The disappearance of the volcanic tremor at the end of the eruption made it possible to detect weaker, shallow seismicity, also consisting of long-period events. After the eruption, the seismicity rate showed a very slow decline, with hypocenters located generally at depths shallower than 10 km. Since March 2022, the deployment of a temporary network around the newly formed volcanic edifice of Tajogaite allowed detecting and characterizing of local small-magnitude seismicity consisting mainly of hybrid events located within the volcanic edifice.

We characterize the seismicity of the whole pre- syn- and post-eruptive periods by waveform clustering, high-resolution relocation and determination of the source mechanisms. We show how a different behaviour characterizes the various phases with respect to the evolution of event families and stress drop analysis.

1319

The magma ascent process during the 2021 Tajogaite (La Palma, Canary Islands) eruption: a geodetic study

Mrs Monika Przeor[1,2], Dr Raffaele Castaldo[3], Dr Luca D'auria[1], Dr Antonio Pepe[3], Dr Susi Pepe[3], Prof Takeshi Sagiya[4], Dr Giuseppe Solaro[3], Dr Pietro Tizzani[3]
[1]Instituto Volcanológico de Canarias (INVOLCAN), San Cristóbal de La Laguna, Spain, [2]Instituto Tecnológico y de Energías Renovables (ITER), Spain, , , [3]Istituto per il Rilevamento Elettromagnetico dell'Ambiente (CNR-IREA), Italy, , , [4]Nagoya University, Japan, ,

On the 19th of September 2021, an eruption started on the Cumbre Vieja volcano of La Palma Island (Canary Islands). The pre-eruptive phase lasted only eight days and was characterized by a seismic sequence that began on the 11th of September. The GPS network of Instituto Volcanológico de Canarias (INVOLCAN) observed a rapid and significant ground deformation reaching more than 10 cm in the vertical component of the station ARID (Aridane). There was an intense deformation on the western side of the island and intense seismicity with the upward migration of hypocenters. After the eruption's onset, the deformation increased a few cm more, reaching a maximum on the 22nd of September and showing a nearly steady deflation trend in the following months.

To understand this magma ascent process preceding this eruption, we determined the ground deformation source geometry using both a Sentinel-1 DInSAR dataset and the seismicity distribution. The results indicate the existence of a dike with complex geometry starting from a depth of about 10 km. Using this geometry, we applied the geodetic imaging of D'Auria et al. (Sc. Rep. 2015) to retrieve the time-varying spatial distribution of the dike aperture. The final results show a rapid upward dike propagation and complex magma ascent kinematics.

277

Challenging the paradigm of 238U-excesses dominating arc settings: A Uranium-series isotopic investigation of Mt Taranaki, New Zealand

Miss Alexandra Davidson[1], Dr Simon Turner[1], Dr Shane Cronin[2]
[1]*Macquarie University, Sydney, Australia,* [2]*University of Auckland, Auckland, New Zealand*

Rear arc volcanism is typically potassic in composition but its origins are not well understood. In New Zealand, Mount Taranaki stratovolcano is most commonly attributed to subduction-related magmatism but is located 400 km behind the Hikurangi arc-trench system where seismic evidence for a Wadati-Benioff zone is ambiguous. Alternative magma generation scenarios have subsequently been proposed, invoking lithospheric delamination and asthenosphere inflow. For the purpose of understanding the magma generation scenario in greater detail, we have undertaken the first Uranium-series disequilibria analysis for a suite of high-K andesitic Taranaki pyroclastic rocks aged between 0.35 to 22 ka. All but one of these have 230Th excesses (up to 45%) and form a broad horizontal array on the U-Th equiline diagram. The 230Th excesses cannot be explained by crystal fractionation or crustal assimilation and may instead be indicative of the addition of sediment melts into a depleted mantle wedge or of an eclogitic source. To further model the source characteristics, Sr, Nd and O isotope data has been collected from a complementary suite of samples and presented herewith in. Irrespective of the ultimate origin of the magmas, the horizontal U-Th isotope array constrains the total time elapsed from partial melting to eruption to 4.5 ± 0.59 kyr. This implies short residence times and rapid magma ascent rates that may help explain the periodic variations of eruption frequency and composition seen in the long-lived tephra record of this volcano.

985

Constraining ash dispersal from historical eruptions: Experiments with ash dispersal modelling and methodological recommendations

Dr Lauren Davies[1], Prof Christine Lane[1], Dr Anja Schmidt[2,3,4], Dr Johannes de Leeuw[4], Ms Josephine Bailey[1]
[1]Department of Geography, University of Cambridge, Cambridge, United Kingdom, [2]Institute of Atmospheric Physics (IPA), German Aerospace Center (DLR), Oberpfaffenhofen, Germany, [3]Meteorological Institute, Ludwig Maximilian University of Munich, Munich, Germany, [4]Yusuf Hamied Department of Chemistry, University of Cambridge, Cambridge, United Kingdom

Here we present details for a new methodology, combining records of distal volcanic ash deposits (cryptotephra) and historical observations of ashfall with numerical ash dispersal model simulations. We aim to better characterise the deposition of distal fine ash from pre-1979 eruptions.

Since protocols for cryptotephra extraction were published in the 1990s, records have shown that Holocene eruptions frequently dispersed fine ash 1000s of km from their sources. However, we have a poor understanding of their ash transport pathways. Dispersion models that forecast the movement of volcanic ash clouds can offer a potential solution to this problem, but there are several associated challenges.

Firstly, 4D meteorological data strongly influence ash transport and deposition in such models but are not available at high spatial and temporal resolution before 1979. Choosing appropriate modern data to use as an analogue for past conditions presents many issues. Secondly, some eruption source parameters (e.g. grain size, sphericity) are not frequently reported for cryptotephra, and thirdly, the models themselves may lack detailed representation of the long-range fine ash dispersal that results in cryptotephra deposition.

To test these concerns, we have produced a range of volcanic ash dispersal scenarios for a case study of Askja 1875, Iceland. These were compared with records of cryptotephra presence and historical observations, which we used to calculate a quantitative agreement index for each model scenario. We were then able to identify the most likely subset of transport paths through the independent verification of model results.

We investigated the impact of using different modern meteorological data as well as variations in eruption source parameters (e.g. grain size distributions and grain shape, based on measurements of proximal and distal ash samples; varying ash release height in the plume). Our results and recommendations for future work in this field are summarised here.

993

Constraining ash dispersal from historical eruptions: Quantitative assessment of volcanic ash model scenarios using historical observations and stratigraphic records

Dr Lauren Davies[1], Prof Christine Lane[1], Dr Johannes de Leeuw[2], Dr Anja Schmidt[2,3,4]
[1]Department of Geography, University of Cambridge, Cambridge, United Kingdom, [2]Yusuf Hamied Department of Chemistry, University of Cambridge, Cambridge, United Kingdom, [3]Institute of Atmospheric Physics (IPA), German Aerospace Center (DLR), Oberpfaffenhofen, Germany, [4]Meteorological Institute, Ludwig Maximilian University of Munich, Munich, Germany

Here, a new approach is used to characterise fine ash dispersal and deposition from past eruptions. We have explored using a combination of data from ash dispersal modelling, low concentration distal fine ash deposits (cryptotephra) and historical observations of ash fall. Key aims included compiling a probabilistic map of ash deposition for case study eruptions and testing output sensitivity to key eruption source parameters.

Volcanic eruptions can affect far-off populations through the long-range dispersal of volcanic ash and aerosols. But while well-studied modern eruptions may have satellite and field observations, these events only represent a small fraction of the eruption scenarios that have occurred over time. Estimations of historical eruption behaviour can be made using ejected tephra deposits or contemporaneous observations (if available). These provide some information on the source location and eruption dynamics (e.g., explosivity, volume, duration) as well as weather conditions.

Widespread cryptotephra deposits have shown that Holocene eruptions frequently dispersed fine ash over 1000s of km, but their ash transport pathways are poorly understood. Dispersion models that forecast the transport and location of volcanic ash clouds offer a potential solution here, but with some challenges: they require high-resolution meteorological data that are not available before 1979 and they may lack detailed representation of the long-range fine ash dispersal that results in cryptotephra deposition.

To test these limitations, we have produced volcanic ash dispersal scenarios for a case study of Askja 1875, Iceland. These are compared with detailed records of cryptotephra presence and historical observations, which are used to calculate a quantitative agreement index for each model scenario. High-resolution eruption scenarios that have not been observed in the modern period but have historical equivalents can therefore be assessed (e.g. eruptions: from currently inactive volcanoes, that are larger than recent events, or occurring in different seasons or climatic settings).

482

The ASTER Volcano Archive (AVA): Over Twenty Years of Global Monitoring of Active Volcanoes

Dr Ashley Davies[1], Dr Michael Abrams[1], Mr Alexander Torres[1]
[1]Jet Propulsion Laboratory - California Institute of Technology, Pasadena, United States

Orbital remote sensing is the only tool allowing global, systematic monitoring of all 1500+ active volcanoes (based on the Smithsonian Holocene catalog). A specialized archive has been developed at the NASA's Jet Propulsion Laboratory: the ASTER Volcano Archive (AVA). AVA is comprised of over 200,000 ASTER frames spanning over 20 years of the NASA's Terra platform mission. The ASTER Volcano Archive (AVA: http://ava.jpl.nasa.gov) is the world's largest (at 100+Tb), and the only high spatial resolution (15-30-90m/pixel), multi-spectral (visible-SWIR-TIR), downloadable (kml-enabled) dedicated archive of volcano imagery. The system is designed to facilitate parameter-based data mining, and for the implementation of archive-wide data analysis algorithms. After a system redesign, restoring full functionality of the AVA is currently underway, which will include thermal anomaly detection and mapping, the temporal variability of individual volcanic emissions, as well as the detection of SO2 plumes from both explosive eruptions and from passive emissions, and USGS alteration maps derived from ASTER data. In addition, we plan to afford access to the 1972-present Landsat dataset, and NASA Earth Observing-1 multispectral and hyperspectral imagery (10-30 m/pixel) of a subset of the Holocene catalog volcanoes obtained between 2004 and 2017. The newest version of AVA has been ported from the Amazon Web Services cloud to dedicated servers at JPL, yielding considerable savings in cost, and is managed by the Jet Propulsion Laboratory's Hybrid Science Data System (HySDS). The system is updated with new data daily, with a latency of a few days following data acquisition. A new user interface facilitates easy, fast and efficient access to the archive. This work was performed at the Jet Propulsion Laboratory, California Institute of Technology under contract to NASA. © 2023 Caltech.

490

Modelling Turbulent and Laminar Lava Flow Emplacement to Understand Io's Powerful, Voluminous "Outburst" Eruptions

Dr Ashley Davies[1], Prof Lionel Wilson[2], Prof James W. Head III[3], Prof Imke de Pater[4], Prof Katherine de Kleer[5]
[1]Jet Propulsion Laboratory - California Institute of Technology, Pasadena,, United States, [2]Lancaster University, Lancaster,, United Kingdom, [3]Brown University, Providence,, United States, [4]University of California-Berkeley, Berkeley,, United States, [5]California Institute of Technology, Pasdaena,, United States

Io's powerful "outburst" eruptions are characterised by lava fountaining and subsequent emplacement of thick, extensive lava flows [1], similar in style to that of ancient lunar eruptions [e.g., 2]. Ground-based telescope observations [3] yielded detailed temporal coverage of these eruptions at low spatial resolution. To constrain eruption parameters and lava composition, we have developed a numerical model of these eruptions to fit to the available data. The thermal emission from these eruptions requires high initial magma discharge rates generating rapidly-spreading lava flows whose initial motion is fully turbulent. We model radiative heat loss from the evolving eruption for a range of compositions, constrained by telescope observations. Critical to understanding the time-variation of spectral radiance is establishing how far from the vent, and precisely when, lava motion becomes laminar. We track how cooling of turbulent lava causes growth of phenocrysts and the progressive onset of non-Newtonian rheology. Increasing viscosity causes the Reynolds number, Re, to decrease, and increasing yield strength causes the Hedstrom number and the critical Reynolds number for turbulence, Re_crit, to increase. When Re < Re_crit the transition to laminar flow allows the growth of a cooling crust and cooling basal thermal boundary layer. Fitting the telescope data [3], our modelling suggests an initially high discharge rate eruption emanating from a long fissure or fissures. There is, subsequently, a rapid decrease in discharge rate, and flow transitions to a laminar regime as lava spreads across Io's surface. This initial modelling suggests a basaltic composition for the lava. This work is supported by the NASA SSW Program and was performed at the Jet Propulsion Laboratory under NASA contract. References: [1] Davies, A. G. (1996) Icarus, 124, 45-61. [2] Wilson, L. and Head, J. W. (2018) GRL, 45, 5852–5859. [3] de Pater, I. et al. (2014) Icarus, 242, 352-364.

850

Permeability and degassing of surficial Krafla lithologies: implications of the subsoil variability

Mr Robert Davoli[1], Katharina Engels[1], Dr. Cristian Montanaro[1], Dr. Tullio Ricci[2], Dr. Alessandra Sciarra[2], Prof. Dr. Bettina Scheu[1]

[1]Earth and Environmental Sciences, Ludwig-Maximilians-Universität München, Theresienstrasse 41, 80333 , Munich, Germany, [2]Istituto Nazionale di Geofisica e Vulcanologia, Via di Vigna Murata 605, 000143, Rome, Italy

The Krafla geothermal system in Iceland is a thermal field highly exploited for energy production. The extent of the geothermal system, as well as the degassing and alteration patterns, appear to be controlled mainly by the properties of hyaloclastite products and lavas at shallow depth and the existence of explosive vents and faults. Additionally, variations in permeability within the subsoil layers, due to alteration and compaction effects may further influence fluid flow to the surface.

Here we present a study on surficial lithologies of the Krafla area to investigate the relationship between the different lithologies and the main degassing zones. In particular, we studied how hydrothermal alteration affects the petrophysical properties of these lithologies and thus fluid circulation. In a field campaign in June 2022, we measured the in situ petrophysical properties (permeability, mechanical strength, temperature) of over 100 samples in 11 profiles mainly in the Víti and Hveragil areas. Where possible, the profiles contained different levels of alteration of the same lithology, from unaltered to highly altered. For selected profiles we also obtained soil diffuse CO_2 flux measurements. Field permeability varied from 1.02 x 10^{-12} to 9.24 x 10^{-15} m^2 and CO_2 fluxes from 1.25 to 2628.33 g/m^2day. Both, measured samples and additional undisturbed soil samples were collected to analyze grain size distribution and componentry. For the undisturbed samples, we measured porosity, and tested the variation of permeability and strength after slight compaction. We combine our results with regional tectonic controls on the fluid circulation to improve the field map of degassing patterns.

Our results contribute to a better understanding on which surficial lithologies act as main fluid pathways and which act as barriers. They further reveal the variability of the subsoil lithologies and help estimate changes and evolution with ongoing alteration and compaction processes.

1426

The interplay among civil society, authorities and scientists in facing risks and disasters: the example of Stromboli Island community, 2019-2022

Dr Gianfilippo De Astis[1]
[1]*Istituto Nazionale di Geofisica e Vulcanologia - Roma1, Rome, Italy*

"Risk society" is by now a consolidated cultural and sociological concept. It implies that modern society is permeated by the presence of risks, whose perception and communication has become crucial in driving political decisions and public opinion reactions or behavior. Here, the "relations of definition", having the power to define hazards and vulnerability of territory, become essential for an effective risk management. Today, the definition(s) need to be communicated and understood - mutually, among different social groups - even more because the disasters are socio-political events that disrupt normal social life. Therefore, a transparent and thorough communicative interplay among scientists, civil society, governmental Institutions becomes crucial to define, understand and face the risks.

Moreover, social media are incessantly and increasingly reshaping this paradigm, to the point that the speed of communication and connectivity of people overwhelm that of the tools aimed at correctly addressing information and dissemination. This has created a continuous dialectical contest between civil society and authorities especially where doubtful risk perceptions and political inertia make the communities "confused".

How does a community with a history punctuated by responding to environmental disasters deal with the uncertainty posed by slow or contradictory actions by government(s)? Could the swirling changes in communication flows and the common relations between decision making subjects, scientists and the civil society turn into new practices of citizenship and virtuous policies?

Stromboli Island experienced two paroxysmal eruptions in summer 2019, followed by two years of worldwide outbreak conflicting with its social and economic life, and two further disastrous events in 2022: a large arson, largely responsible for the torrential flood occurred shortly after.

The multifaceted community of Stromboli finally reacted by creating a crucible of resilience, able to favor supportive actions for its own rebirth, supported by a constructive and circular alliance with Institutions and scientists.

538

Integration of multi-platform remote sensing techniques applied to the 2021 Etna lava flows: timely mapping and volcanological parameters quantification.

Mrs Emanuela De Beni[1], Dr. Cristina Proietti[1], Mr. Massimo Cantarero[1], Dr. Tullio Ricci[2], Dr. Gaetana Ganci[1]
[1]Istituto Nazionale Geofisica e Vulcanologia, Osservatorio Etneo, Catania, Italy, [2]Istituto Nazionale Geofisica e Vulcanologia, Roma 1, Roma, Italy

The 2021 eruptive activity at Mt Etna was characterized by 57 paroxysmal events at the South East Crater, the most active among its four summit craters. These episodes of Strombolian activity and high lava fountains fed lava flows towards East, South, and South-West and caused ashfall in the surroundings of the volcano and the fallout of large ballistics (with a diameter larger than 3 m) in the proximal area. Although the impacted area does not include permanent infrastructures, thousands of tourists, especially in the summertime, visited it. Hence, timely mapping of each lava flow field and preliminary assessment of ballistics distribution were mandatory for hazard mitigation. The high frequency of the paroxysms, up to two events in 24 hours, urged us to integrate different remote sensing techniques, with different spatial resolutions and revisiting time. In particular, several satellite images were processed, depending on data availability and weather conditions. Data acquired by Sentinel-2 MSI, PlanetScope, Skysat, Landsat-8 OLI, and TIRS allowed us to map the lava flow fields at a spatial resolution ranging from 0.5 to 90 meters. High-spatial resolution (from 4.5 up to 55 cm) DEMs and orthomosaics were also realized elaborating the visible and thermal images acquired through Unmanned Aerial Systems (UASs) surveys. Moreover, data acquired by the thermal cameras of the Istituto Nazionale di Geofisica e Vulcanologia permanent network were re-projected into the topography for analyzing the lava flow field evolution at 5-meter spatial resolution. These multi-platform remote sensing data allowed for mapping the lava flows and compiling a geodatabase reporting the main geometrical parameters (e.g. length, area, average thickness). The resulting multi-sensor methodology enabled, for the first time on Etna, to timely and accurately characterize frequently occurring effusive events.

1310

A new workflow for real-time probabilistic assessment of volcanic hazard for tephra dispersal and its application to 2021 Mt.Etna paroxysims

Dr. Federica Pardini[1], Dr Mattia de' Michieli Vitturi[1], Dr. Daniele Andronico[2], Dr. Tomaso Esposti Ongaro[1], Dr. Antonino Cristaldi[2], Dr. Augusto Neri[1]
[1]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Pisa, Pisa, Italy, [2]Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo, Catania, Italy

We present an automated workflow based on the release of VONAs (Volcano Observatory Notice for Aviation) aimed at the real-time assessment of the volcanic hazard due to tephra fall, and its application to the February-April 2021 paroxysms at Mt. Etna. In that period, Mt. Etna (Italy) experienced intense explosive activity with 17 lava fountain episodes between 16 February and 1 April 2021. During the eruptive crisis, the Istituto Nazionale di Geofisica e Vulcanologia−Osservatorio Etneo (INGV−OE) issued 62 VONAs to inform the aeronautical authorities about the ongoing volcanic activity. When a VONA reporting tephra emission was issued by INGV−OE, the newly developed workflow automatically started a set of numerical simulations accounting for atmospheric and eruptive uncertainties to produce probabilistic hazard maps of tephra fallout and atmospheric dispersal. We present here the workflow outputs for some lava fountains that occurred during the 2021 eruptive activity, with a comparison of the simulated ground load with field data, and of the extent and position of the simulated volcanic cloud with the observed or estimated volcanic cloud from the Toulouse Volcanic Ash Advisory Center. The results show how accurate information on eruptive conditions, particularly column height and duration, supplied by the VONA significantly improve the match between simulated and observed quantities (tephra loads and volcanic cloud distributions).

393

New bathymetric map of Lake Rotorua, New Zealand

Dr Cornel de Ronde[1], Dr Fabio Caratori Tontini[2], Dr Jenny Black[1], Lake Rotorua RNZN[3]
[1]GNS Science, Lower Hutt, New Zealand, [2]University of Genoa, Genoa, Italy, [3]RNZN, Wellington, New Zealand

A new bathymetric map of Lake Rotorua is the fourth map to be produced in the GNS Science Rotorua lakes map series. The bathymetric survey was undertaken over two field seasons between 2016 and 2017 using the Navy vessel Adventure, with a multibeam echo sounder system used to map the lakefloor at ~1 m resolution. The lake was also surveyed for magnetics (2016 and 2017), gravity, and heat flow (both 2020). A total of ~40 km2 was covered by the bathymetric surveys, or ~80% of the lake surface area. A magnetometer was towed behind the vessel during the multibeam surveys, while ~160 line km were surveyed for gravity, with 84 heat flow stations occupied on the lake.

The maximum depth of Lake Rotorua is ~54 m, with much of the lake between 10 and 20 m; a relatively wide (~1.5 km) zone of shallow (<5 m) water surrounds the margin of the lake. The map reveals a number of features on the lakefloor, including; 1) a series of nested craters that extend off Motutara Point for ~1.8 km which are discharging hydrothermal fluids, 2) a long (~5.7 km), narrow (~1 km) basin that extends northwards from the craters, to west of Mokoia Island, and 3) up to 2000 pockmarks, some up to 110 m in diameter, that locally are discharging gas bubbles. The magnetic map of the lake is dominated by negative anomalies associated with the craters and an area immediately south of Mokoia Island where hot springs occur. Prominent positive magnetic and gravity anomalies are associated with rhyolite lava flows projecting into the lake from the SW and the SE. Heat flow measurements >100 W/m2 are recorded in the craters—coincident with a large resistivity anomaly—and represent the sublacustrine extension of the Rotorua geothermal system.

388

Ongoing activity within the submarine caldera Hunga Tonga – Hunga Ha'apai: results from water column surveys with the USV Maxlimer

Dr Cornel de Ronde[1], Ms Sharon Walker[2], Dr Michael Williams[3], Dr Karolina Zwolak[4], Mr Ben Simpson[5]
[1]GNS Science, Lower Hutt, New Zealand, [2]NOAA/PMEL, Seattle, USA, [3]NIWA, Wellington, New Zealand, [4]K2sea, Gdynia, Poland, [5]Sea-Kit International Ltd, Tollesbury, UK

The Hunga Tonga-Hunga Ha'apai eruption on January 15 2022 marked the most powerful volcanic eruption in the past ~30 years. The blast shot ash high into the atmosphere and caused a sonic boom that reverberated around the world while also triggering a destructive tsunami that locally reached 16 m in height.

The Tonga Eruption Seabed Mapping Project (TESMaP) included an expedition to investigate the status of ongoing eruptive and/or hydrothermal activity within the caldera using the uncrewed surface vessel (USV) Maxlimer, operated by Sea-Kit International Ltd (UK). This included the first ever remote deployment of sensors to measure discharge in the water column. Two Miniature Autonomous Plume Recorders (MAPRs) and a CTD were deployed in a custom-built cage at the end of 300 m of cable. MAPRs measure pressure, temperature, turbidity and oxidation-reduction potential (ORP), key tracers of submarine hydrothermal and volcanic plumes.

A total of 30 vertical casts and 8 tow-yo's were completed, with the majority located inside the caldera. Results show there was ongoing activity within the caldera during July/August 2022. Acoustic water column reflectors (WCR) located probable bubble plumes rising from the seafloor from depths up to ~650 m. Most occurred on the caldera walls adjacent to each island and in the east/southeastern part of the caldera. Negative ORP anomalies coincided with intense turbidity plumes near WCR sites, indicating the presence of reduced chemical species common to both submarine volcanic and hydrothermal plumes (e.g., Fe2+, H2S and H2), thus making it difficult to strictly differentiate the type of ongoing activity. Positive ORP anomalies in the plume elsewhere within the caldera suggest a significant concentration of dissolved CO2, likely due to dissolution of bubbles in the water column. Particle plumes were detected in all directions outside the caldera at rim breach depths, indicating transport to the surrounding ocean.

1234

Resurgence at large calderas: Toba Caldera, Sumatra

Professor Shanaka de Silva[1], Dr. Adonara Mucek[1], Dr. Martin Danišík[2], Professor Axel Schmitt[3], Dr. Indyo Pratomo[4]

[1]Oregon State University, Corvallis, United States, [2]Curtin University,, Bentley, Australia, [3]Ruprecht-Karls-Universität Heidelberg, Heidelberg , Germany, [4]Geological Agency of Indonesia, , Indonesia

Understanding the post-climactic recovery at large calderas remains one of the foremost challenges for caldera science. Over the last decade we have endeavoured to understand the timescale, rates, duration, and mechanisms of the Toba caldera, Sumatra, the site of the earth's largest recent supereruption. Our findings to date include:

1) Zircon double dating (ZDD), 40Ar-39Ar, thermal modeling and Bayesian statistical analysis reveal that resurgent uplift and volcanism initiated ~5 kyr after the climactic eruption and eruptions were of cold-stored subsolidus rhyolite (Mucek et al., 2021, Earth and Environment).
2) ZDD also revealed that resurgent volcanism continued for ~15,000 years after the climatic 74 ka supereruption, and 14C dating revealed local uplift to as recently as 2 ka. Zircon U-Th crystallization ages indicate a link to the actively erupting Sinabung volcano (Mucek et al., 2017, Nat. Comm.).
3) An age model created by combining paleomagnetic stratigraphy and 14C ages of lake sediments revealed that resurgent uplift was piecemeal and asynchronous across Samosir Island. (Solada et al., 2021, Quat. Res.).
4) Minimum uplift rates were high (4.9 cm/year) for the first 11.2 ky but diminished after that to <1 cm/year for the last 22.5 ky. Numerical modeling suggests that rebound of remnant magma augmented by deep recharge appears to be the most likely driver for uplift (de Silva et al., 2015, Frontiers).
5) The YTT of Toba appears to be synchronous with an antipodal supereruption, the Los Chocoyos from the Atitlán caldera in Guatemala (Cisneros de Leon et al., 2022; Frontiers).

A synthesis of the implications of our findings for the post-climatic history of Toba and other large caldera systems (supervolcanoes) will be presented.

634

Dynamics of Askja caldera, Iceland studied using decades of relative microgravity measurements.

Mathijs Koymans[1,2], Dr Elske De Zeeuw Van Dalfsen[1,2], Josefa Sepulveda Araya[3], Dr Erik Sturkell[4], Dr Andy Hooper[3], Dr Freysteinn Sigmundsson[5], Dr Hazel Rymer, Dr Jeanne Giniaux[3]

[1]The Royal Netherlands Meteorological Institute (KNMI), De Bilt, Netherlands, [2]Department of Geoscience and Remote Sensing, Delft University of Technology, Delft, Netherlands, [3]School of Earth and Environment, University of Leeds, Leeds, United Kingdom, [4]Department of Earth Sciences, University of Gothenburg, Gothenburg, Sweden, [5]Nordic Volcanological Center, University of Iceland, Reykjavik, Iceland, [6]Open university, Milton Keynes, United Kingdom

A uniquely long time series of relative microgravity measurements exists for the Askja caldera in Iceland, covering both an extensive period of subsidence and a recent reversal to rapid uplift. Microgravity measurements complement other geodetic observations and are essential to understand subsurface mass changes. After decades of subsidence, in August 2021, the Askja caldera started to show uplift. The centre of uplift is located at the northwestern edge of lake Öskjuvatn and an order of magnitude larger than the subsidence in the last decade.

The relative microgravity network currently consists of fourteen benchmarks of which three are located in the centre of the caldera where maximum uplift occurs. Throughout the years three previously measured benchmarks became obsolete because they were unstable and nine were added around the caldera to increase detection capabilities. Relative microgravity measurements at Askja are challenging due to the long walking distances and uneven terrain between benchmarks, which makes a “double loop” procedure impossible. Also the unpredictable harsh weather conditions and remoteness reduce the time window during which a survey can be completed.

We revisit existing LaCoste & Romberg (1988-2010) and Scintrex (2015 onward) relative microgravity data sets and analyse the latter using the same software based on a joint weighted least squares inversion routine. The two most recent campaigns took place just after the start of the uplift, in September 2021, and when the uplift had reached 40 centimetres in the centre of the caldera, in August 2022.

We define recommendations for future relative microgravity campaigns at Askja which will be important to i) establish the cause of the ongoing uplift and ii) assess hazard implications of a possible future eruption.

425

Monitoring the active volcanoes Mnt. Scenery on Saba and The Quill on St. Eustatius in the Caribbean Netherlands.

Dr Elske De Zeeuw Van Dalfsen[1,2], Reinoud Sleeman[1], Dr Andreas Krietemeyer[1]
[1]*Department of Seismology and Acoustics,The Royal Netherlands Meteorological Institute (KNMI), De Bilt, Netherlands,*
[2]*Department of Geoscience and Remote Sensing, Delft University of Technology, Delft, Netherlands*

In the Caribbean Netherlands, the islands of Saba and St. Eustatius each host an active volcano. Saba is, with 13 km², the smallest of the two islands and hosts 1900 people, while 3200 people live on St. Eustatius, which has a size of 21 km². Both islands have an international airport and ferries regularly serve both islands.

The volcanoes Mnt. Scenery and The Quill are part of the Lesser Antilles volcanic arc and the abundant pyroclastic flow deposits are evidence of their violent explosive history. There are no eyewitness accounts of any eruptive activity, as the last activity occurred before European settlement, around 1640 for Mnt. Scenery and 400 for The Quill. One of the hotsprings on Saba reaches temperatures of 83 degrees Celsius and drilling for water wells on St. Eustatius in the nineties had to be abandoned because of the high concentration of solubles due to volcanic activity.

The Royal Netherlands Meteorological Institute (KNMI) is responsible for the timely warning for geophysical phenomena including volcanic eruptions or unrest on the islands and therefore operates a permanent monitoring network consisting of eight continuous GNSS stations, ten broadband seismometers and two on-site temperature sensors in the hotspring. Data are transmitted to KNMI using fixed internet (61%), 4G wireless (17%) or satellite communication (22%). Operational challenges include harsh environmental conditions such as sea spray, UV radiation and lightning, island wide power outages and remoteness of some of the sites. Currently data indicate both volcanoes display background levels of activity.

Apart from data acquisition and interpretation, KNMI also communicates these findings to the public, local governments and disaster preparedness agencies. In case of acute potential hazardous situations the departmental crisis coordination centre of the ministry would assist the islands taking needed actions.

237

Towards an understanding of magmatic flux influence on modeled zircon populations

Ms Annika Dechert[1], Josef Dufek[1], Nathan Andersen[2]
[1]University of Oregon, Eugene, United States, [2]United States Geological Survey, Vancouver, United States

Zircon geochronology and thermometry, as well as thermal and multiphase numerical modeling of magma reservoirs, have revolutionized our understanding of the genesis, evolution, and storage of silicic magma bodies. However, these approaches are rarely integrated, their interpretations are individually non-unique, and past work predominantly focuses on the largest systems. Additionally, questions remain about the range and timescales of physical processes recorded by zircon crystals and how faithfully they record the entire thermal history of these bodies. For example, can zircon crystals in eruptive products constrain specific magmatic processes and on what length and timescales? What thermal pathways lead to dissolution of some zircons, removing part of the magmatic record? We address some of these uncertainties by modeling zircon age populations produced by intrusions of different compositions into an upper crustal mush. We use conditions informed by observations of Mount St. Helens, WA, and South Sister, OR, in the Cascades, U.S., to determine general trends for moderate-scale arc systems.

We use a magma reservoir model coupled to a zircon growth model. A three-dimensional multiphase numerical model focuses on the long-term evolution of the system. Starting with an initial mush with stochastically-determined properties, we then perturb it by varying the composition and volume of the magmatic flux, in addition to eruption intervals. The thermal and chemical conditions of this model through time are used to calculate the compositional and temperature dependence on zircon crystal growth or dissolution, coupling reservoir-scale and crystal-scale models. Outputs of the zircon diffusion model include crystal growth rate and zircon saturation temperature, as well as the uranium and titanium concentrations in the crystals. Integration of zircon petrochronology and magma dynamics modeling will better constrain the thermal histories of magma reservoirs and provide insight on interpreting zircon ages from natural samples with respect to magmatic systems and events.

1030

Gelling diffusion and the classroom: teaching diffusion chronometry with gelatin

Dr Rebecca deGraffenried[1], Maria Dias[2], Linda Sobolewski[2], Andrea Tonato[3], William Nelson[3], Nabila Nizam[3], Thomas Shea[3]

[1]Arizona State University, Tempe, United States, [2]Ruhr-Universität Bochum, Bochum, Germany, [3]University of Hawaiʻi at Mānoa, Honolulu, United States

Diffusion chronometry has gained increasing use in the past couple of decades as a tool to investigate timescales of geologic processes. It is a flexible technique that can be applied if the process of interest generates a concentration gradient and the rate at which a species (e.g., element, ion, molecule, etc.) diffuses to homogenize the gradient is known. This versatility of diffusion chronometry has been leveraged across many fields in earth and planetary sciences, making it useful for students to learn. However, it rarely enters our schooling curriculum early on, partly because it can be difficult for students to visualize processes that occur at small scales: the motion of diffusing species is on the molecular level, and the generated concentration gradients can be on the scale of microns. To teach the concept of diffusion and how to extract time information from concentration gradients, we have developed an activity that uses gelatin and food coloring. This activity can be tailored to suit students of different education levels, from high school to graduate school, and can be modified to investigate the influence of different parameters, including temperature and different diffusing species.

The diffusion activity uses a classic “diffusion couple” setup in which colored gelatin is poured on top of non-colored gelatin. Over the course of hours to days, the once-sharp boundary becomes “blurry”, and the food coloring diffuses into the non-colored gelatin. The exercises can be modified to be purely qualitative, or to quantitatively solve for diffusivity with Excel or coding. In addition, these modifications can incorporate lessons on other computational and thermodynamic concepts, including linear regressions, coding skills, and Arrhenius relationships. This experiment makes diffusion modeling a fun, more accessible concept and gives students an understanding of the work needed to derive common diffusivity expressions and limitations of published diffusivity expressions.

775

Multidisciplinary characterization of the explosive degassing at Stromboli volcano from high-frequency UV, thermal, visual and acoustic time series

Dr Elisabetta Del Bello[1], Dr. Emanuela Bagnato[2], Dr. Giancarlo Tamburello[3], Dr. Laura Spina[1], Dr Tullio Ricci[1], Dr. Jacopo Taddeucci[1], Dr. Piergiorgio Scarlato[1], Dr. Daniele Andronico[4], Dr. Francesco Pennacchia[1]
[1]Istituto Nazionale Di Geofisica E Vulcanologia, Sezione di Roma 1, Italy, [2]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Napoli - Osservatorio Vesuviano, Italy, [3]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Bologna, Italy, [4]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy

Stromboli volcano offers a rare opportunity to study active volcanic processes using a multitude of techniques, such as UV camera, thermal and visible imagery and acoustic signals. These integrated approaches enable high-frequency acquisition of volcanic phenomena, providing insights into rapid processes, such as Strombolian explosions, and quantification of several parameters, including mass or volume flow rates of gas and pyroclasts, output rates, onset, duration and energy of explosions.
We recorded high-frequency, multi-parametric measurements of the ongoing explosive activity in October 2020, when discrete ordinary Strombolian events occurred, and in May 2021, when we observed a peculiar spattering activity. Daily, we acquired 2-5 hours-long continuous time series of UV, thermal infrared and visible imagery, and acoustic data. UV images were processed to calculate SO2 fluxes along sections perpendicularly oriented to the plume transport direction. Thermally, we integrated the frame-by-frame maximum brightness temperature obtaining the time variation of the explosions-related temperature anomaly. Visually, we applied an optical flow algorithm obtaining the plume and pyroclast ejection speed variations. From acoustic signals we obtained the temporal evolution of the spectral properties of the different eruptive styles. Wavelet analysis of a subset of ordinary events also provided information on the dynamics of volcanic jets.

The integrated analysis of the datasets allowed us to identify different active and passive degassing patterns occurring at the summit vents, and to discriminate between the observed activity styles. A correlation of the thermal and SO2 signals is observed both in terms of frequency and amplitude of mean peaks, particularly at the onset of each explosion. In some cases, the mean vent-specific masses and fluxes emitted by individual explosions were also determined. The high acquisition rate of our data provided more refined quantitative eruption parameters than those obtained by standard, low-frequency methodologies, further constrained by the estimates obtained using independent methods.

878

Tephrostratigraphy of deep-sea marine sequences. What could be learnt from Montagne Pelée volcano?

Giulia Del Manzo[1], Anne Le Friant[1], Benoît Villemant[2], Benoît Caron[2]
[1]Institut De Physique Du Globe, Université Paris Cité, Paris, France, [2]Institut des Sciences de la Terre de Paris, Sorbonne Université, Paris, France

Volcaniclastic material have a major contribution in sedimentation around active volcanic island with input almost as high as the background's sedimentation of hemipelagic and siliciclastic material.

Marine tephrostratigraphy is the key for understanding what onshore deposits cannot tell us due to their repeated destruction by the eruptive processes themselves and the volcano flank collapse events.

We studied the exceptionally long and weakly disturbed sediment record of the drilling site IODP U1397A offshore Martinique, to reconstruct the volcanic history of the central segment of Lesser Antilles Arc during the last ~130 ka. Combining marine tephrostratigraphy and sedimentology of deposits, morphology and geochemistry of volcaniclastic material, we infer the frequency, the chronology, the eruptive dynamic and the magmatic evolution of this part of the Arc, with special emphasis to Mt. Pelée volcano.

Tephra layers, representing ash fallouts are distinguished from all other gravity-driven deposits generated either by primary eruption or by secondary remobilization processes.

A wide variety of lithofacies are found in deposits that origin from different types of sediment gravity flows of juvenile and reworked material (i.e. ocean bottom current deposits, low-density and high-density turbidites, granular flows and slump/slide, debris flows). A comprehensive framework was established and related to the on-land activity from Martinique and Dominica island.

One of the major results of this work is the interplay of the subaerial volcanic activity with the sediment gravity flows. Where the airborne-tephra fallout record becomes more degraded, deposits from gravity flows result more frequent and capable to record the primary volcanic signature of earlier eruptions with little lag in deposition.

1183

Updating the 1992 Island of Hawaiʻi Lava-Flow Hazard Zone Map

Dr Natalia Deligne[1], Dr James Kauahikaua[1], Mr Frank Trusdell[1], Ms Katherine Mulliken[2], Dr Kyle Anderson[3], Dr Jessica Ball[3], Dr Hannah Dietterich[4], Dr David Hyman[1]
[1]US Geological Survey - Hawaiian Volcano Observatory, Hilo, United States, [2]Research Corporation of the University of Hawai'i, Hilo, United States, [3]U.S. Geological Survey - California Volcano Observatory, Moffett Field, United States, [4]U.S. Geological Survey - Alaska Volcano Observatory, Anchorage, United States

In 1992, the U.S. Geological Survey published a long-term lava-flow hazard map for the Island of Hawaiʻi, which comprises five volcanoes (Wright and others, 1992, USGS MF-2193). The 1992 map divided the island into nine zones, ranging from the highest hazard at the summit and rift zones of Kīlauea and Mauna Loa (the two most active volcanoes) to the lowest hazard at Kohala volcano, which has not erupted in 60,000 years.

Long-term hazard was based on lava flow coverage rates derived from geologic mapping of the whole island. While the text on the 1992 map stresses that it shows "relative hazard…. and [is] meant to be used for general planning purposes," in practice, external entities have applied it in other ways. For example, hazard zonation has been used to determine home insurance access and rates, which the U.S. Geological Survey did not intend for.

Informal discussions with partner agencies following the 2018 Kīlauea eruption indicated confusion and misunderstanding about the map's purpose, and concerns that it might be outdated and obsolete. Both issues provided an opportunity to (1) revise the map based on geologic mapping undertaken during the intervening years, (2) update the explanatory text to incorporate product usability standards, and (3) explore user-friendly map symbology that is color-blind accessible and better conveys the gradational nature of the zone boundaries.

Here, we detail our process for updating the map. New geologic data is consistent with the 1992 long-term hazard assessment. While we have kept the nine lava zones, we have modified the zone definitions to remove references to specific volcanoes, adjusted the zone boundaries, and reassigned three areas based on the new definitions. Further, we are reviewing our partners' needs and developing a communications plan to promote better comprehension and more appropriate use of the updated map.

684

Responding to an evolving situation at Taʻū volcano in the Manuʻa Islands of American Samoa

Dr Natalia Deligne[1], Mrs. Elinor Lutu-McMoore[2], Mr. Marcus Langkilde II[2], Dr. Jefferson Chang[1], Dr. Drew Downs[1], Dr. Matthew Haney[3], Dr. Ken Hon[1], Dr. Art Jolly[1], Ms. Katherine Mulliken[4], Dr. Wendy Stovall[5], Dr. Aaron Wech[3]

[1]US Geological Survey - Hawaiian Volcano Observatory, Hilo, United States, [2]NOAA National Weather Service Pago Pago Office, Pago Pago, United States, [3]US Geological Survey - Alaska Volcano Observatory, Anchorage, United States, [4]Research Corporation of the University of Hawai'i, Hilo, United States, [5]US Geological Survey - Yellowstone Volcano Observatory, Vancouver, United States

The Manuʻa Islands (Ofu, Olosega, and Taʻū) of American Samoa are small, remote volcanic islands in the South Pacific, ~100 km east of the population center on Tutuila. These islands were the first place Polynesian people arrived in the Samoan Islands, and were the center of power for many generations. Today, the proud legacy continues, with a strong adherence to Faʻa Sāmoa – the traditional cultural way of life.

Formed by the Samoan hotspot, the Manuʻa Islands are the exposed tops of extensive underwater volcanoes. The only documented eruption occurred ~3 km off the coast of Olosega in 1866. Until mid-2022, there was no volcano monitoring in American Samoa.

This changed after onset of felt seismicity in the Manuʻa Islands in late July 2022, first reported to the NOAA National Weather Service Pago Pago Office (NWS). The USGS (responsible for geohazards monitoring) become involved on August 7. Initially, seismicity was attributed to Vailuluʻu, a young seamount ~40 km east of Taʻū Island. On August 11, USGS personnel travelled to American Samoa, and a few days later, with NWS, rapidly installed 2 rudimentary short-period seismometers in the Manuʻa Islands. Within a day, the source of seismicity was narrowed down to somewhere within the Manuʻa Islands. Within two weeks, 3 broadband and 2 additional short-period seismometers were installed, and Taʻū volcano was identified as the source of the swarm.

At the time of writing, the seismic swarm has been ongoing for over a month. We do not know what the coming weeks and months holds. We share our journey serving the people of the Manuʻa Islands and American Samoa. We discuss building and strengthening partnerships across different levels of government, engaging affected communities in a culturally sensitive manner, rapidly building a monitoring network from scratch, and communicating hazard information during uncertain times.

1325

Perceived risk vs. objective risk: understanding the gap to minimize it

Professor Pierfrrancesco Dellino[1], Dr. Anna Rinaldi[1]
[1]*Università Di Bari, Bari, Italy*

From the comparative analysis of the fields of natural sciences, economic sciences, and psychological sciences it is possible to decline for the same type of event as an objective (statistical) risk and as a subjective (perceived) risk. The objective risk can be thought of as an independent variable of the harmful event; while the subjective risk - understood as the perception of the objective risk - is more composite: it is closely linked to the representation of the harmful event, to the individual characteristics of the subject dealing with it, to its management and communication and to the implementation of citizens and policy makers' choices.

The aim of this work is to investigate, in a behavioral experimental perspective, the deviation between objective and subjective risk of the calamitous of residents in areas at risk of eruption event, in order to predict – via a.i. - their choices. We intend to focus on the individual prevention behaviour in the framework of risky choice considered as a function of perceived risk and expected benefit.

1313

Probabilistic hazard maps of dilute pyroclastic density current at Vesuvius

Professor Pierfrrancesco Dellino[1], Professor Roberto Sulpizio[1], Professor Daniela Mele[1], Dr. Fabio Dioguardi[1], Dr. Anna Rinaldi[1]
[1]*Università Di Bari, Bari, Italy*

Dilute pyroclastic density currents are one major source of hazard at Vesuvius. By combining data of deposits of the explosive eruptions of the last 6 thousands years, and interpolating data of impact parameters (Velocity, Density, particle volumetric concentration, temperature, dynamic pressure), which were calculated by modeling the currents as stratified turbulent boundary layer flows, probabilistic hazard maps were obtained. They show the decay trend of the impact as a function of distance from the vent, and allow depicting the expected damage. This outcome can help civil protection authorities to more precisely implement mitigation measures and communicate more effectively the risk to decision makers and the population.

1009

Volcanic explosive eruptions sequestrate more carbon in soils than what they emit into the atmosphere

Professor Pierre Delmelle[1], Dr Sebastien Biasse[2], Dr Mathilde Paque[1], Benjamin Lobet[1]
[1]Earth & Life Institute, Uclouvain, Louvain-la-neuve, Belgium, [2]Department of Earth Sciences, University of Geneva, Geneva, Switzerland

Soils buried beneath natural sediments contain a substantial but poorly quantified store of soil organic carbon (SOC). Volcanically-active regions likely represent hot spots of SOC burial as organic-carbon-rich volcanic soils are, over time, repeatedly isolated from the surface by tephra fallout from explosive eruptions. Each tephra deposit initiates new volcanic soil formation and concomitant rapid SOC accretion until the next burial. The efficacy of SOC sequestration beneath tephra remains unconstrained, hindering estimation of the SOC reservoir size in these regions. Moreover, the tephra-buried SOC store may be offset by the magmatic CO2 emissions accompanying explosive eruptions. Here we develop a modelling framework for predicting the spatio-temporal evolution of the SOC stock in areas repeatedly affected by tephra fallout. Applying this to the Ecuadorian Andes, we find that a substantial amount of SOC accumulated in tephra-buried soils throughout the Holocene, possibly representing ~30% of the country's total SOC stock (to 1 m depth). This mass of buried SOC is also consistently higher than the total magmatic carbon released explosively over the same period. Our study provides a novel method for quantifying SOC storage in areas prone to tephra fallout. It also reveals, counterintuitively, that explosive eruptions ultimately act as carbon sinks.

215

Short-term probabilistic eruption forecasting at Whakaari, New Zealand

Dr David Dempsey[1], Assoc. Prof. Andreas Kempa-Liehr[2], Dr Alberto Ardid[1], Prof. Shane Cronin[2]
[1]University of Canterbury, Christchurch, New Zealand, [2]University of Auckland, Auckland, New Zealand

Phreatic explosions at tourist-visited volcanoes are difficult to forecast, as illustrated by the deadly 2019 Whakaari (New Zealand) eruption. Quantifying eruption likelihood is essential for risk calculations that underpin volcano access decisions and disaster response. Here, we develop two models for short-term (48-hour) probabilistic forecasting of phreatic eruptions at Whakaari, and evaluate their accuracy alongside expert elicitation. The two models are based on pseudo-prospective analysis of seven Whakaari eruptions whose precursors were identified by time-series feature engineering of continuous seismic data.

The first model, an alarm-style system, could anticipate six out of seven eruptions at the cost of 14 alarm days each year. When an alarm is in effect, the probability of eruption is 8.1% in 48-hours, about 126 times higher than outside the alarm. The second model used isotonic calibration to map forecast model output onto a probability scale. When applied 48-hours prior to the Dec 2019 eruption, this method indicated an eruption probability up to 400 times higher than the background.

Finally, we quantified the accuracy of these data-driven forecasts as well as expert elicitation. To do this, we used a forecast skill score that was benchmarked against the average rate of eruptions at Whakaari between 2011 and 2019. This score highlighted the conditions under which the different forecasting approaches performed well, and where potential improvements could be made.

575

The gas hazard increase at Vulcano, Italy, caused by the sudden injection of volcanic carbon dioxide into the air

Dr Roberto M. R. Di Martino[1], Dr Sergio Gurrieri[1], Dr Marco Camarda[1], Vincenzo Francofonte[1]
[1]*Istituto Nazionale Di Geofisica E Vulcanologia, Palermo, Italy*

Volcanic degassing raises the concentrations of some components above the air background (i.e., carbon dioxide, sulfur compounds) and imprints its isotopic signatures on some elemental components (i.e., carbon, oxygen, and sulfur). Both chemical and isotopic signals can help tracking the evolution of volcanic degassing and risks. The gases establish the potential for magma ascent and eruption, and the rate of degassing determines various risks for lava effusions, explosions, and emissions of some asphyxiating gases (i.e., the so-called “gas hazard”).

This study reports on some ground-based observations aimed to quantify the impact of volcanic degassing on the atmosphere at Vulcano, Italy. We adopted a combined approach based on the continuous monitoring of ϕCO_2, air CO_2 concentration at fixed points of interest, and periodic surveys for studying spatial variations of the air CO_2 concentration and its isotopic composition (i.e., carbon and oxygen). In June 2021, four stations were deployed at Vulcano for gas hazard monitoring purposes. Each station measures the ϕCO_2, CO_2 concentration in the air at various altitudes, and some environmental variables (i.e., atmospheric pressure, air temperature, wind speed, wind direction, and rain). Five surveys of stable isotopes in the air CO_2 have been performed at Vulcano, using a mobile laboratory equipped with a laser-based isotope analyser.

The stable isotope surveys allow estimating the volcanic CO_2 in the air. The ϕCO_2 and the crater plume affect the gas hazard at Vulcano Porto. The ϕCO_2 and air CO_2 concentration revealed that in the late summer of 2021 the increase in volcanic degassing affected the air CO_2 at Vulcano. The results of this study show that gas hazard mitigation includes prompt actions based on a combination of periodic surveys to identify the point of interest for gas monitoring, and detection of volcanic degassing changes through continuous monitoring of ϕCO_2 and air CO_2 concentration.

968

Non-Linearity probed with Distributed Dynamic Strain Sensing (DDSS) in a Volcanic Regime

Mr Sergio Diaz[1,2], Dr Philippe Jousset[1], Dr Gilda Currenti[3], Mrs Lucile Costes[1], Dr Charlotte Krawczyk[1,2]
[1]GFZ-Potsdam, Potsdam, Germany, [2]TU Berlin, Berlin, Germany, [3]INGV, Catania, Italy

Energy released during volcanic eruptions is partitioned as seismic waves and acoustic waves, that propagate in the ground and in the atmosphere, respectively. Understanding the interaction between acoustic waves from volcanic explosions and non-compacted media is relevant for addressing hazards such as induced landslides. In this work, Mt. Etna, one of the most active volcanoes in the world, serves as ideal site to observe this interaction. During 3 months in 2019, we recorded signals from thousands of mild volcanic explosions using a multi-instrument network deployed at ca. 2.5 km distance from the active craters. Infrasound sensors were laying at the surface, broadband seismometers (BB) and an optical fiber were buried in a scoria layer at ca. 30 cm depth. The BB and Distributed Dynamic Strain Sensing (DDSS, also known as DAS) records show arrivals of seismic waves with low frequencies (1-10 Hz) followed by high frequency signals (15-30 Hz) arriving at the same time as the infrasound signals. These observations suggest that the ground response of the loose granular medium (scoria) is triggered by the acoustic pressure pulses as a resonance of the scoria layer above the substratum. Nevertheless, not all infrasound events trigger this high frequency ground response. To characterize this phenomenon, we relate the peak-to-peak (p-p) amplitudes of infrasound signals and their derivative against p-p amplitudes of DDSS filtered signals (15-50 Hz). The results indicate that some parts of the fiber exhibit a non-linear relationship between these variables, which seems to be related to the properties in the medium (local thickness of the loose material, fractures, etc.). The outcomes of this work bring up new challenges to achieve a better understanding of acoustic-to-ground energy coupling in volcanic environments and their potential to trigger other hazards.

969

Gases measurements by drones for plume content analysis in Italian volcanic and geothermal areas

Dr Jorge Andres Diaz[1,2], Dr Vito Romaniello[3], Dr Rosario Avino[3], Dr Malvina Silvestri[3], Dr Federico Rabuffi[3,4], Dr Enrica Marotta[3], Dr Fabrizia Buongiorno[3], Dr Ernesto Corrales[2], Dr Massimo Musacchio[3], Dr Gala Avvisati[3], Dr Pasquale Belviso[3]

[1]INFICON Inc., Esat Syracuse, USA, [2]GasLab. CICANUM. Universidad de Costa Rica, San Jose, Costa Rica, [3]Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy, [4]Dipartimento di Scienze, Università degli Studi Roma Tre, Rome, Italy

The measurement of volcanic gases as CO2 and SO2 emitted from summit craters and fumaroles is a crucial parameter to monitor the volcanic activity, providing gas flux and geochemical information that helps to determine the status and risk of an active volcano.

During high degassing events, the measurements of volcanic emissions is a risky task that cannot be performed using hand portable or backpack carried gas analysis systems. Measurements of active plumes could be safety achieved by using in situ and near remote optical sensors mounted on UAS (Unmanned Aerial System). In this work, we present the measurements of H2O, CO2, SO2, and H2S gases obtained with different airborne multi-gas analysis systems as well as visible and thermal images to access volcanic activity. The field campaigns took place in three Italian thermally active areas: Parco delle Biancane (Grosseto, Tuscany), Solfatara (Naples, Campania) and Stromboli vulcano (Messina, Sicily). The UAS gas information also serves as in situ calibration for spaceborne satellite instruments.

990

Aerodynamic characteristics and genesis of aggregates at Sakurajima Volcano, Japan

Miss Maria Carolina Diaz Vecino[1], Dr. Eduardo Rossi[1], Dr. Valentin Freret-Lorgeril[1], Dr. Allan Fries[1], Dr. Pietro Gabellini[2], Dr Jonathan Lemus[1], Dr. Stefano Pollastri[1], Dr. Alexandros Poulidis[3], Dr. Masato Iguchi[4], Prof. Costanza Bonadonna[1]

[1]University of Geneva, Geneva, Switzerland, [2]University of Florence, Florence, Italy, [3]University of Bremen, Bremen, Germany, [4]Kyoto University, Kagoshima, Japan

Aggregation of volcanic ash is known to significantly impact sedimentation from volcanic plumes. The study of particle aggregates during tephra fallout is crucial to increase our understanding of both ash aggregation and sedimentation. In this work, we describe key features of ash aggregates and ash sedimentation associated with eleven Vulcanian explosions at Sakurajima Volcano (Japan) based on state-of-the-art sampling techniques. We identified five types of aggregates of both Particle Cluster (PC) and Accretionary Pellet (AP) categories. In particular, we found that PCs and the first and third type of APs can coexist within the same eruption in rainy conditions. We also found that the aerodynamic properties of aggregates (e.g., terminal velocity and density) depend on their type. In addition, grainsize analysis revealed that characteristics of the grainsize distributions (GSDs) of tephra samples correlate with the typology of the aggregates identified. In fact, bimodal GSDs correlate with the presence of cored clusters (PC3) and liquid pellets (AP3), while unimodal GSDs correlate either with the occurrence of ash clusters (PC1) or with the large particles (coarse ash) coated by fine ash (PC2).

674

Developing and communicating the next generation of lava flow hazard products in Hawaiʻi

Dr Hannah Dietterich[1], Dr David Hyman[2], Dr Roger Delinger[3], Dr Kyle Anderson[4], Dr Frank Trusdell[5], Dr Natalia Deligne[5], Dr Jim Kauahikaua[5], Ms Katie Mulliken[2], Mr Talmadge Magno[6]
[1]USGS Alaska Volcano Observatory, Anchorage, United States, [2]Hawaiian Volcano Observatory - Center for the Study of Active Volcanoes, Hilo, United States, [3]USGS Cascades Volcano Observatory, Vancouver, United States, [4]USGS California Volcano Observatory, Moffett Field, United States, [5]USGS Hawaiian Volcano Observatory, Hilo, United States, [6]Hawaii County Civil Defense Agency, Hilo, United States

Volcanic hazard assessments are critical to inform eruption planning, response, and recovery by scientists and stakeholders. However, needs vary greatly between the short-term (hours to days) forecasts required during eruptions and longer-term hazard maps intended for use over decades to centuries. In Hawaiʻi, effusive eruptions frequently threaten local communities, inspiring a long history of work assessing lava flow hazards. We are now creating the next generation of lava flow hazard products in Hawaiʻi using physics-based lava flow models and probabilistic frameworks, with development informed by input from the Hawaiʻi County Civil Defense Agency. In addition to assessing regions at risk of lava inundation, these new methods address timescales of lava advance and warning from different potential source regions using Bayesian methods. The results form the basis for improved short-term (hours to days) lava flow forecasts and more detailed intermediate-term (years) lava flow hazard maps. The short-term forecasts use a new physics-based depth-averaged lava flow model with thermal stratification to simulate lava flow propagation on operational timescales (< hours) and produce maps of inundation through time. To effectively respond to eruption crises, we plan to integrate monitoring data into ensemble forecasts which incorporate uncertainty in eruption parameters and physics using sets of model runs. Output includes forecasts of both inundation area and timing of lava advance. Over longer timescales, the same Bayesian statistical framework incorporates eruptive history data from geologic mapping and topographic data to generate maps of the probability of lava flow inundation. These products incorporate fine-scale topographic changes from recent eruptions to generate updated results relevant in the intermediate-term (years), thus bridging the gap between short-term forecasts and the existing zonal long-term lava hazard map.

675

Multi-sensor remote sensing of effusive eruption dynamics and lava flow morphology at Great Sitkin Volcano, Alaska

Dr Hannah Dietterich[1], Dr Simon Plank[2], Dr Matthew Loewen[1]
[1]Usgs Alaska Volcano Observatory, Anchorage, United States, [2]German Aerospace Center (DLR), Oberpfaffenhofen, Germany

Remote sensing of effusive eruptions is critical for monitoring and assessment of lava flow morphology and dynamics. For remote eruptions, such as the 2021–present explosive and effusive eruption of Great Sitkin Volcano in the central Aleutian Islands, Alaska, remote sensing provides our primary dataset for characterizing eruptive behavior and assessing hazards. Following precursory seismicity, SO2 emissions, and elevated surface temperatures, a vulcanian eruption at Great Sitkin on 26 May 2021 marked the onset of an ongoing eruptive period (as of submission). More than 14 months of lava effusion has filled most of the volcano's summit crater with lava (~1.1 km in diameter) and spilled down the upper flanks of the edifice, forming flow lobes up to 1.2 km long. We integrate a time series of multi-sensor remote sensing from thermal, optical, and radar sensors to track the three-dimensional emplacement and thermal emissions of ongoing lava effusion at Great Sitkin. Very-high-spatial-resolution (≤1-meter) synthetic aperture radar imagery and bistatic acquisitions from TerraSAR-X/TanDEM-X and optical imagery from Maxar, including stereo and shortwave infrared acquisitions, have allowed detailed quantification of the lava flow morphology (including flow extent, thickness, volume, and surface morphology) through time. We also analyze multi-sensor thermal imagery (MODIS, VIIRS) to track the thermal evolution of the lava flow at higher temporal resolution (hours) but coarser spatial resolution (0.4¬–1 km). Higher spatial resolution (90-meter) night-time Landsat-8/9 data allow more detailed analysis of thermal activity. Our results combine with modeling to indicate effusion rates of up to 7 m^3/s, viscosities of ~10^{10} Pa s, and the evolving emplacement dynamics from endogenous to exogenous growth and interaction with both glacial ice and topography. We compare these to corresponding geochemical and geophysical datasets, including samples from the 2021 explosive phase and past Great Sitkin eruptions, to assess eruption composition, evolution, and hazards.

1486

Observations and insights into lava flow emplacement dynamics during the Mauna Loa 2022 eruption

Dr Hannah Dietterich[1], Dr Matthew Patrick[2], Mr Michael Zoeller[2], Dr David Hyman[3], Mr Frank Trusdell[2], Dr Natalia Deligne[2], Dr Drew Downs[2], Dr Elisabeth Gallant[4], Dr Kendra Lynn[2], Dr Carolyn Parcheta[2], Dr Tim Orr[1], Dr Johanne Schmith[3], Dr Julie Chang[4], Dr Brett Walker[4], Ms Katherine Mulliken[3], Ms Lil DeSmither[3], Dr Benjamin Andrews[5], Ms Magdalen Grismer[6], Dr Kathy Cashman[7], Mr Adam Mosbrucker[8], Dr Jessica Ball[9], Dr Paul Lundgren[10]

[1]US Geological Survey Alaska Volcano Observatory, Anchorage, United States, [2]US Geological Survey Hawaiian Volcano Observatory, Hilo, United States, [3]Hawaiian Volcano Observatory - Research Corporation of the University of Hawaiʻi, Hilo, United States, [4]Hawaiian Volcano Observatory, Hilo, United States, [5]Smithsonian Institution National Museum of Natural History, Washington, United States, [6]New Mexico Institute of Mining and Technology, Socorro, United States, [7]University of Oregon, Eugene, United States, [8]US Geological Survey Cascades Volcano Observatory, Vancouver, United States, [9]US Geological Survey California Volcano Observatory, Moffett Field, United States, [10]NASA Jet Propulsion Lab, Pasadena, United States

On November 27, 2022, Mauna Loa volcano started erupting for the first time in 38 years, sending ~200 million m³ of lava across 43 km² over thirteen days, and threatening a highway on the Island of Hawaiʻi. The eruption initiated in the summit caldera of Mokuʻāweoweo, before propagating primarily into the upper Northeast Rift Zone to form four fissures, and by December 2 was focused solely at fissure 3. This fissure produced a braided ʻaʻā flow that traversed the steep north flank at >1 km/hr, before slowing as slopes shallowed. As the eruption progressed, channel blockages caused back-ups and overflows. Effusion rates peaked at onset and then were mostly steady at 100–150 m³/s DRE for the main fissure 3 phase. Lava effusion became variable and then waned on December 8, and the eruption ended on December 10 with a final flow length of 19 km.

Lava flow emplacement was documented using remote sensing, field, and laboratory observations. Flows were mapped from optical and infrared imagery, uncrewed aircraft systems, and airborne single-pass InSAR. Eighteen cameras, including livestream and video-lapse cameras, were rapidly deployed to observe fountain, channel, and flow front dynamics. Daily field crews collected spatter and lava samples and measured channel and cone morphology, fountain heights, and channel velocities. Data were quickly processed to extract estimates of effusion rates, rheology, and changes in eruptive behavior. These were directly applied to lava flow forecasts (Lava2d model) that were provided to emergency managers. Eruptive volume, effusion rates, rheology, and ʻaʻā flow dynamics were within the range of past observed eruptions of Mauna Loa but monitored in unprecedented detail. Despite significant challenges due to rapid eruption onset, limited access, and weather, advance HVO planning and equipment preparation enabled us to collect valuable data regarding fountain and channel dynamics and flow field developments.

988

VIGIL: a Python tool for volcanic and non-volcanic gas hazard quantification

Dr Fabio Dioguardi[1,2], Dr. Silvia Massaro[1,3], Dr. Giovanni Chiodini[3], Dr. Antonio Costa[3], Dr. Arnau Folch[4], Dr. Giovanni Macedonio[5], Dr. Laura Sandri[3], Dr. Jacopo Selva[3], Dr. Giancarlo Tamburello[3]

[1]University Of Bari "Aldo Moro", Dipartimento di Scienze della Terra e Geoambientali, Bari, Italy, [2]British Geological Survey, The Lyell Centre, Edinburgh, United Kingdom, [3]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Bologna, Bologna, Italy, [4]Geociencias Barcelona (GEO3BCN-CSIC), Barcelona, Spain, [5]Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Vesuviano, Naples, Italy

Volcanic and non-volcanic gas emission represent a widespread and frequent hazard. In fact, some gas species (e.g., CO_2, H_2S, SO_2) can affect human health and even threaten life at concentrations and doses above species-specific thresholds. Depending on the starting buoyancy relative to the surrounding atmosphere at the emission location, gas emissions can be classified as dilute passive degassing and dense gas flow. The former occurs when the density of the gas plume is lower than the atmospheric density (e.g. fumaroles), the latter when the gas density is higher than the atmosphere and the gas accumulates on the ground and may flow due to the density contrast with the atmosphere to form a gravity current (e.g. cold CO_2 flows).

Here we present the latest version of VIGIL (automatic probabilistic VolcanIc Gas dIspersion modeLling), a Python simulation tool capable of handling the complex and time-consuming gas dispersion simulation workflow and interfaced with two dispersion models: a dilute (DISGAS) and a dense gas (TWODEE-2) dispersion model. VIGIL allows exploring the uncertainty of the meteorological conditions and gas emission location and strength. The post-processing script offers the option to create Empirical Cumulative Distribution Functions (ECDF) of the gas concentrations combining the outputs of multiple simulations. The ECDF can be interrogated by the user to produce maps of gas concentration at specified exceedance probabilities. Tracking points can also be used to produce time series of gas concentration at selected locations and hazard curves if ECDF is produced. Furthermore, the new gas persistence calculation capability creates maps of the probability to overcome specified gas specie-specific concentration thresholds over specified durations. We also present results from applications at different volcanically and tectonically active areas showcasing the various capabilities of VIGIL.

1434

Computational fluid dynamics tools to investigate multiphase flow dynamics active in real poly-disperse granular flows

Mr FRANCESCO NEGLIA[1], Professor Roberto Sulpizio[1], Dr Fabio Dioguardi[1], Dr Damiano Sarocchi[2]
[1]*University of Bari, BARI, ITALY,* [2]*Universidad Autónoma de San Luis Potosí, Fasano, Italia*

Granular flows consist of discrete macroscopic particles. If they are non-cohesive, their status is determined by the interaction of particle-particle frictional forces, external boundaries and gravity. In particular, the understanding of the transport mechanisms of granular materials is of paramount importance for the characterization of volcanic granular flows and for hazard assessments associated with these flows. In order to investigate dynamics of these kinds of flows, we replicated large-scale experiments with multiphase computational fluid dynamic (CFD) simulations using the Two-Fluid Model approach, with an emphasis on the polydispersity effect on the flow behaviour. The CFD simulations were run using the software MFIX. The present work consists of: 1) investigations on the drag force relationships implemented in MFIX; 2) applications of MFIX to replicate large-scale experiments on volcanic dry granular flows sliding on an inclined channel; 3) comparisons between experimental and simulated data with particular emphasis on the velocity of the granular flow front. Simulations on poly-disperse granular flows demonstrated the simulated flows capability to replicate segregation dynamics active in real granular flows, and the polydispersity effects on velocities and shapes of granular flows. In particular, the greater the number of the solid phases, the lower the velocity of granular flows and the mean square error, which decreases by ca. 50 %. The non-uniformity of solid phases highly affects the dynamic of the whole flow and results in a better agreement between simulated and experimental flow velocities than the simplest mono-disperse particles systems.

1122

The volcanic risk perceptions of residents in and near the Auckland Volcanic Field: lessons for planning in a multi-hazard environment

Dr Angela Doherty[1], Mr. Aidan Milner[1], Ms. Jasmine Fowler[1], Ms. Melanie Hutton[1]
[1]*Auckland Council - Auckland Emergency Management, Auckland, New Zealand*

Tāmaki Makaurau - the Auckland Region, is the most populated and culturally diverse region in Aotearoa - New Zealand, and also contributes approximately 40% of the country's GDP. A large proportion of the population, lifelines, trade and business infrastructure is concentrated in the centre of the region, atop the active, monogenetic Auckland Volcanic Field. Residents are also at risk from the impacts of volcanic eruptions located outside of the Auckland region, including impacts from eruptions around the world on global trade and travel routes.

Over 80% of the respondents to Auckland Emergency Management's twice-yearly preparedness survey indicate they have a good general understanding of hazards that might impact them in their area, and the response needed in most emergencies. However, while volcanic eruptions are often rated as one of the top 2 hazards that concern Auckland residents, 60% of residents do not feel confident they know the steps to take specifically in response to a volcanic eruption.

According to the survey, over half of respondents would still look to Auckland Emergency Management for instruction in times of volcanic crisis as well as the traditional and social media. However, static guidance in the form of website and written information (brochures, lists, guidebooks) are still the preferred form of preparedness engagement outside of emergency events.

Qualitative risk assessments being developed by Auckland Emergency Management with their operational and welfare support partners will identify the specific impacts both near and far-field volcanic hazards may have on our communities. Using the risk assessments and results of the preparedness survey, an updated contingency plan will be developed in 2023 to ensure the preparedness messaging, processes and information developed for our communities to use in times of volcanic crisis will be fit for purpose.

183

Monitoring of landslide displacements in Owakudani, Hakone volcano, Japan using SAR interferometry

Dr Ryosuke Doke[1], Mr Satoru Sanoki[2], Mr Shoji Iwanaga[2], Dr Masaru Sato[2], Mr Kenichi Hosono[2], Mr Eiji Tominaga[2]

[1]Hot Springs Research Institute of Kanagawa Prefecture, Odawara, Japan, [2]Geosciences Research Laboratory, Yamato, Japan

The area around Hakone volcano, which is located western part of Kanagawa Prefecture, is one of the heaviest rainfall areas in Japan. Owakudani (Owakuzawa Valley), the largest fumarole area in the volcano, is a sightseeing spot that approximately 3 million people visit per year and a major hot spring water production site. On the other hand, Owakudani is a place where volcanic disasters occur all the time, such as the mudslide disaster that killed six people in 1910 and the phreatic eruption in 2015. Therefore, it is important to monitor surface displacements that may lead to slope failure to protect life and property. This study estimated 1) 3-D displacement around Owakudani by DInSAR analysis and 2) time series slope displacements by SBAS-InSAR analysis of ALOS-2/PALSAR-2 data. The results of this study are as follow;

1) 3-D displacement around Owakudani
3-D displacement around Owakudani was estimated using multiple DInSAR analysis results between 2017 and 2020. The result shows approximately 15 cm of displacement in the NNW direction, which corresponds with the inclination direction of slope, at the right bank of the Owakuzawa Valley for three years.

2) Result of InSAR time series analysis
The SBAS-InSAR time series analysis of ALOS-2/PALSAR-2 data (Path 18) during 2014-2021 shows that the right bank of the Owakuzawa Valley was displaced away from the satellite, and its velocity was estimated to be more than 4.0 cm/year. The displacement time series at this site tends to accelerate from autumn to winter, suggesting that landslide displacement may have accelerated during heavy rainfall (such as typhoon) seasons.

We performed an inversion analysis of this landslide displacement to identify areas of decrease in rigidity on the slope and its subsurface. In the presentation, we will also present the result of the inversion analysis.

182

Structure of the shallow hydrothermal system in Hakone volcano, Japan, inferred from InSAR analysis

Dr Ryosuke Doke[1], Dr Kazutaka Mannen[1], Mr George Kikugawa[1], Mr Kazuhiro Itadera[1]
[1]*Hot Springs Research Institute of Kanagawa Prefecture, Odawara, Japan*

Detecting and monitoring a hydrothermal system can play an important role in predicting a phreatic eruption. In this presentation, we present surface deformations caused by the hydrothermal system of Hakone volcano, as detected by Interferometric Synthetic Aperture Radar (InSAR) before, during, and after the 2015 eruption.

The opening of the NW-SE-trending crack and localized uplift in the Owakudani fumarole area were captured by InSAR analyses during the 2015 unrest at Hakone volcano (Doke et al., 2018 EPS). Based on models explaining these surface displacements, the shallow hydrothermal system of Hakone volcano is characterized by NW-SE to WNW-ESE-trending crack-shaped fluid supply paths and pocket-shaped fluid reservoirs. During the 2015 and previous phreatic eruptions, it is probable that fluid was supplied using the same crack-like path, implying that fluid was repeatedly supplied using the same structure. Moreover, the InSAR time series analysis before the eruption showed subsidence considered as deflation of an old fluid reservoir on the west side of the Owakudani fumarole area (Doke et al., 2020 Remote Sensing).

After the 2015 eruption, the InSAR time series analysis result shows the subsidence of the central cones of Hakone volcano (Doke et al., 2021 GRL). One possible cause of this subsidence is compaction due to a decrease in pore pressure caused by rupture and fluid migration during and after the eruption. Based on this hypothesis, approximately 5 mm/year of subsidence is predicted even 100 years after the eruption. However, if the sealing ability confining the pressure of the hydrothermal system is restored, this deflation will terminate shorter than predicted. Therefore, it is important to monitor the displacement at the ground surface to assess the pressure conditions of the hydrothermal system and the risk of future phreatic eruptions.

1187

Tales from wrinkly lavas: estimating lava flow volumes and the implications of lava surface folds on lava viscosity

Pedro Doll[1], Ben Kennedy[1], Alex Nichols[1], Alina Shevchenko[2], Graham Leonard[3], Dougal Townsend[3], Geoff Kilgour[4], Jim Cole[1]
[1]University Of Canterbury, Christchurch, New Zealand, [2]German Research Centre for Geosciences GFZ, Potsdam, Germany, [3]GNS Science, Lower Hutt, New Zealand, [4]GNS Science, Wairakei, New Zealand

Understanding the recurrence, magnitude and characteristics of effusive volcanic eruptions is essential for accurate hazard assessments and for developing future hazard and impact scenarios. Erupted volumes and physical properties (e.g. lava viscosity) are challenging to estimate for prehistoric effusive deposits, especially andesitic flows. Because of this, we are currently unable to fully quantify the original magnitude and rheological properties of lava flows to better inform our hazard models.

We combine high-resolution DTMs derived from a recently flown LiDAR survey with regional 1-m resolution DTMs and apply surface interpolation and geological modelling to estimate, respectively, the minimum and a most likely volume for prehistoric (<18 ka) andesitic lava flows on Mt. Ruapehu, New Zealand. In addition, we show how the apparent viscosity (ηa; which we calculated from morphological dimensions) of these lavas is correlated to the dominant surface fold wavelength (λD), which we obtain by applying Discrete Fourier Transform Analysis to elevation profiles from lava flows with prominent surface folding. We then compare the andesitic results with flows from other volcanoes ranging from basaltic to rhyolitic compositions. Comparison between λD, bulk lava composition and ηa supports the hypothesis that λD are exponentially related to lava viscosity (and therefore related to lava composition, crystallinity and volatile content) rather than purely to its SiO_2 content.

These results demonstrate the correlation between viscosity and surface fold morphology and present a simple and quick way to estimate viscosities of solidified folded lava flows. Our analysis of prehistoric data is a step towards improved understanding of magnitudes, physical properties and hazards of lava flows on Ruapehu.

1050

Compound hazards and their cascading impacts: a forensic analysis of the 2021 Cumbre Vieja eruption (Canary Islands, Spain)

Ms Lucia Dominguez Barragan[1], Dr Corine Frischknecht[1], Mrs Maria-Paz Reyes Hardy[1], Mrs Luigia Di Maio[1], Prof Costanza Bonadonna[1], Dr Nemesio Pérez[2]
[1]University of Geneva, Geneva, Switzerland, [2]Instituto Volcanológico de Canarias (INVOLCAN), San Cristóbal de La Laguna, Tenerife, Spain, [3]Instituto Tecnológico y de Energías Renovables (ITER), Granadilla de Abona, Tenerife, Spain

Comprehensive post-event impact assessments represent a fundamental component of risk reduction strategies. Unravelling the root causes of impacts allows to better understand the different orders of cascading effects that are frequently associated with compound volcanic hazards affecting modern societies. Assessing the impacts of eruptions involve major challenges to elucidate the correlation of hazardous phenomena (involving large variability of volcanic processes and products) with multi-dimensional vulnerabilities (physical, systemic, social, economic) of exposed systems. The 2021-eruption of Cumbre Vieja (La Palma, Spain) represents a typical example where impacts of a monogenetic volcanism and several volcanic products (i.e., lava, tephra and gas) on an insular urban and rural context generated important cascading effects on the critical infrastructure and population. Due to low redundant infrastructure networks, typical of insular environments, major disruptions of the ground transportation and water systems occurred across 10 of the 14 municipalities. Complex cascading effects were subsequently triggered due to the interconnection of these critical infrastructures with facilities (e.g., schools) and economic sectors (e.g., tourism, agriculture). Following a forensic approach, here we identify three orders of impact: i) a first order associated with the physical impact on the road network (i.e., total destruction due to the lava flows); ii) a second order associated with the lack of functionality of the ground transportation in terms of roads disruption (e.g., increasing travel time between areas); and iii) a third order associated with the systemic impacts due to the interconnection between the road network and the water/electricity infrastructure, generating significant impacts on the agriculture and tourism sectors. This forensic analysis of the Cumbre Vieja eruption highlights the importance of considering the different orders of impact to clearly disentangle the role of each component of volcanic risk (i.e., hazard, exposure, vulnerability and resilience). Obtained results can therefore support more targeted preparedness and prevention actions.

1048

Effects of particle grainsize, shape and composition on the aeolian remobilisation of volcanic ash

Ms Lucia Dominguez Barragan[1], Dr Allan Fries[1], Dr Eduardo Rossi[1], Dr Jonathan Merrison[2], Mr Jens Jacob Iversen[2], Dr Paul A Jarvis[3], Prof Costanza Bonadonna[1]

[1]Department of Earth Sciences, University of Geneva, Geneva, Switzerland, [2]Department of Physics and Astronomy, Aarhus University, Aarhus, Denmark, [3]GNS Science, Lower Hutt, New Zealand

Aeolian remobilisation of volcanic ash represents one of the major secondary volcanic hazards affecting public health as well as infrastructures and economic sectors on various temporal and spatial scales. Volcanic eruptions can generate large volumes of fine ash that, once deposited, are often recurrently remobilised by the wind, covering wider areas than primarily affected, for long periods of time (even millennia after eruptions). Whilst aeolian processes of mineral sand (≥ 63 μm), and dust (≤ 63 μm) have been relatively well studied, the removal mechanisms of volcanic ash remain poorly characterised. Magma composition plays a major role in magmatic (or phreatomagmatic) fragmentation and, consequently, the particles emitted, dispersed and deposited display a wide spectrum of grainsizes, densities and morphologies. These properties ultimately determine the threshold friction velocity at which particles will first move (be removed) under the influence of wind. Here we explore the effects of grainsize, particle shape and composition of volcanic ash on remobilisation potential through experiments conducted in a horizontal wind-tunnel. We investigate the removal processes and quantify the threshold friction velocities of three magma compositions (i.e., basalt from La Palma, Spain, 2021; andesite from Sabancaya, Peru, 2018; and rhyolite from Cordón Caulle, Chili, 2011 eruptions) by using sieved samples of known grainsize fractions. We measured the quantity and physical properties (size, shape) of remobilised particles by using horizontal collectors and adhesive tape, as well as airborne particle concentration through optical particle counters at different heights downwind. Additionally, through high-speed image analysis, we describe the relative importance of direct (individual detachment) versus indirect wind entrainment (saltation/reptation induced) processes. Our experiments provide valuable information on the threshold friction velocities of different ash compositions, fundamental for forecasting modelling of remobilisation events.

1037

Textural and compositional fingerprints of Mount Epomeo Green Tuff (Ischia island, Italy) eruption (56.0±1.0 ka): correlation among different proximal outcrops

Dr Claudia D'Oriano[1], Dr Paola Del Carlo[1], Dr. Lucia Pappalardo[2], Dr. Ilenia Arienzo[2], Dr. Sandro De Vita[2], Dr. Mauro Antonio Di Vito[2], Dr. Carlo Pelullo[2], Dr. Gianmarco Buono[2], Prof. Richard Brown[3], Prof. Paola Petrosino[4], Dr. Patrizia Landi[1]

[1]Istituto Nazionale di Geofisica e Vulcanologia (Pi), Pisa, Italy, [2]Istituto Nazionale di Geofisica e Vulcanologia - OV, Napoli, Italy, [3]Durham University, Durham, United Kingdom, [4]Università Di Napoli, Napoli, Italy

Textural and compositional investigations of the juvenile products of an eruption provide a unique picture of the syn-eruption conduit processes. In particular, the magma degassing can be investigated by vesicularity, and the variations in groundmass glass composition and texture can be used for deriving the dynamics and mechanisms of magma ascent and fragmentation. Moreover, information on the kinetic of magma ascent in the conduit can be derived from the microlite and vesicle size distribution, by relating bubble and crystal number density to decompression rate. All this information together provides a complete picture of syn-eruptive processes that are typical of each single eruption.
Here we present the results of a study carried out on a range of deposits exposed along the coastline of Ischia and on Procida and the mainland. These deposits were attributed to the caldera-forming, Monte Epomeo Green Tuff eruption (MEGT; 56±1.0 ka) (Ischia, Italy), based on their stratigraphical and lithological features. Due to the complexity of this high magnitude eruption, we linked geochemical and textural features of groundmass glasses of juvenile clasts, in order to better constrain the different eruptive phases of the MEGT eruption and refine the correlation among different proximal outcrops.
Starting from a detailed componentry characterization of juvenile material, selected in the lapilli-size fraction, we performed analyses of: 1) groundmass glass composition (EMPA; INGV-Rome) to characterize the chemical variability of the identified components; 2) 3D textural data for bubbles (X-ray computed microtomography; INGV-OV), to reconstruct the vesicles-size distribution and bubbles interconnection, which play a fundamental role in the degassing and fragmentation mechanisms. Bubble number density was then used to infer the timescales of magma ascent.

1053

Mapping shallow conduits feeding eruptive vents during the 2021 Fagradajsfjall eruption, Iceland, using high-resolution ICEYE SAR satellite interferometry.

Vincent Drouin[1], Valentyn Tolpekin[2], Michelle Parks[1], Freysteinn Sigmundsson[3], Daniel Leeb[4], Shay Strong[2], Ásta Rut Hjartardóttir[3], Halldór Geirsson[3], Pall Einarsson[3], Benedikt Gunnar Ófeigsson[1]

[1]Icelandic Met Office, Reykjavik, Iceland, [2]ICEYE Oy, Espoo, Finland, [3]Nordic Volcanological Center, University of Iceland, Reykjavik, Iceland, [4]Iceland Space Agency, Reykjavik, Iceland

Using ground deformation measurements of high spatial and temporal resolution, the understanding of new vents created during volcanic eruptions can be improved with 3D mapping of the activated shallow magma plumbing system. Interferometric analysis of radar data from ICEYE X-band satellites with daily coherent ground track repeat (GTR) provides unprecedented time series of deformation in relation to the opening of 6 eruptive vents over 26 days in 2021, at Fagradalsfjall, Iceland. High seismicity started in this location at the end of February. It was linked to gradual formation of a magma-filled dike in the crust and triggered seismicity along the plate boundary. On 19 March, an eruptive fissure opened near the center of the dyke. New vents and eruptive fissures opened on the 5th, 7th, 10th, and 13th April. The daily acquisition rate of the ICEYE satellite facilitated the observation of the ground openings associated with each new vents. Each event can be observed individually and with minimal loss of signal caused by new lava emplacement, which would occur if images were acquired at a slower rate. Being able to retrieve deformation near the edge of the fissure ensures that we have the optimal constraints needed for modelling the subsurface magma path. The descending 1-day interferogram covering each individual event is used to invert for the distributed opening along the dike plane. This allows us to get the approximate conduit structure within the shallow crust. We find that each fissure was associated with opening of up to 0.5 meters in the topmost 200 m of crust. Combining these results with GNSS measurements, it appears the conduits propagated vertically at least 50–80 m/h.

489

Dyke propagation in glacial-volcanotectonic heterogeneous regimes. The case study of Stardalur laccolith, Iceland

Kyriaki Drymoni[1], Alessandro Tibaldi[1,2], Federico Pasquaré Mariotto[3], Fabio Luca Bonali[1,2]
[1]Department of Earth and Environmental Sciences, University of Milan-Bicocca, 20126, Milan , Italy, [2]CRUST-Interuniversity Center for 3D Seismotectonics with Territorial Applications, 66100 , Chieti Scalo, Italy, [3]Department of Human and Innovation Sciences, Insubria University, Como, Italy

Magma ascent in the shallow crust occurs most of the time through dyking. Dykes are pure Mode I extension fractures that supply magma from deep reservoirs to the surface. Subject to their successful propagation, they can feed volcanic eruptions. Anyway, dykes do not always propagate but can also mechanically stall in the heterogeneous crust or deflect through pre-existing fractures. As such, they change their paths and form sills. Although several studies have explored dyke propagation in heterogeneous regimes, the conditions under which dykes propagate in glacial-volcanotectonic regimes remain elusive. Here, we coupled field observations with FEM numerical modelling to explore the mechanical and geometrical conditions that promoted, or did not, dyke-sill transitions in glacial-tectonic conditions. We used as a field example the Stardalur cone sheet-laccolith system, which lies on the Esja peninsula, between the western rift zone and the Tertiary basalts that occur NW of the Icelandic rift. The laccolith is composed of a number of vertical dykes that bend into sills and form a stacked sill structure. Initially, we modelled a heterogeneous crust composed of lavas and hyaloclastites, emplaced by a dyke with varied overpressure (1-10 MPa) and extension (0.5-3 MPa) loading conditions. In the second stage, we added an ice cap to explore dyking subject to loading and unloading due to glacier thickness variations (0-1 km).
Our results have shown that the presence of the ice cap can affect the dyke paths and the spatial accumulation of tensile stress below the cap. They finally enable gaining key insights into dyke-sill interactions in subglacial regimes.

1121

Control of crustal heterogeneities and pre-existing structures on dyke geometries in composite volcanoes

Kyriaki Drymoni[1], John Browning[2], Agust Gudmundsson[3]
[1]Department of Earth and Environmental Sciences, University of Milan-Bicocca, 20126 Milan, Italy, , , [2]Department of Mining Engineering and Department of Structural and Geotechnical Engineering, Pontificia Universidad Católica de Chile, Santiago, , Chile, [3]Department of Earth Sciences, Queen's Building, Royal Holloway University of London Egham, Surrey TW20 0EX, , UK

Magma ascent in the shallow crust occurs primarily through the formation of dykes and inclined sheets. Magma propagates towards the surface and feeds volcanic eruptions by generating predominantly tensile (opening-mode) fractures. However, the crust underlying polygenetic volcanoes is heterogeneous and anisotropic, which are factors known to promote fracture arrest and deflection. Furthermore, dyke-propagation paths may become deflected into existing structures such as fault zones or along previous dyke segments. When combined, these complexities result in a wide variety of dyke geometries that make it difficult to reconstruct the principal emplacement drivers. Deciphering the controls on magma ascent requires detailed examination of dyke geometries in the field and the structure and mechanical properties of the crust underlying composite volcanoes as well as the properties of the rocks that constitute the polygenetic volcanoes themselves.

In this work we present data from fossilised dyke swarms, with a primary focus on a swarm located within the northern caldera wall of Santorini volcano, Greece. The dykes were emplaced in a heterogeneous crustal segment, which is exposed after multiple caldera collapses and un-roofing. We report on dykes that propagated through or, alternatively, became arrested at, layers with varying mechanical properties. We further report dykes that rotated almost 90 degrees to become sills as well as dykes that interacted with both existing fault zones and previously emplaced dykes to form multiple/composite dykes. Finally, we explore dyke-tip geometries of arrested dyke segments in relation to the mechanical properties of the units in which they are located. Common dyke tip geometries range from rounded to thin-out (taper away) tips.

1063

Extrusion rate change during the 2021 dome growth at La Soufrière, St. Vincent quantified from Synthetic Aperture Radar backscatter

Edna Dualeh[1,2], Dr Susanna K. Ebmeier[1], Professor Tim J. Wright[1], Dr. Michael P. Poland[3], Dr. Raphaël Grandin[4], Dr. Adam J. Stinton[5,7], Dr. Michal Camejo-Harry[6,7]

[1]COMET, School of Earth and Environment, University of Leeds, Leeds, United Kingdom, [2]COMET, School of Earth Sciences, University of Bristol, Bristol, United Kingdom, [3]USGS, Yellowstone Volcano Observatory, Vancouver, United States, [4]Université de Paris, Institut de Physique du Globe de Paris, Paris, France, [5]Montserrat Volcano Observatory, Flemmings, Montserrat, [6]Department of Earth Sciences, University of Oxford, Oxford, United Kingdom, [7]The University of the West Indies, Seismic Research Centre, St. Augustine, Trinidad and Tobago

The extrusion rate of a lava dome is critical for monitoring eruptions and forecasting their development. However, it can be challenging to measure due to hazards associated with ground-based measurements, and photogrammetry from UAVs, aircrafts or satellites can be limited by accessibility and cloud cover. For these reasons extrusion rates are often not available at high temporal resolution. Satellite-based Synthetic Aperture Radar (SAR) backscatter can provide unique information about changes in topography during a volcanic eruption, especially when other datasets (e.g., optical, thermal) are limited.

We present an approach to estimating topography from individual SAR images. Using a temporally dense timeseries of SAR backscatter data (TerraSAR-X, COSMO-SkyMed, Sentinel-1) obtained through the CEOS Working Group on Disasters Volcano Demonstrator, we apply this method to the dome-building stage of the 2021 eruption at La Soufrière, St. Vincent. In late December 2020, La Soufrière started a new episode of volcanic activity, with 3-months of dome growth before the eruption transitioned from effusive to explosive in April 2021. We measure a steady extrusion rate (1.8 m^3/s) between December 2020 and March 2021 before observing a rapid increase (17.5 m^3/s) two days prior to the explosive eruption on 9 April. Extrapolating from our SAR measurements, we estimate a final dome volume of 19.4x10^6 m^3, with approximately 15% of the total extruded volume emplaced in the last two days.

We compare our dome volumes retrieved from the SAR images to other measurements made during the eruption (e.g., photogrammetry, seismicity, and SO_2) to examine the accuracy of our method and better understand the transition from effusive to explosive. We show that SAR backscatter can be a powerful tool that can provide quantitative measurements of topographic changes during a volcanic eruption.

419

Understanding volcanic deformation patterns for silicic caldera systems

Edna Dualeh[1], Professor Juliet Biggs[1]
[1]*COMET, School of Earth Sciences, University of Bristol, Bristol, United Kingdom*

High-resolution maps of volcano deformation reveal complexity that was not apparent during the era when volcano geodesy was based on infrequent point measurements. There is no single conceptual model capable of fitting the observations from all systems suggesting that magmatic architectures vary with magma composition, flux rate and evolve with time. Over the long-term (10^3-10^5 years) magma reservoirs grow through short, discrete injections, starting with small, transient magma chambers, which coalesce over time to produce extensive regions of partial melt. Since the response of a magma system to a fresh input of magma depends on the geometry and rheology of the system and the expected patterns of surface deformation should also evolve over time. In this study, we compile Sentinel-1 deformation measurements from silicic caldera systems and compare the patterns observed to geophysical measurements of subsurface melt distribution. For example, Santorini experienced two pulses of uplift in 18 months after >50 years of quiescence and the pattern can be fit by a point source suggesting a source radius of <2 km. In contrast, Laguna del Maule has been uplifting continuously since 2008 and the preferred source is an ellipsoid with semi-axes 10 by 3 km. Both deformation sources are located at 4-5 km depth and recent eruptions are rhyolitic to dacitic at both, so differences in depth or magma viscosity cannot explain the radically different intrusion timescales. However, seismic tomography shows major differences in the distribution of partial melt: beneath Laguna del Maule is a large (~450 km^3), low melt-fraction (~5%) mush zone, whereas the low velocity region at Santorini is just 35±8 km^3 but the melt fraction is higher (4-13%). We conclude that understanding the long-term evolution of magmatic systems is critical to understanding their short-term behaviour, and in particular interpreting deformation patterns.

965

Widespread fracture movements: observations of the 2019–2021 volcano-tectonic episode on the Reykjanes Peninsula from TerraSAR-X interferometry

Cécile Ducrocq[1], Páll Einarsson[1], Vincent Drouin[2], Thóra Árnadóttir[1], Sigurjón Jónsson[3], Ásta Rut Hjartardóttir[1], Halldór Geirsson[1]

[1]Nordic Volcanological Center, Institute of Earth Sciences, University of Iceland, Reykjavík, Iceland, [2]Icelandic Meteorological Office, Reykjavík, Iceland, [3]King Abdullah University of Science and Technology, Thuwal, Saudi Arabia

Mapping of active faults is crucial for assessing the potential tectonic and volcanic hazard within a region. The 2021 eruption of the Fagradalsfjall volcanic area (Reykjanes Peninsula, SW Iceland) was preceded by two years of volcanic unrest. Within this time span, four inflation episodes in the Svartsengi and Krísuvík volcanic areas (~250 km2) were observed and intense seismic activity (including eight MLW ≥ 5 earthquakes) were recorded. Using interferometric synthetic aperture radar (InSAR) analysis of TerraSAR-X data collected in 2019–2021, we mapped fracture motions on the Reykjanes Peninsula. We identified ~1200 active fractures and faults in 54 interferograms during this time period. Our mapping complements previously published data sets, as the InSAR technique allows the detection of mm-scale fracture displacements on both relatively young (<1100 years) and older lava flows. Our study reveals extensive (and at least partly aseismic) faulting and fracture movements across most of the Peninsula, extending from Reykjanes volcanic system in the west to northeast of the Krísuvík volcanic system. We report previously unknown faults beneath the town of Grindavík as well as faulting in the Fagradalsfjall area, active during summer-autumn 2020, prior to the 2021 dyke intrusion. As the location of the long-lasting vent of the 2021 eruption appeared to be co-located on this latter fault, we hypothesise that it may have provided a weakness in the shallow crust that influenced the location of the main eruptive activity. The observations presented in this study are important for improving our understanding of volcano-tectonic interactions in Iceland and worldwide.

350

Induced fuel-coolant interaction: how thermohydraulic explosion mechanisms work in deep-sea settings and how we can identify them

Dr Tobias Duerig[1], Prof. James D. L. White[2], Prof. Bernd Zimanowski[3], Prof. Ralf Büttner[3], Prof. Daniela Mele[4], Prof. Pierfrancesco Dellino[4], Dr. Louise S. Schmidt[5]
[1]University Of Iceland, Reykjavík, Iceland, [2]University of Otago, Dunedin, New Zealand, [3]University of Würzburg, Würzburg, Germany, [4]University of Bari, Bari, Italy, [5]University of Oslo, , Norway

How can deep-ocean high-pressure eruptions produce explosions and volcanic ash? Molten-fuel coolant interaction (MFCI), a thermohydraulic mechanism that leads to powerful explosions and to the fragmentation of magma, requires a pre-mix of magma with entrapped water in a setting where both components are separated by an insulating vapour-film. The latter is sensitive to the ambient pressure, which means that MFCI processes are suppressed in submarine settings at depths larger than 100 m. Recent studies have identified, however, a pressure-insensitive type of explosive interaction between liquid water and hot magma, termed induced fuel-coolant interaction (IFCI). This thermohydraulic mechanism is initiated by the formation of cracks in cooling magma into which the water coolant can infiltrate, driving explosive fragmentation and thus “boosting” the production of fine ash. IFCI was identified as the main process that generated notable amounts of fine ash in the kilometre-deep 2012 submarine eruption of Havre volcano, Kermadec arc, New Zealand. We show results from both numerical models and laboratory experiments with Havre melt that mimic deep-sea explosive eruptions and examine the consequences of our findings for deep-sea eruption scenarios in terms of energy release and resulting products. For example, at surface pressures the force produced during dry gas-driven fragmentation increases by 50% with IFCI, and the proportion of extremely fine ash doubles. We demonstrate that IFCI between magma and water can occur in a wide range of wet environments regardless of pressure, from subaerial to the deep sea, suggesting that induced fuel-coolant interaction might play an unappreciated role in deep submarine eruptions and probably in other eruptions involving water. We discuss differences and similarities between IFCI and MFCI explosions and present a set of indicators that can help volcanologists to identify IFCI processes as main drivers of explosive eruptions.

351

Strategies to improve the real-time mass eruption rate prediction quality of simple and fast plume models

Dr Tobias Duerig[1], Prof. Magnús T. Gudmundsson[1], Prof. Fabio Dioguardi[2], Dr. Louise S. Steffensen[3]
[1]University Of Iceland, Reykjavík, Iceland, [2]University of Bari, Bari, Italy, [3]University of Oslo, Oslo, Norway

When monitoring volcanic ash plumes in real-time during explosive eruptions, plume models are applied to constrain the source conditions, in particular the mass eruption rate (MER). To date, modelling volcanic ash plumes in windy conditions is still challenging. While simple plume models that only require plume height as input tend to underestimate the MER at high windspeeds, explicitly wind-affected plume models account for the atmospheric conditions including windspeeds. The latter models, however, often require the input of adjusted plume heights, which are not necessarily identical to the plume‘s top elevation detected by the monitoring instruments, e.g., by radar. A further source of uncertainties, especially in long-term eruptions with incomplete plume height records, is the dependence of a model's output on the plume height data handling strategy (sampling rate, gap reconstruction methods and statistical treatment). Representing such a scenario with an eruption that featured a wind-affected plume, we compared the model estimates for the different phases of the 2010 Eyjafjallajökull eruption with measured fallout mass and studied the impact of the parameters mentioned above on the MER prediction quality. We tested the sensitivity of simple and explicitly wind-affected plume models against 22 data handling strategies and discuss the results from four different approaches to convert the plume‘s top elevation data into adjusted plume heights. We found that different models, plume height handling and adjustment strategies work best under different conditions. A solution for obtaining accurate estimates in real-time would therefore be to not rely on a single combination of plume model and plume height treatment, but to use a range of such combinations with the possibility to adapt to the scenario monitored.

945

Fluid Entrainment and Flow Mobility in Pyroclastic Density Currents

Dr Josef Dufek[1], Dr. Eric Breard[1]
[1]*University Of Oregon, EUGENE, United States*

Explosively erupting volcanoes generate complex mixtures of gas and particles that can be dominated by turbulence and shocks in dilute domains and by granular interactions in more concentrated regions of flow. The entrainment and mixing of ambient gas can play a predominant role in the dynamics of these flows from determining the height of erupting columns to the propagation of pyroclastic density currents. In this work we conduct a series of highly resolved multiphase numerical calculations to trace parcels of air that are mixed in turbulent structures and examine the two-way feedback in dynamics. We focus on the pyroclastic density current problem in which steady gravitational forcing is oriented roughly perpendicular to flow motion. These calculations are presented in the context of a series of validation studies completed over the past several years, and also present integrated particle and gas flux calculations that can be readily incorporated into recent multilayer depth averaged approaches to improve predicted runouts.
Many previous parameterizations of entrainment are based on experiments of relatively dilute flows, usually with water as the working fluid. We show that values from previous parameterized entrainment coefficients can vary significantly from predicted entrainment in particle-stratified currents. The accumulation of particles at the base of these currents that is enhanced by particle-fluid interaction, leads to a rough dichotomy in the thermal structures and in the differential mobility of the concentrated and dilute portions of the flow. Further we show through passive tracers how entrained air at the top and front of these flows gives rise to pore pressure in the concentrated regions of the flow and self-fluidizes the basal parts of the flow. Finally, we compare a subset of conditions that correspond to highly resolved portions of volcanic jets, with implications for the radial thermal structure of the near vent flow region.

947

Multiscale Dynamics in Eruptive Plumes: Integrating Dispersed Sensor Arrays with Computational Infrastructure

Dr Josef Dufek[1], Dr. Joshua Mendez Harper[1]
[1]*University Of Oregon, EUGENE, United States*

One of the challenges in understanding explosive eruption dynamics is the shortage of constraints from the interior of these complex, compressible, multiphase flows. We have increasing relied on numerical simulations to understand these dynamics, and here we report on the integrated strategy of incorporating dispersed and remote measurements into meso-scale, multiphase simulations in a data assimilation framework. These simulations include a continuum description for gas species and particles, and we have incorporated microphysical relationships to describe hydrous interactions and particle charging. For the sensor component of this work we leverage work on measurement systems in industrial, commercial, and healthcare settings. However, volcanology has some unique challenges, and, in particular, the performance of the wireless channel—that is, how reliably sensors can deliver data from remote, rugged locations using limited amounts of power and bandwidth—remains to be characterized.

To meet the combined challenge of measuring more properties of these flows and incorporating them into physics-based models we discuss: 1. The simulation framework and required subgrid models to incorporate multiscale observations into numerical simulations, 2. Plug and play sensor design and low cost sensor packages that can be rapidly deployed, 3. Aggregating and communicating data from dispersed sensors in rugged terrains. Here, we evaluate the performance of a network of ash detection and gas sensors connected to an internet gateway using three different wireless protocols: 1) 915 MHz LoRa Meshtastic; 2) 433 MHz LoRa Meshtastic; and 3) 2 meter band APRS. We use this data to update simplified simulation parameters at a local cluster facility. We test these procedures using wildfire ash and smoke as a proxy in the rugged Coast and Cascade ranges in Oregon.

444

Testing models for dynamic triggering of volcanic seismicity at Sierra Negra, Galápagos

Miss Eleanor Dunn[1], Professor Chris Bean[1], Dr Andrew Bell[2], Dr Ivan Lokmer[3]
[1]Dublin Institute For Advanced Studies, Dublin, Ireland, [2]University of Edinburgh, Edinburgh, United Kingdom , [3]University College Dublin, Dublin, Ireland

Changes in volcanic activity or unrest often accompany the stress changes associated with large earthquakes. Dynamic earthquake triggering is the process where local earthquakes are triggered by the dynamic stress perturbations associated with the arrival of transient seismic waves from distant earthquakes. Dynamic earthquake triggering has been observed at many volcanoes world-wide, and at earthquake-volcano separation distances of thousands of kilometres. Repeated episodes of dynamic earthquake triggering have been reported at Sierra Negra, a large basaltic shield volcano on Isabela Island, Galápagos. It has a large elliptical summit caldera and a trap-door fault system with a 2km deep sill-like magma reservoir below the caldera. Sierra Negra erupted in June 2018, as part of a cycle involving pre-eruption inflation, co-eruption deflation, and renewed post-eruption inflation. Dynamic earthquake triggering was observed following high magnitude teleseismic events that occurred from 2010-2018, with the number of dynamically triggered earthquakes increasing with increasing inflation of the magma reservoir. However, the locations and mechanisms of triggering have not been determined. Here we use single station methods to constrain the location of triggered and background seismicity, and investigate their timing relative to phases of the triggering waves. We also use data from a temporary seismic deployment to reduce the threshold for detecting triggering, and to support location methods. Our results will offer new insights as to how and why dynamic triggering is prominent at Sierra Negra, and potentially a new tool for monitoring volcano unrest state.

558

Combined aerial and ground-based measurements of mercury in the eruption plume of Fagradalsfjall volcano, Iceland

Brock Edwards[1,2], Melissa Pfeffer[3], Evgenia Ilyinskaya[4], Celine Mandon[5], Alessandro Aiuppa[6], Peter Outridge[1,2], Feiyue Wang[1]

[1]Department of Environment and Geography, University Of Manitoba, Winnipeg, Canada, [2]Natural Resources Canada, Ottawa, Canada, [3]Icelandic Meteorological Office, Reykjavík, Iceland, [4]University of Leeds, School of Earth and Environment, Leeds, United Kingdom, [5]Institute of Earth Sciences, University of Iceland, Reykjavík, Iceland, [6]Università di Palermo, Dipartimento di Scienze della Terra e del Mare (DiSTeM), Palermo, Italy

One of the many volatiles present in volcanic plumes is the trace metal mercury (Hg), which occurs in both gaseous and particulate-bound forms. The dominant species in the atmosphere, gaseous elemental mercury (GEM), has an atmospheric lifetime of 0.5 to 2 years and can be transported globally upon emission from natural and anthropogenic sources, broadening the impact of this environmentally significant element to remote regions such as the Arctic. GEM has generally been assumed to constitute the dominant Hg fraction in volcanic plumes (>90%), but plume geochemical modelling suggests co-emitted volcanic halogens and particulate matter may alter post-emission Hg speciation and fluxes. However, there is lack of direct measurements to evaluate these processes. This work presents gaseous Hg and major gas (SO2, CO2, H2O) measurements from aerial (drone-based) and ground-based active sampling in the near-source plume of the 2021 and 2022 fissure eruptions at Fagradalsfjall volcano, southwest Iceland. These data were used to establish Hg/SO2 mass ratios and characterize plume geochemical conditions. To our knowledge, these are the first such aerial near-source measurements of Hg in a concentrated volcanic plume during the early phases of an eruption. This study will provide novel insights into plume Hg concentrations, speciation and mass ratios from direct mantle-sourced volcanic eruptions.

474

Seismic and Video Monitoring of Episodic Lava Effusion during the Fagradalsfjall Eruption, Iceland 2021

Ms Eva Eibl[1], Thor Thórðarson, Ármann Höskuldsson, Egill Á. Gudnason, Gylfi Páll Hersir, Thorbjörg Ágústsdóttir
[1]*University Of Potsdam, Potsdam, Germany*

The Fagradalsfjall eruption on the Reykjanes peninsula, Iceland, lasted from 19 March to 18 September 2021. While it continuously effused lava at the beginning, 5 further vents opened in April and the activity focused on Vent 5 from late April. Surprisingly, the continuous effusion changed to episodic lava effusion from 2 May that was seismically recorded as tremor episodes. We examined the frequency of more than 10 000 lava fountaining episodes based on seismological data recorded at station NUPH some 5.5 km from the active vent and station LHR at 2 km from the vent.

We subdivide the time interval from 2 May to 18 September into 9 periods based on sudden changes in the fountaining duration, repose time and seismic amplitude. We present the different fountaining patterns and systematic changes and discuss their origin. Our comparison with vent height, vent stability and lava effusion style, led us to conclude that the changes in the pulsing behaviour highlight a shallow magma compartment that evolved in the first 10 days of May and in early July and was stable in other time periods. We further interpret changes in seismic amplitude as caused by increasing crack dimensions due to thermal erosion and increases in repose time as due to an increasing amount of degassed lava that accumulates in the growing crater edifice.

1023

Using Past Eruptions (1980-2019) to Determine Spatial and Temporal Resolution Needs for Volcano Topography Change Datasets and Future Satellite Missions

Elizabeth Eiden[1], Dr. Paul Lundgren[2], Dr. Matthew Pritchard[1]
[1]*Cornell University, Ithaca, USA,* [2]*Jet Propulsion Laboratory, California Institute of Technology, Pasadena, USA*

Updated topography datasets are essential for forecasting volcanic hazards and monitoring deformation. Digital elevation models (DEMs) are used in many flow modeling programs, such as ones that forecast the potential directions of lava flows, lahars, landslides, and pyroclastic density currents (PDCs). Furthermore, updated DEMs are necessary to accurately process interferometric synthetic aperture radar (InSAR) data for surface deformation, and for some physical volcano models to quantify eruptive rates. There are many ways to track topography change at volcanoes, through fieldwork, airborne instruments, and satellites, with the latter providing the greatest potential for global coverage. For future satellite missions we need to know the optimal horizontal and vertical spatial resolution and repeat intervals for topography change data for the science and application needs.

Despite the global availability of satellite topography data, we still do not know the number of volcanoes that have detectable topographic changes or the characteristics of those changes over a given time interval. We aim to define the specific acquisition needs for topography data using topographic change detected from recent eruptions. We review existing literature and compile a database of eruptive products (lava flows, domes and PDCs) from eruptions between 1980 and 2019. We focus on eruptions VEI 3 or greater because they make up over 75% of the erupted mass over those 40 years. Of the 238 erupted products (93 flows, 51 domes, 94 PDCs) surveyed thus far, 25% do not have published spatial dimensions. Our preliminary results show that a vertical resolution of 2m would capture 84% of all eruptions studied and an acquisition rate of every week would capture 88% of lava flow and dome-forming eruptions. PDCs had the smallest average thickness with only 66% resolvable at 2m and occurred on the order of minutes, indicating different sensing capabilities are required for different use cases.

790

Multiple Scales of Deformation and Dynamic Gravity Measurements Elucidate Role of Fluids in Transcrustal Magma System at Uturuncu Volcano, Bolivia

Elizabeth Eiden[1], Karissa Rosenberger[2], Patricia MacQueen[1], Dr. Scott Henderson[3], Dr. Joachim Gottsmann[4], Dr. Tobias Fischer[2], Dr. Matthew Pritchard[1]

[1]Cornell University, Ithaca, United States, [2]University of New Mexico, Albuquerque, United States, [3]University of Washington, Seattle, United States, [4]University of Bristol, Bristol, United Kingdom

While active volcanoes have historically been defined as those with an eruption within the last 10,000 years, there is evidence of volcanoes in the central Andes that erupt with repose times greater than 100,000 years. These “zombie” volcanoes must also be monitored for changes in activity to discern the causes of unrest and likelihood of eruption. Uturuncu volcano last erupted 250,000 years ago and is located in the southern Bolivian Andes. Uturuncu is showing signs of activity such as a 70 km diameter surface uplift at 3-10 mm/yr lasting decades, a short-lasting ~25 km^2 region of surface subsidence, fumarolic activity, and elevated seismicity. We use Interferometric Synthetic Aperture Radar data, a dynamic gravity survey, and preliminary gas measurements to explore the causes of subsurface dynamics. Preliminary results show that Uturuncu’s broad surface uplift corresponds to a volume change in the hydrothermal system of 14.5×10^6 m^3/yr which has dropped to 1.3×10^6 m^3/yr in recent years. We use modeling of CO_2 and H_2O flow in the hydrothermal system to see how much gas input results in the measured volume change. From preliminary observations of the composition and flux of gases emitted by the fumaroles, we find the flux of diffuse CO_2 is more than expected for a typical stratovolcano. We use the dynamic gravity data from 2010-2018 to constrain subsurface density changes and find that fluids ascending from the Altiplano-Puna Mush Body (~20 km b.g.l.) can account for the deformation and gravity changes in this time period. We develop a conceptual model that relates these varying depths and time scales of activity in a transcrustal magma system: an active shallow hydrothermal system with the formation and collapse of brine lenses fed by volatiles from the Altiplano-Puna Mush Body.

821

Exploring melt generation and lithospheric magma transport by modeling U-series isotopes: Advances and limitations

Dr Lynne Elkins[1]
[1]*University of Nebraska-lincoln, Lincoln, United States*

Uranium-series disequilibria remain the only lava geochemical measurements that provide direct information about the timing of mantle melting and melt transport beneath volcanic regions, but interpreting U-series compositions is complex and relies on time-dependent partial melting models. Recent advances in open-source porous flow modeling make it easier to predict and interpret U-series lava compositions for a variety of regimes, from pure chemical equilibrium to disequilibrium flow scaled by a Damköhler number, and for bilithologic melting with pyroxenite in the mantle source. However, the lithospheric magma transport regime is mechanistically different from asthenospheric decompression melting, and it is harder to predict the effects of such transport on melt composition due to, e.g., melt-rock interactions with an unknown solid matrix.

For divergent settings, transport includes lateral flow along a two-dimensional, triangular regime. Although simplistic, modeling can most easily compute the outcomes of pure disequilibrium magma transport (i.e., radioactive decay due to aging of the magma after physical separation from the convecting mantle, without further chemical exchange). Radioactive decay during transport, though simple, nonetheless impacts melt compositions in 2D scenarios: slow lithospheric transport with decay in a triangular regime can effectively decouple U-series isotopes from other geochemical indicators, as melts derived from the outer corners of the triangle cannot effectively preserve U-series signatures, and integrated melts approach the 1D outcome. Rapid transport alternatively preserves deep melt signatures from the outer corners of the regime.

Melt-rock lithospheric interactions could be modeled by pure chemical equilibrium flow through an externally-imposed solid; this approaches an “endmember” equilibrium scenario, but it requires knowledge of the composition of the whole lithospheric layer, and the local liquid proportion is unknown. Such a scenario could not easily reproduce, e.g., the buffering effects of magma mush transport, which may instead require approaches such as continuous open-system reactions and diffusion effects.

1484

Geophysical observations of Mauna Loa: from volcanic unrest to onset of the 2022 eruption

Dr Andria Ellis[1], Dr Ninfa Bennington[1], Dr Jefferson Chang[1], Peter Dotray[1], Dr Ingrid Johanson[1], Dr Arthur Jolly[1], Megan McLay[2], Dr Patricia Nadeau[1], Dr Michael Poland[2]
[1]U.S. Geological Survey Hawaiian Volcano Observatory, Hilo, United States, [2]U.S. Geological Survey Cascades Volcano Observatory, Vancouver, United States

Mauna Loa Volcano on the Island of Hawaiʻi erupted on November 28, 2022 at 09:23 UTC (November 27, 2022 at 23:23 HST), marking the end of decades-long unrest since its last eruption in 1984. Here we present observations from the U.S. Geological Survey Hawaiian Volcano Observatory's (HVO) geophysical and geochemical monitoring networks spanning two decades. Based on long-term, continuous seismic and geodetic (tilt, GNSS, and InSAR) monitoring data, the 2022 eruption was preceded by periods of elevated seismic activity and rates of deformation under Mokuʻāweoweo (Mauna Loa's summit caldera) and the upper Southwest Rift Zone. Since 2013, rates of seismicity and surface deformation at Mauna Loa waxed and waned, with seismicity rates ranging from tens of earthquakes per day to swarms of hundreds of earthquakes per day. Gas monitoring stations installed in 2017 (upper Southwest Rift Zone) and 2020 (summit) showed no indication of precursory CO_2 or SO_2 emissions. In addition to the long-term buildup to the eruption, we highlight distinct pre-eruptive seismic and geodetic signals that started in September 2022 indicating an increased likelihood of eruption. These precursory signals include unprecedented tiltmeter excursions related to shallow magma movement beneath Mauna Loa's summit as well as concurrent seismic swarms in historically chronologically isolated seismic zones. Together, these geophysical signals prompted HVO to increase frequency of community updates and public presentations to increase awareness of various eruption scenarios and encourage preparedness.

316

Volcano-tectonic interactions at caldera volcanoes in New Zealand: deformation and stress tools for hazard assessment

Dr Susan Ellis[1], Dr Simon Barker[2], Professor Colin Wilson[2], Dr Finnigan Illsley-Kemp[2], Dr Pilar Villamor[1], Dr Hannah Elms[2], Dr Ian Hamling[1], Dr Sigrun Hreinsdottir[1], Dr Graham Leonard[1], Professor Martha Savage[2], Eleanor Mestel[2], Dr James Muirhead[3], Peter Otway[4], Dr Rafael Benites[1], Bubs Smith[5]
[1]GNS Science, Lower Hutt, New Zealand, [2]Victoria University, Wellington, New Zealand, [3]University of Auckland, Auckland, New Zealand, [4]Omokoroa, Tauranga, New Zealand, [5]Ngāti Tūwharetoa, Turangi, New Zealand

We present a hierarchy of physical models that can be used to assess and model deformation and stress changes associated with magmatic inflation and associated tectonics at New Zealand's active onshore caldera volcanoes (Taupō and Ōkataina). The tools have been developed with the aim of easy utilisation by New Zealand's hazard community. Analytical and numerical methods predict deformation and detection limits for inflating magma bodies and their ascent through the crust, and demonstrate the challenges of detecting even substantial volumes of inflating magma (with volume changes up to 0.01 cubic km) due to physical barriers such as Lake Taupō restricting station placement. Calculated detection limits are useful for planning future geodetic station placement to optimise long term monitoring. Predicted stress changes from inflation or faulting can be added to longer-term models of regional lithospheric stress to assess the geophysical signature of the perturbation i.e., changes in stress magnitudes, failure states on nearby faults, and orientations of principal strain and stress. These predictions can be compared to stress inversions from seismicity to evaluate different scenarios for magma unrest. It is important to first modify regional depth-varying brittle-ductile stresses to account for the presence of weak mid-crustal mush layers, since the lower background differential stresses in these regions will enhance the rotation in principal stress orientations from fault movement or magma inflation sources such as spheres, ellipsoids, sills or dikes. We present worked examples based on historic unrest events and past caldera eruptions. Future modifications to our models could: (1) account for topography and further effects of mid-crustal mush on magma inflation stresses, and (2) incorporate more sophisticated techniques such as Boundary Element and Direct Boundary Integral methods to represent modern caldera structures and reconstructed source geometries of previous eruptive magma bodies.

584

Recent deformation signals and geodetic network upgrades at Kīlauea Volcano

Dr Andria Ellis[1], Dr. Ingrid A Johanson[1], Dr Jefferson Chang[1], Dr Ashton Flinders[1], Kevan Kamibayashi[1], Megan McLay[2], Dr David Phillips[1], Dr Michael Poland[2]

[1]USGS Hawaiian Volcano Observatory, Hilo , United States, [2]USGS Cascades Volcano Observatory, Vancouver, United States

Since the 2018 Kīlauea lower East Rift Zone eruption and summit collapse, the United States Geological Survey (USGS) Hawaiian Volcano Observatory (HVO) deformation monitoring program has performed geodetic network upgrades as part of the Additional Supplemental Appropriations for Disaster Relief Act of (H.R. 2157) to support recovery and rebuilding activities. GNSS instruments lost in the eruption were replaced, other parts of the network are being modernized, new sites are being added, and network telemetry was enhanced across the Island of Hawai'i. These improvements are focused on Kilauea volcano, both at the summit and in critical areas along the rift zones to ensure data can continue to flow during crises. Network hardening supports early detection of magma movement and more accurate and timely characterization of hazards for Kilauea.

HVO has also started to rebuild and enhance its gravity monitoring network, which was restarted from scratch following the 2018 events. With supplemental funds, HVO acquired an iXBlue Absolute Quantum Gravimeter (AQG), which will eventually be co-located with other instruments at Kīlauea's summit. The continuous gravity network at Kilauea was also re-established with three new sites added in 2022 accompanying the single station installed in 2018.

In addition to describing details regarding HVO's geodetic network upgrades, we also highlight several deformation data observations (GNSS, tilt, gravity, and InSAR) associated with unrest at Kilauea Volcano's summit from 2020 to 2022, including the 2020 and ongoing 2021 Kīlauea summit eruptions and two pre-eruptive intrusions.

336

Constraining the post-caldera magmatic recovery, architecture and operational timescales of active caldera volcanoes: a case study from Ōkataina Volcanic Centre

Dr Hannah Elms[1], Prof Colin Wilson[1], Dr Bruce Charlier[1], Dr Simon Barker[1]
[1]*Victoria University Of Wellington, Wellington, New Zealand*

Forecasting the future activity and the likely warning times of a volcano requires a quantitative understanding of the sub-surface magmatic architecture and processes, and the timescales over which these processes operate. Here we summarise the results of a holistic study of the evolution of Ōkataina Volcanic Centre, central Taupō Volcanic Zone, Aotearoa New Zealand, since the last caldera-forming event at c. 53 ka. Melt-phase trace element and isotopic analyses reveal rapid post-caldera rebuilding and re-organising of the mush into a tiered, branching structure, followed by a period of stabilisation and slow evolution towards more fractionated, yet less radiogenic, rhyolitic compositions. These compositions are periodically influenced by extra-caldera magmatic sources, with separate evolutionary trends for volumetrically-minor mafic eruptives. Zonation and textural features combined with Fe-Mg interdiffusion studies on orthopyroxenes from selected recent (post-16 ka) eruptions record operating timescales of decades to centuries for magma accumulation, residence and priming processes. Likely eruption triggers, although not recorded in crystal zonation, are inferred from physical volcanological and geochemical evidence to involve basaltic dike injection and/or rifting events, associated with the Taupō Rift that traverses the volcano. Accumulated magma bodies are inferred from volatile studies in quartz-hosted melt inclusions to have occupied shallow pre-eruptive storage depths of c. 4-8 km, with younger eruptions trending towards shallower positions. Magma bodies experienced variable degrees of pre-eruptive degassing during storage and slow initial rise, while final ascent to the surface occurred at rates of 0.1-4.4 m s-1. Field evidence also suggests that hiatuses in activity of up to several months may be a regular feature of these eruptive episodes. These results provide new constraints for warning times for likely future activity at Ōkataina, which can be combined with geophysical studies to improve the forecasting of future events and the mitigation of the associated risks.

726

Characterising Pyroclastic Density Current Grainsize Data

Dr Samantha Engwell[1], Prof Eliza Calder[2], Dr Eric Breard[2]
[1]British Geological Survey, Edinburgh, United Kingdom, [2]University of Edinburgh, Edinburgh, United Kingdom

Grainsize data is used across volcanology to aid interpretation of deposit trends and inform transport and depositional process. Collected grainsize data and the way it is presented varies for different processes, for example tephra fall versus pyroclastic density currents: grainsize information is more easily measured for fall deposits and is thus more available in the published record. This is related to the preservation and size distribution of a deposit. Pyroclastic density current (PDC) deposits are often focused in valleys and are therefore prone to rapid erosion and reworking and tend to have a much larger range in grainsize at a given location than tephra fall deposits. This relative lack of data, and differences in ways of data presentation, mean that it can be difficult to compare information from different events, and inform our understanding of PDC process.

Here, we present a review of PDC grainsize data as presented in the published record. We analysed information from 175 papers, extracting grainsize information from 71 papers, covering 83 PDC events. Information collected includes whether grainsize distributions or statistics were presented, and their characteristics, for example bin size. Within these papers, there is a wide range in the way grainsize information is presented, from distribution statistics to complete distributions, and often using different units (for example phi and mm). Given the large range of clasts in PDC deposits, distributions are often truncated at the course and/or fine extent. There is also a wide range in how the data is visualised, for example use of median versus sorting coefficient, ternary plots and plots of fine proportions. We use insight from this metadata analysis to understand how different treatments of PDC grainsize data affect their interpretation and comparison of data from different eruptions and can provide different insights into PDC processes.

761

Investigating the development of eruption source parameters probability density functions

Dr Samantha Engwell[1], Dr Mattia de' Michieli Vitturi[2], Dr Federica Pardini[2], Dr Mauro Di Vito, Dr Simona Scollo
[1]British Geological Survey, Edinburgh, United Kingdom, [2]Istituto Nazionale Geofisica e Vulcanologia, Pisa, Italy, [3]Istituto Nazionale Geofisica e Vulcanologia, Naples, Italy, [4]Istituto Nazionale Geofisica e Vulcanologia, Catania, Italy

Eruption source parameters are required for the initiation of numerical models, and significant work has gone into their estimation for volcanic ash transport and dispersal models. In application of these models, typically a given scenario or range of scenarios is used to inform source parameters and modelling approach. However, increasing computational competencies allow for more complex input parameters to be used with a look towards probabilistic model outputs.

Here, we investigate the potential for developing probability density functions for inputs, in particular plume height, for ash-dispersal models using Etna volcano, Italy as a case study. We brought together information from the published record, from eruption databases, and from volcanic ash advisories (VAAs), to inform eruption source parameters. Despite being one of the most well studied and monitored volcanoes in the world, difficulties arose around data availability and bias. Published records tend to have a low temporal resolution and, through analysis of deposits, focus on larger eruptions, while the VAAs capture more recent activity at high temporal resolutions, but which has tended to be at lower levels. Distributions of plume height produced from combining information from these different datasets had long tails to large plume heights, which were difficult to confidently fit with commonly used distributions. Our analysis shows that producing probability density functions of eruption source parameters for a given volcano is nontrivial and limited by uncertainties and bias within eruption data.

239

Global assessment of the impact that seismic network locations have in the detection of magma migration using SARA

Dr Tania Espinosa Ortega[1], Katie Elizabeth James[1], Dr Chiou Ting Tan[1], Prof Benoit Taisne[1,2]
[1]Earth Observatory Of Singapore, Singapore, Singapore, [2]Asian School of the Environment, , Singapore

Volcanic eruptions are frequently preceded by magma migration towards the surface that trigger seismic swarms, these seismic events often overlap and saturate the seismic signal, limiting the analysis techniques that can be effectively applied in real time crises. The Seismic Amplitude Ratio Analysis (SARA) provides a simple method to image the dynamics of seismic magma migration as it happens using the continuous seismic wave form.

In this project, we analyse how the location of the seismic networks can impose spatial constraints that limit the effectiveness of SARA. We introduce a method to quantify the detection capability of the seismic network for different magma migrations and analyse how the detection capability could be improved by changing the seismic stations locations.

We use the Global volcano monitoring infrastructure database (GVMID) to study different seismic networks and the land elevation data from NASA's Shuttle Radar Topography Mission (SRTM) to consider the volcano's topography. For each seismic network we analyse their potential to detect vertical magma migration and side vent formations. Moreover, we estimate the magma migration coverage volume and the impact of adding or removing a seismic station in the detection capability of the network.

This method provides a quick and straightforward way for volcano observatories to identify any detection gaps in a network, as well as a guide of how the seismic networks location could improve their coverage to detect magma migration in real time. Thus, we expect our work to help observatories to enhance their monitoring and hazard prevention capabilities.

283

Correlation of lava extrusion with seismic energy at Mt. Merapi volcano in the presence of uncertainties in the eruption time-line

Dr Tania Espinosa Ortega[1], Dr Agus Budi-Santoso[3], Dr Sulistiyani Sulistiyani[3], Nang T. Z. Win[1], Dr Christina Widiwijayanti[1], Prof Fidel Costa[2]

[1]Earth Observatory Of Singapore, Singapore, Singapore, [2]Institut de Physique du Globe de Paris,, Paris, France, [3]Balai Penyelidikan dan Pengembangan Teknologi Kebancanaan Geologi,, , Indonesia

Volcanoes can produce a range of eruptive behavior even during a single eruption. The eruption phases (e.g. phreatic explosion, magmatic explosion, lava extrusion, etc.) can led to different volcanic hazards and require timely assessment for the implementation of mitigation measures.

We present a simple and general probabilistic approach to correlate monitoring time series with a specific type of eruption phase accounting for uncertainties in the historical records with Monte Carlo simulations. We calculate the probability to detect lava extrusion (lava-dome formation) at Mt. Merapi as a function of the multiphase seismic energy (which is associated to brittle fracture). To achieve this, we classify the seismic energy values during lava extrusion days from 1993 to 2012. The days when the lava extrusion activity is uncertain are accounted using a stochastic simulation that randomly selects different lava extrusion time-lines and calculates the conditional probabilities for each scenario.

We identify a seismic energy threshold that is associated with the lava extrusion phase with an accuracy of ~90 %, a precision of ~73%, a specificity of ~96%, and a sensitivity of ~56%.We further test our method with the recent 2018 eruption (not used in the thresholds calculations) and seismically detect the onset of the lava extrusion phase 14 days earlier than the CCTV. Given the link between dome-collapse pyroclastic flows and growth episodes of the lava dome at Merapi, our analysis also allows us to establish that 83% of the most energetic pyroclastic flows occur within the first 3 months after the onset of the lava extrusion phase.

Our method allows to identify monitoring threshold values associated with lava extrusion and their evolution over time, it can help improve quantitative assessment of hazards during volcanic crisis and thus may help to mitigate the impacts.

354

A geodetic and seismic survey of the volcanically active Lipari and Vulcano islands in the Tyrrhenian subduction zone (Italy)

Dr Alessandra Esposito[1], Dr Luigi Cucci[1], Dr Francesca Di Luccio[1], Dr Mimmo Palano[2], Dr Patricia Persaud[3], Dr Vincenzo Sepe[1], Dr Marco Anzidei[1]

[1]Istituto Nazionale Di Geofisica E Vulcanologia, Roma, Italy, [2]Istituto Nazionale Di Geofisica E Vulcanologia, Osservatorio Etneo, Catania, Italy, [3]Louisiana State University, Department of Geology and Geophysics, Baton Rouge, USA

The Aeolian Archipelago is an arc-shaped structure located at the southern border of the Tyrrhenian Sea (Southern Italy). Magmatism of the volcanic arc started ~1.3 Ma as the result of a NW-dipping subduction of the Mesozoic Ionian slab beneath the Calabrian Arc. The central volcanic ridge (Vulcano, Lipari and Salina Islands) formed along a Subduction-Transform-Edge Propagator (STEP) fault, the Aeolian Tindari-Letojanni (ATL) fault system that bounds the western edge of the subduction of the Ionian Sea below the Calabrian Arc and transfers stress across northeastern Sicily at the Sisifo-Alicudi fault system (Govers and Wortel, 2005; Billi et al., 2006; Scarfì et al., 2018).

In the active central-southern Aeolian islands, hydrothermalism in western Lipari suggests a link between fluid migration from depth to surface and regional tectonics (Di Luccio et al., 2021). Vulcano island, in turn, has experienced a long period of relative quiescence, after the 1888-1890 eruption, with fumarolic activity located on and around La Fossa crater. In Vulcano, changes of the chemical and physical properties of the gas emissions have been monitored in various periods between 1996 and 2005 and very recently in 2021. Significant transients in the time-series of continuous GNSS stations installed in Vulcano and Lipari have been recorded during the 2021 volcanic activity.

In this work we reviewed recent geodetic and seismic data available for Lipari and Vulcano thus contributing to the understanding of the geodynamics of the central Aeolian Islands as well as of the interplay of present-day tectonics and volcanic deformation.

782

SO_2 emissions during the 2021 eruption of La Soufrière St. Vincent, revealed with back-trajectory analysis of TROPOMI imagery

Dr Ben Esse[1], Prof Mike Burton[1], Dr Catherine Hayer[1], Dr Rodrigo Contreras Arratia[2], Dr Thomas Christopher[2,3], Dr Erouscilla Joseph[2], Dr Matthew Varnam[4], Dr Chris Johnson[5]
[1]COMET, Department of Earth and Environmental Sciences, The University Of Manchester, Manchester, United Kingdom, [2]Seismic Research Centre, University of the West Indies, St. Augustine, Trinidad and Tobago, [3]Montserrat Volcano Observatory, Flemmings, Montserrat, [4]Lunar and Planetary Laboratory, University of Arizona, Tucson, USA, [5]Department of Mathematics and Centre for Nonlinear Dynamics, The University of Manchester, Manchester, UK

La Soufrière volcano, on the island of St. Vincent, erupted explosively in April 2021 after months of extrusive, dome-building activity. The eruption consisted of a series of explosions lasting until 22nd April, injecting volcanic ash and gases into the stratosphere.

Determining the SO_2 emission time series from such eruptions provides important insights into the driving magmatic processes, however sometimes accurate ground-based measurements are difficult to collect in real-time and pose a risk for monitoring scientists. Satellite platforms provide SO_2 imagery, however translating this to the altitude- and time-resolved emission history required to unravel volcanic processes is a major challenge. SO_2 emission time series are therefore rarely quantified for major eruptions, producing a gap in our understanding of explosive volcanism.

We apply PlumeTraj, a back-trajectory analysis toolkit, to SO_2 imagery from the TROPOspheric Monitoring Instrument (TROPOMI) to reconstruct the time- and altitude-resolved SO_2 emission for the explosive eruption of La Soufrière. Precursory SO_2 emissions were quantified the day before the eruption, with emission rates agreeing with ground-based measurements. We estimate mass eruption rates from plume injection altitudes and calculate pre-eruptive magma sulphur contents, finding that the initial explosion was sulphur poor (up to 24 ppm S) compared to the main eruption phase (up to 660 ppm S). This supports the petrological analysis of the new dome material, and suggests that the initial explosion cleared old, previously degassed magma in the shallow plumbing system, followed by the eruption of the main, mostly un-degassed magma source.

As the data required are available in near real-time, use of TROPOMI and PlumeTraj could be applied to future eruptive crises to rapidly provide key information on SO_2 emission rates and injection altitudes. This would help inform plume dispersal forecasts, as well as helping to understand eruption mechanisms and forecast the evolution of eruptive activity.

979

The evolution of a hyperactive caldera: A record of magma storage across the caldera cycle at Rabaul, Papua New Guinea

Dr Gareth Fabbro[1,2], Chris O. McKee[3], Mikhail E. Sindang[4], Dr Jeffery A. Oalmann[2], Dr Caroline Bouvet de Maisonnueve[2]

[1]University Of East Anglia, Norwich, United Kingdom, [2]Earth Observatory of Singapore, Nanyang Technological University, , Singapore, [3]Port Moresby Geophysical Observatory, Port Moresby, Papua New Guinea, [4]Rabaul Volcano Observatory, Rabaul, Papua New Guinea

Many calderas show cycles of large, explosive eruptions interspersed with minor activity. Despite improvements in our ability to forecasting the onset of eruptions, it is still difficult to forecast their sizes. To address this, we focused on Rabaul, Papua New Guinea, where at least 4 large ignimbrites have been erupted over the last 20 ky alongside numerous smaller eruptions. Our data spans a complete caldera cycle, from the penultimate (~10.5-ka Vunabugbug Ignimbrite) to the most recent (~1.4-ka Rabaul Pyroclastics) caldera-forming eruptions.

We present whole-rock, glass and groundmass, and mineral chemistry data from the 2 climactic eruptions, 12 minor inter-caldera eruptions, and 3 minor eruptions from the most recent cycle. A total of >4,300 analyses allow a detailed reconstruction of the long-term evolution of the sub-caldera plumbing system. Whole-rock and groundmass compositions range from basalt to dacite. The caldera-forming dacites were stored at 930–950 °C and <250–350 MPa, the inter-caldera basalts were stored at 1060–1150 °C and at a wide range of pressures (mostly 100–350 MPa, with some crystals recording greater depths), and the inter- and post-caldera dacites were stored at 920–980 °C and pressures of <100 MPa.

After the Vunabugbug caldera-forming eruption, and after the largest inter-caldera eruption, basalt was free to reach the surface from vents outside of the caldera. As a dacitic reservoir developed, basalt was prevented from reaching surface due to rheological contrast or the stress imposed by the reservoir. It is not clear whether the minor eruptions tapped the growing caldera-forming reservoir, but they were stored at more shallow depths before erupting within the caldera. Currently, basalt can make it to the surface again, as enclaves and hybrid andesites also erupted within the caldera. This implies that a large, dacitic melt body does not currently exist beneath Rabaul.

1253

Comparison of ash particle residence times in the atmospheres of Earth, Venus, and Mars

Dr Sarah Fagents[1], Eleni Ravanis[1], Shirin Wyckoff[1], Dr Stephen Baloga
[1]*University of Hawai'i, Honolulu, United States*

We compute settling times and downwind translation of ash-sized particles in the range 50–1000 µm released at plausible heights in the atmospheres of Earth, Venus, and Mars to determine the extents of the resulting fall deposits. We allow atmospheric density, temperature, and wind speed to vary through each step of the particle descent, and account for particle density variation as a function of grain size. We note some interesting comparative aspects of particle settling dynamics: (1) The aerodynamic resistance to particle motion offered by the high density venusian atmosphere leads to low settling velocities. However, the high density also produces higher particle Reynolds numbers than is the case for Mars or Earth. The venusian particles fall in transitional (1 < Re < 1000) to inertial (Re > 1000) settling regimes for their entire trajectory. The transitional regime requires more detailed treatment of the drag coefficient than does the typical assumption of Stokes settling (Re < 1). (2) On Mars, the present-day low atmospheric density means that fall velocities are greater than on Venus or Earth, despite the lower gravity, but particles <300 µm in diameter fall in the Stokes regime. However, a denser past atmosphere would lead to lower settling velocities than on Earth. (3) Very fine ash particles (<100 µm) injected high into the martian atmosphere are subject to non-Newtonian motion for at least the early part of their descent through the extremely rarefied atmosphere, which leads to more rapid fallout than is calculated using a conventional Newtonian approach. (4) Ash-sized particles take up to ~18 times longer to reach the ground on Venus than on Mars. Even accounting for different windspeeds on these two bodies, downwind dispersal distances up to four times greater are predicted on Venus than on Mars for identical source conditions.

1238

Helium Isotope Variations in the Taupo Volcanic Zone: Evidence from the rock record; basalt to rhyolite

Mr David Farsky[1], Dr Michael Rowe, Dr Isabelle Chambefort, Dr Simon Barker, Professor David Graham
[1]*University Of Auckland, Auckland, New Zealand*

The Taupo Volcanic Zone (TVZ) is a rifting volcanic arc overlying westward subduction of the Pacific plate under New Zealand. For the last 1.8 Ma, magmatism in the TVZ has been dominantly rhyolitic with only minor volumes of mafic to intermediate lavas. Prior investigations have debated the relative significance of crustal versus mantle sources and processes in generating arc magmas. In this study, we utilize He isotopic compositions and abundances to investigate the role of mantle components across a spectrum of TVZ magma compositions.

Helium isotopes were analyzed in phenocrystic olivine and pyroxene from basaltic to rhyolitic magmas, including from the two active caldera systems; the Taupo Volcanic Centre (TVC) and the Okataina Volcanic Centre (OVC). In mafic magmas, olivine generally records a higher 3He/4He (5.0-6.6 RA) than clinopyroxene (2.9-5.3 RA), and the differences between olivine and clinopyroxene are more extreme in the southern TVZ. Notably, clinopyroxene and orthopyroxene from OVC dacites (5.0-6.4 RA) and TVC rhyolites (4.0-6.6 RA) have 3He/4He similar to pyroxenes from Central TVZ basalts (4.7-5.3 RA).

The greater distinction between pyroxenes from the southern TVZ compared to olivine implies a more dominant role for crustal contamination during cooling and crystallization of basaltic andesites. Lower 3He/4He correlates with a decrease in the abundance of helium released by crushing for many samples, possibly from increased susceptibility to small additions of crustal 4He after degassing. The 3He/4He of evolved magmas in the OVC and TVC also suggests the prevalence of a mantle-derived gas phase similar to that observed in the Central TVZ basalts, distinct from crustal and atmospheric helium compositions. Results from melt generation modeling combined with mineral chemistry suggest less than 10% contamination of partially degassed mantle-derived melts with a crustal anatectic melt, and prior degassing can reproduce the He isotopic data.

827

What about law? Communicating the role of legal frameworks in disasters, an Auckland Volcanic Field case study.

Holly Faulkner[1], Professor John Hopkins, Professor Thomas Wilson
[1]*University of Canterbury, Christchurch , New Zealand*

A decade of disasters in New Zealand has revealed a widespread perception that if the existing legal framework is unfit for purpose, then the solution is to create a new legal framework. This highlights an issue about how to communicate the risks involved in creating new legal frameworks in the aftermath of a disaster.

Creating new legal frameworks post-disaster carries an inherent risk that the new framework will provide unnecessarily broad powers which may be misused. These risks were exposed in the aftermath of the Christchurch earthquakes in 2010/2011, as the existing framework was unfit for purpose and was replaced with a completely new legal framework. The extent of the powers available was highly controversial as they mirrored the powers available during a state of emergency.

Communicating the risk of creating new legal frameworks will be crucial in planning for the Auckland Volcanic Field. This is a high impact, low probability event which has the potential to create a large-scale, multi-hazard disaster. As a volcanic field located in a densely populated urban area it presents ongoing, long-term impacts and the possibility of multi-hazard events. To avoid a repeat of the Christchurch experience, the risks of creating new frameworks needs to be properly communicated to avoid assumptions that creating new legal frameworks post-disaster is inevitable. A way to bring about this change is to communicate the importance of assessing the existing legal frameworks in advance, by highlighting the risks of creating new frameworks and challenging the assumption that new frameworks are inevitable.

This project analyses the current legal frameworks around emergency management in Aotearoa New Zealand, using the Auckland Volcanic Field as a case study. It considers the trend for creating new legal frameworks post-disaster and the risks that this trend poses for an Auckland Volcanic Field event.

736

Water ingestion and fate of large pumice clasts

Kristen Fauria[1], Mikkel Louis
[1]*Vanderbilt University, Nashville, United States*

Giant pumice clasts, >1 m diameter, are notable features in some subaqueous silicic eruptions. Submarine deposits suggest that these giant clasts travel kilometers in the water column before settling to the seafloor, however, the transport processes that control giant pumice deposition are not well understood. Clast buoyancy - and thus liquid water ingestion - likely play pivotal roles in giant pumice transport, yet water ingestion models have only been tested against laboratory data from small lapilli size clasts. We created an experimental set-up that can measure the rate of water ingestion in hot (200-700°C) pumice clasts up to ~15 cm diameter. We performed more than thirty experiments on pumice clasts with diameters of ~10 cm. We found that the time it took the water ingestion front to reach the clast center is consistent with the time predicted by a conductive cooling model on a sphere. This result supports the conclusion that cooling and water ingestion are coupled. In addition, we compare ingestion rates between clasts that are initially air-filled and those that are heated in a steam-oven. We find that the water ingestion rates between steam-filled and air-filled clasts are identical. These experiments provide water ingestion data on the largest, and thus most applicable to giant pumice, pumice clasts to date.

735

Umbrella cloud characteristics and fall deposit size of the January 15, 2022 eruption of Hunga Tonga-Hunga Ha'apai

Kristen Fauria[1], Dr. Ashok Gupta, Liam Kelly, Tushar Mittal, Ralf Bennartz, Michael Manga, Shane Cronin
[1]*Vanderbilt University, Nashville, United States*

The January 15, 2022 eruption of Hunga Tonga-Hunga Ha'apai was remarkable, in part, because of its extensive umbrella cloud, the region where the volcanic cloud spreads laterally as a neutrally buoyant gravity current. Here we use remote sensing to evaluate the umbrella cloud top height. Specifically, we use brightness temperatures from the Himawari-8 satellite to identify an umbrella cloud at 31 +/- 3 km and a second umbrella cloud at 17 +/- 2 km on January 15. We find that the umbrella clouds contained significant water and estimate a volumetric flow rate of 5 x 10^11 m^3 s^-1 for the upper umbrella cloud. In addition, we use satellite imagery from MODIS to see that there was discoloration of the ocean water >80 km around HTHH following the eruption. We interpret this discoloration to result from ash fallout from the umbrella cloud. By relating the intensity of ocean water discoloration to measurements of fall deposit thickness in the Kingdom of Tonga, we estimate that the 2022 HTHH fall deposit contained approximately 2 km^3 of material. Overall, our assessments show that the 2022 HTHH eruption was unique because of its production of a double umbrella cloud and small fall deposit volume relative to its high umbrella cloud heights.

299

Inferences on the 2021 - ongoing volcanic unrest at Vulcano Island (Italy), derived from the INGV multidisciplinary surveillance network

Dr Cinzia Federico[1], Dr Ornella Cocina[2], Dr Salvatore Gambino[2], Dr Antonio Paonita[1], Dr Giuseppe Salerno[2], Dr Stefano Branca[2], Dr Francesco Italiano[1], Dr Mauro Coltelli[2], Dr Sergio Bellomo[1], Dr Valentina Bruno[2], Dr Tommaso Caltabiano[2], Dr Marco Camarda[1], Dr Giorgio Capasso[1], Dr Sofia De Gregorio[1], Dr Giuseppe Di Grazia[2], Dr Iole Serena Diliberto[1], Dr Roberto MR Di Martino[1], Dr Ferruccio Ferrari[2], Dr Alessandro Gattuso[1], Dr Leonardo La Pica[1], Dr Mario Mattia[2], Dr Giovannella Pecoraino[1], Dr Antonino Pisciotta[1], Dr Mariangela Sciotto[2], Dr Francesco Sortino[1]
[1]Istituto Nazionale Di Geofisica E Vulcanologia, Palermo, Italy, [2]Istituto Nazionale di Geofisica e Vulcanologia, Catania, Italy

The La Fossa volcano in Vulcano Island (Aeolian Archipelago, Italy) is characterized by fumarolic activity since its last eruption in 1888-1890. During the 80's of last century, an embryonic geochemical and geophysical surveillance network, now managed by the Istituto Nazionale di Geofisica e Vulcanologia, was deployed on Vulcano Island, and it detected some episodes of volcanic unrest.
In September 2021, a new unrest phase started and is still ongoing. The gas and steam output from the crater drastically increased, and in few days produced an impressive plume. The content of magmatic gases in the crater fumaroles was the highest ever measured since the beginning of the record, in 1988. Local seismicity sharply increased and was characterized by the appearance of VLP events (peak frequency 0.2-0.3 Hz), never recorded since the installation of the broadband network in 2006. Permanent GPS and tiltmeter networks measured an inflation of the crater area with displacements up to about 3 cm.
In October, a strong increase of CO_2 degassing was observed also on the lower flanks of the cone. Meanwhile, some anomalies in chemo-physical parameters appeared in thermal aquifers in the same areas. Most parameters marked the climax of the crisis in late October- early November, confirming a massive increase of the gas and steam output, as deduced from the plume measurements of SO_2 flux.
After November, the monitoring system revealed either the persistence of anomalies for some parameters or, on the contrary, the gradual or even drastic decrease for others. At present (August 2022), the entire set of signals is slowly decreasing although some parameters are far from their background levels.
We present a comprehensive report on geochemical and geophysical data acquired in the period between July 2020 and April 2022, which provided an interpretative framework of the evolving unrest in the volcano-hydrothermal system.

447

Dense infrasound and multiparameter observations of the May 13, 2022 major explosion of Stromboli Volcano, Italy

David Fee[1], Valeria Cigala[2], Corrado Cimarelli[2], Julia Gestrich[1], Alexandra Iezzi[3,4], Ulrich Kueppers[2], Giorgio Lacanna[5], Maurizio Ripepe[5], Markus Schmid[2], Caron Vossen[2]

[1]Alaska Volcano Observatory, Geophysical Institute, University of Alaska Fairbanks, Fairbanks, United States, [2]Department of Earth & Environmental Sciences, Ludwig-Maximilians-Universität München, Munich, Germany, [3]USGS Cascades Volcano Observatory, Vancouver, United States, [4]Department of Earth Science and Earth Research Institute, University of California, Santa Barbara, Santa Barbara, United States, [5]Dipartimento di Scienze della Terra (UNIFI), Università di Firenze, Firenze, Italy

Eruption intensity can quickly transition without warning. Stromboli Volcano, Italy is known for regular, well-characterized strombolian eruptions punctuated by occasional larger eruptions. In recent years these larger eruptions have become more frequent, pose an increased risk to the public and scientists, and are a challenge for monitoring. On May 13, 2022 a “major explosion” occurred at Stromboli with few geophysical precursors and during a period of low activity. This eruption produced extensive ballistics and would have been hazardous to anyone near the summit. In addition to the comprehensive local monitoring networks at Stromboli, a dense temporary network of infrasound, high-frequency acoustic, and volcanic lightning equipment was also deployed at the time and captured the eruption in unprecedented detail. Analysis of these campaign data show the eruption occurred as a series of at least 6 distinct events emanating from multiple vents in the crater terrace. Infrasound amplitudes exceeded 1000 Pa, some of the highest ever recorded anywhere, and infrasound-derived locations from the 9 campaign stations pinpoint the different erupting vents. Notable electrical signals mark the explosive events. Opportunistic Uncrewed Aerial Systems (UAS) surveys before and after the eruption show multiple craters were eroded by up to 10.5 m and provide a rare glimpse into explosive excavation to compare with geophysical data. The vent erosion is consistent with the main eruptive vents derived via infrasound. In this presentation we highlight our multiparameter observations, focusing on syn-eruptive processes and the acoustic, electrical, and UAS observations, with the goal of improving understanding and monitoring of these hazardous events.

1045

Magma transport processes leading to "surges" in magma supply at Kīlauea Volcano, Hawaiʻi

Gaetano Ferrante[1], Helge M. Gonnermann[1]
[1]*Rice University, Houston, United States*

Between 2003 and 2007 Kīlauea Volcano, Hawaiʻi underwent accelerating rates of summit inflation in conjunction with an increase in CO2 emissions. This has been interpreted as the consequence of a surge in deep magma supply. Magma transport from depth into Kīlauea's shallow subvolcanic magma storage system requires passage through the olivine cumulates known to exist beneath Kīlauea. A surge therefore implies an increase in the rate of magma flow through this crystal mush, either due to an increase in the magnitude of the average upward pressure gradient, or an increase in the conductance of the magma transport pathway, or both. We test the hypothesis of an increase in the effective conductance of Kīlauea's deep magma transport system, due to the opening of a feeder dike. This would result in an abrupt increase in magma pressure at shallower depth and gradual propagation upward through the olivine mush into Kīlauea's shallow subvolcanic system. We present results from numerical modeling and show how it can explain the observed inflation and increase in CO2 emissions between 2003 and 2007. In particular, the surge is characterized by an initial increase in the rate of inflation that eventually starts to level off. This can be explained by the feedback between the upward propagation of increased magma pressure through the olivine cumulates and the concurrent increase in pressure within the summit storage system, due to the imbalance between increasing magma supply into and outflow from Kīlauea's summit storage. The resultant peak in magma supply correlates with the peak in the rate of summit CO2 emission, as well as the change from increasing to decreasing rates of inflation. Our model also allows us to examine to what extent the aftermath of this surge in magma supply may have contributed to Kīlauea's inflation prior to the 2018 eruption.

617

The Compositionally Diverse Postglacial Volcanic Field at Laguna del Maule, Chilean Andes

Judy Fierstein[1], Patricia Sruoga[2], Alvaro Amigo[3], Manuela Elissondo[2]
[1]U.s. Geological Survey, Menlo Park, United States, [2]SEGEMAR, Buenos Aires, Argentina, [3]SERNAGEOMIN, Santiago, Chile

The concentration of postglacial rhyolites (72-77% SiO_2) in the Laguna del Maule volcanic field (LdM) on the Argentina-Chile border (36° S) is known to be an extraordinary anomaly in the Quaternary Andes. The silicic focus, which includes rhyodacite and rhyolite coulees and domes encircling the lake, and the recognition of ongoing uplift between 18-30 cm/yr, has prompted recent work on the LdM magmatic system. Less well-appreciated is that the postglacial volcanic field—all erupted within the last 16 kyr—includes 72 separate vents distributed over ~360 km^2, of which 25 are rhyolitic (73%–77% SiO_2), 13 are rhyodacitic (68%-72% SiO_2), 3 are dacitic (63%-66% SiO_2), 29 are intermediate (54-62% SiO_2), and 2 are true basalts (50%-53% SiO_2). Investigation of 323 tephra sections and related lavas that originated from these vents has established an eruptive history that includes >90 effusive and explosive events, with a pyroclastic/lava ratio of 4:1. Of these, most originated from single-vent domes, cones, or craters, each with relatively short lifespans. A few make up multi-vent complexes, including the largest one—the Barrancas complex SE of the lake—which has as many as 14 vents that erupted over as much as 10 kyr. Each multi-vent center was built over decades to millennia, while eruptions continued elsewhere in the LdM basin. Calculated volumes for LdM postglacial eruptive units total a cumulative 36.8 km^3 (DRE), nearly half of which is a single unit—the 15-ka, high-silica, Plinian Rhyolite of Laguna del Maule (unit rdm: 17.1 km^3 DRE). Of the 19.7 km3 (DRE) of lavas and ejecta that erupted over the subsequent ~13 kyrs, most was rhyolitic (87.8%); subequal amounts were rhyodacitic and intermediate (5.6%, 6.0%, respectively), and only a small fraction was basaltic (0.5%). Age estimates show neither systematic distribution of sequential eruptions nor systematic changes in compositions through time.

998

Frequency-magnitude distribution of earthquakes at Etna volcano unravels critical stress changes along magma pathways

Dr Marco Firetto Carlino[1], Dr. Luciano Scarfì[1], Dr. Flavio Cannavò[1], Dr. Graziella Barberi[1], Dr. Domenico Patanè[1], Dr. Mauro Coltelli[1]
[1]*Istituto Nazionale Di Geofisica E Vulcanologia, Osservatorio Etneo, Catania, Italy*

The high seismic productivity of volcanic areas provides the chance to investigate the local stress conditions with great resolution, by analysing the slope of the Gutenberg & Richter frequency-magnitude distribution of earthquakes, namely the b-value.

In this work (Firetto Carlino et al., 2022) we investigated the seismicity of Mt. Etna between 2005 and 2019, focusing on one of the largest known episodes of unrest in December 2018, when most of the intruding magma aborted, rather oddly, its ascent inside the volcano. We found a possible stress concentration zone along magma pathways that may have inhibited the occurrence of a larger eruption. If the origin of such hypothetical loaded region is related to tectonic forces, one must consider the possibility that geodynamic processes can locally result in such rapid crustal strain as to perturb the release of magma.

The b-values time series strongly increase within the “intermediate Etna magma storage” due to an overpressurization of the system starting on 01 December 2018 and culminating on the 06th of the month, about 19 days before the 24 December 2018 major unrest event. This latter was preceded by an abrupt fall of b that started 2 days in advance within the magma storage and then propagated to the shallower sectors of the plumbing system, tracking dykes’ propagation for depth to the surface.

This methodology enables investigating large crustal volumes, wherever they are “illuminated” with a sufficient number of earthquakes. Our results suggest that the spatial and temporal analysis of the b-value, in broader correlation with other monitoring measurements, may offer an opportunity for better outlining and understanding plumbing systems and improving the assessment of impending volcanic eruptions.

Firetto Carlino, M., et al. Frequency-magnitude distribution of earthquakes at Etna volcano unravels critical stress changes along magma pathways. Communications Earth & Environment 2022, 3, 68.

1404

Continuous monitoring of Etna summit craters activity by a Doppler radar system will improve the issuing of the VONA messages

Dr Mauro Coltelli[1], Dr Marco Firetto Carlino[1], Dr Giuseppe Giammello[1]
[1]*Ingv Osservatorio Etneo, Catania, Italy*

The monitoring of explosive volcanic activity can be done in real-time and under any weather condition by using the radar remote sensing technique. A system aimed at continuously monitoring the frequent explosive activity of Etna summit craters (more then 200 lava fountains occurred in the last 25 years), by using a S-band pulse Doppler radar located at about 3 km afar from the active volcanic vents, was realized at INGV-OE (Istituto Nazionale di Geofisica e Vulcanologia - Osservatorio Etneo). To this end, we developed an automatic processing chain of the radar data, and then we analyzed the radar signal recorded during 23 episodes of paroxysmal explosive activity that occurred at the South East Crater during the second half of 2021. To identify the onset of strombolian activity and the subsequent evolution into a lava fountain, empirical thresholds of radar time-series were extracted on the base of the thermal and visible images acquired by the Etna surveillance camera network, to achieve a robust monitoring tool that automatically operates 24/7. This tool improves the capacity to detect the volcanic explosive activity, which is strategic for the task of the volcano observatory to inform air traffic controllers through the issuing of the VONA (Volcano Observatory Notice for Aviation) messages on the eruptive phenomena that produce volcanic ash dispersal in the atmosphere, for the aim to avoid the contaminated air space and improving aviation safety.

319

Magma storage and accumulation preceding mafic-intermediate caldera-forming eruptions

Dr Chris Firth[1], Simon Turner[1], John Adam[1], Shane Cronin[2], Tracy Rushmer[1]
[1]Macquarie University, North Ryde, Australia, [2]University of Auckland, , New Zealand

Caldera-forming eruptions are amongst the most violent and catastrophic natural hazards, producing widespread pyroclastic flows, stratospheric ash columns and potentially initiating tsunami at island volcanoes. Such eruptions are most commonly associated with silicic magma compositions. Literature review shows this may be a misconception however, with 34% of Holocene caldera-forming eruptions involving basaltic to andesitic magmas. This was most recently demonstrated by the eruption of Hunga volcano in Tonga in January 2022. During this event, a ~6-8 km^3 caldera was excavated during a high energy eruption of andesite magma. Using experimentally-derived phase relations for magmas erupted from neighbouring Late island, we show that the Hunga magmas were stored under water-saturated conditions at pressures of ~1 kbar. Storage conditions differ little between caldera-modifying eruptions in c.1100 A.D. and 2022 and lower magnitude events in 2009 and 2015. Petrological similarities between the caldera-modifying eruptions at Hunga and those at other caldera volcanoes in the SW Pacific, such as Tofua (Tonga), Siwi (Vanuatu) and Long Island (PNG) are evident. These suggest mixing and mobilisation of stored crystal mushes occurred prior to eruption. At Hunga, Tofua and Long Island extreme excesses of ^{226}Ra (half-life = 1.6 kyr) in pre- and post-caldera eruptives record fast transfer (<~1 kyr) of magmas from their melt source to eruption, providing the conditions necessary to rapidly accumulate magma. Ignimbrites produced during caldera-forming eruptions typically display more subdued ^{226}Ra excesses, indicating that significant volumes of older, stored magma are incorporated during higher magnitude eruptions. Together, these observations reveal the complexity of shallow magma storage, with adjacent magma/mush zones tapped to differing degrees during eruptions of different magnitudes.

372

CONVERSE: A Community Network for Volcanic Eruption Response

Professor Tobias Fischer[1], Dr. Seth Moran, Prof. Kari Cooper, Dr. Einat Lev, Prof. Christelle Wauthier, Dr. Yolanda Lin, Prof. Charles Connor, Dr. Benjamin Andrews, Prof Bruce Houghton, Dr. Paul Lundgren, Dr. Alex Iezzi, Dr. Wendy Stovall, Dr. Michael Poland
[1]*University Of New Mexico, Albuquerque, United States*

The Community Network for Volcanic Eruption Response (CONVERSE), began in 2018 as a 3-year Research Coordination Network supported by the U.S. National Science Foundation with the aim of coordinating efforts of the broader scientific community and U.S. volcano observatories prior to and during eruptions at US volcanoes. The charge of CONVERSE is to maximize scientific return from eruption responses at U.S. volcanoes by making the most efficient use of limited access and time to collect the most useful remotely sensed and in situ data and samples possible.

Since 2018, CONVERSE has organized several virtual eruption scenarios and participated in its first eruption. In November 2020, we conducted a 2-day eruption scenario exercise for Mt. Hood in the Cascades involving 80 participants. The main goal of the exercise was to develop and test the concept of a Scientific Advisory Committee (SAC) that functions as the liaison between the volcano observatory and the broader scientific community interested in responding to the eruption. The SAC concept was then implemented during the 2020-2021 Kīlauea eruption. Then in February 2022, we ran a virtual eruption scenario exercise involving over 60 participants that focused on a hypothetical crisis at Arizona's San Francisco Volcanic Field.

Participants met online twice a week for four weeks, communicated via Slack, and shared data in a cloud-based drive.

The scenario exercises demonstrated the value of preparing the broader scientific community to coordinate with U.S. volcano observatories during unrest and eruption. The SAC concept proved effective as a means of providing feedback to the community regarding the feasibility and coordination of multi-disciplinary data collection. We also found some aspects of the SAC concept that need adjustments, including the need to find a way to streamline proposal evaluations so that the process is more timely

374

UAV-based CO2 emission rate measurements from the 2021 Cumbre Vieja eruption, La Palma, Canary Islands

Professor Tobias Fischer[1], Mr. John Ericksen[1], Prof Matthew Fricke[1], Dr. Eleazar Padrón González[2], Dr. Pedro Hernandez Pérez[2], Dr. Nemesio Pérez[2], Dr. Scott Nowicki[1], Prof. Melanie Moses[1]
[1]University Of New Mexico, Albuquerque, United States, [2]Instituto Volcanológico de Canarias (INVOLCAN), Tenerife, Spain

Carbon Dioxide (CO_2) is the second most abundant gas in volcanic emissions after water, it is an important greenhouse gas and changes in CO_2 emissions from active volcanoes reflect changes in volcanic activity. Despite CO_2's significance in the Earth System and in magmatic systems, measuring the emission rates of this gas from volcanic craters, diffuse sources and low-level hydrothermal sites has remained a major challenge.

Here we present a novel approach that takes advantage of our experience of measuring the CO_2 concentration of plumes emitted by hydrothermal systems using Uncrewed Aerial Vehicles (UAVs). In the approach presented here we measure the CO_2 concentration in the volcanic plume using an IR CO_2 sensor mounted on the UAV. The UAV transects the plume, continuously obtaining CO_2 concentration readings. This data is then used to obtain a 2D Gaussian plume CO_2 concentration slice which returns the area of this slice and the CO_2 concentration within this area. We then used simultaneous wind speed measurements to obtain the CO_2 flux from the volcano.

We tested this technique during the 2021 Cumbre Vieja Volcanic eruption on La Palma Island, Spain to obtain CO_2 fluxes during the eruptive phases of late November 2021. We also used the UAV to collect samples of the plume to analyze for carbon isotopes by Infrared Spectrometer. Our results show that the eruption of Cumber Vieja emitted highly variable amounts of CO_2 in late November 2021. The isotopic composition of the captured CO_2 is consistent we deeply derived CO_2 and similar to values obtained from xenoliths on neighboring islands.

Our approach shows that valuable information on CO_2 fluxes and sources can be obtained from UAV-based measurements during volcanic eruptions. This information contributes to approaches used for forecasting eruptive volcanic activity.

940

Kīlauea Lava–Water Interactions at the Summit and Sea: A Comparative Approach

Dr Erin Fitch[1], Dr Carolyn Parcheta[2]
[1]University of Oregon, Eugene, United States, [2]Hawaiian Volcano Observatory, Hilo, United States

Kīlauea Volcano, Hawai'i, is one of the only sites where lava–water interactions have been observed at both the summit and at ocean-entry. Lava–water interactions exist on a spectrum from passive quenching of lava to explosive fragmentation and ejection of tephra, both of which can produce ash, but the latter may produce abundant ash. Passive interactions between lava and a crater lake at the summit of Kīlauea were observed during the 2020 eruption, which are unprecedented within Kīlauea written history. An opaque plume rose >10 km above sea level from the vaporization of the lake water, obscuring visual observations. However, the plume might have contained a small component of ash fragmented during the lava–water interactions, which we are exploring through SEM analysis. It is important to identify the processes by which lava–water interactions occurred, and the environments in which even small-scale explosive interactions occur especially, because it will inform hazard assessments and provide inputs for ongoing numerical modeling work. In this study, we determine the morphology and surface textures of ash from the 2020 Kīlauea summit eruption, derived from water interactions. We compare these results with ash from a relatively large littoral lava–water explosion associated with the 2018 lower East Rift Zone eruption of Kīlauea volcano, which was produced from a lava flow in a shallow offshore ocean environment. By comparing the characteristics of ash-sized tephra produced by different end members of lava–water interactions, we will place the lava–water interactions during the 2020 summit eruption into context. We will use this new data and existing knowledge of lava–water interaction in Hawai'i to make interpretations of (1) the mechanisms, (2) intensity, and (3) possible energetics of these events.

384

Phreatic and hydrothermal eruption hazard in geothermal fields

Dr Rebecca Fitzgerald[1,2], Brad Scott[1], Danielle Charlton[1], Christina Magill[1], Don Bogie[3], Hollei Gabrielsen[3], Theo Chapman[3]
[1]GNS Science, , New Zealand, [2]Massey University, Palmerston North, New Zealand, [3]Department of Conservation, , New Zealand

Like many volcanoes, geothermal areas are often popular tourist destinations, potentially exposing many visitors to geothermal hazards. These hazards range from splashing of hot water/mud in surface features onto visitor paths to large phreatic and hydrothermal eruptions. To assess hazard and risk from phreatic and hydrothermal eruptions effectively we must understand how often these eruptions are occurring, the hazards they produce, and the extent and intensity of these hazards. Through a literature review, we compiled 270 reports of hydrothermal eruptions and 18 reports of phreatic eruptions in the past 230,000 years from geothermal fields around the world. Eruption frequency varies with eruption size and also between geothermal fields, with Waimangu, Rotorua and Yellowstone more closely examined. Catalogued eruptions vary in size and subsequently in their hazard extents. As such, we categorise eruptions into small, moderate and large eruptions based on the maximum distance of deposited ejecta, crater size and ejecta column height. Reported hazards from these eruptions include slugs of hot water, steam and sediment, volcanic ballistic projectiles, pyroclastic density currents, gas plumes, ground excavation and wet ash. These hazards can also vary in their intensity. We review the range of temperatures, dynamic pressures, spatial densities, kinetic energies and thicknesses that may be expected from these hazards in geothermal fields. Synthesis of this information may help support hazard and risk managers to assess hazard and risk in geothermal areas.

385

Assessing unmitigated and residual life-safety risk for a data-scarce submarine volcano: The January 2022 Hunga Tonga – Hunga Ha’apai eruption

Dr Rebecca Fitzgerald[1,2], Gill Jolly[1], Greg Tetzlaff[1], Josh Hayes[1], Cornel de Ronde[1], Graham Leonard[1]
[1]GNS Science, Avalon, New Zealand, [2]Massey University, Palmerston North, New Zealand

Risk assessments are an integral part of planning fieldwork around active volcanoes, identifying where and how long it is acceptable to conduct fieldwork. The VEI 5 January 15 2022 Hunga Tonga – Hunga Ha’apai eruption produced many hazards that impacted the Kingdom of Tonga and nations around the world. The need for field reconnaissance to understand the state of the volcano after this large eruption, eruption mechanisms and potential for future eruptions and hazards necessitated a risk to life assessment for scientists planning to conduct fieldwork in the area. However, due to their limited accessibility and often low population exposure, submarine volcanoes are not as well monitored as their subaerial counterparts, providing less data to inform risk assessments. How do you assess risk at an active, at the time under-monitored, submarine volcano with few recorded eruptions? Here we address these issues and present a quantitative volcanic life safety risk assessment for Hunga Volcano. We perform a sensitivity analysis on the data inputs and assumptions used and explore how new data that has emerged over the past year would affect our original estimates. We describe the overarching volcano observatory risk management framework that the assessment sits within and present a risk matrix for assessing residual volcanic risk once mitigation measures have been applied. The process applied in this work may help inform future life safety risk assessments at remote submarine volcanoes.

1344

Emplacement dynamics of lava flows at Lonquimay and Llaima volcanoes using UAVs and petrographic analysis

Luis Flores[1], Dr. Angelo Castruccio[1], Luna Pérez[2]
[1]Universidad De Chile, Santiago, Chile, [2]Sernageomin, Punta Arenas, Chile

We analyzed the emplacement dynamics of 2 lava flows emitted during 2 eruptions of the XX century on the Southern Volcanic Zone of Chile: the 1988-90 Lonquimay eruption and the 1957 Llaima eruption.
We built high-resolution Digital Elevation Models (DEMs) for both lava flows by 2D photogrammetry, using an Unmanned Aerial Vehicle (UAV) together with petrographic analysis to estimate the rheology and eruptive parameters of lava flows. The Lonquimay lava flow has a volume of $2x10^8$ m^3 and was emitted in 13 months. It has a length of 10 km with a mean thickness of 30 m. The composition is andesitic (59% SiO_2).
The Llaima eruption produced 2 lava flows directed to the North and East of the volcano, with volumes of $7x10^7$ and $3x10^7$ m^3 respectively. Both flows were emitted in a lapse of 4 days. The lengths are 13 and 8 km from the vent, with a mean thickness of 10 m. The composition is basaltic andesite (52-53% SiO_2).
Lonquimay unit is a simple lava flow, with an increase in thickness, from 10 m at the vent to 60 m at the front. It has ogives (flow ridges) that increase in abundance and height towards the front. The Llaima units are compound lava flows with multiple flow units, especially close to the vent. They have a thickness that does not increase systematically with distance. Ogives are more abundant closer to the vent. These differences suggest a cooling-limited control for the Lonquimay flow and a volume-limited control for the Llaima flows.
The measurements of ogive dimensions allowed us to estimate rheological parameters such as the yield strength. Our results show that compound lava flows are not always produced by long-lived, low effusion rate eruptions, but depends also on the lava rheology and topography.

1034

Petrologic evidence for phase separation in the Spirit Mountain Batholith: motivation for compaction modeling

Darien Florez[1], Susana Hoyos[2], Chris Huber[1], Matej Pec[2]
[1]*Brown University, Providece, United States,* [2]*Massachusetts Institute of Technology, Cambridge , United States*

The Spirit Mountain Batholith (SMB) is a granitic pluton emplaced during the Miocene in southern Nevada that displays a variety of lithologies ranging from quartz monzonite to leucocratic granite. We use bulk rock chemistries and plagioclase compositions acquired from electron microprobe analyses to show that evolved SMB materials represent melt extracted from their mafic SMB counterparts. We find that despite a broad range of bulk rock SiO_2 content, decreasing from 70-75 to 60-65 wt % SiO_2 with paleodepth within the SMB, the wt % An between these compositions is similar, with frequency peaks restricted to 15-20 wt % An. This suggests that the primary difference in bulk composition between SMB rock suites is due to phase separation. A major limitation in assessing the processes and timescales involved during melt extraction in systems like SMB is the lack of understanding of the rheology of the crystal mush during compaction. To address this issue specifically, we conducted analog phase separation experiments in tandem with a compaction model. The experiments span a range of crystallinities (~0.4-0.6), where the reduction in matrix porosity is accommodated by the rotation and translation of individual grains (mechanical compaction or repacking). These conditions are applicable to melt extraction in long-lived silicic magma systems such as the SMB. The model is tested with different rheological laws that characterize the ability of the matrix to resist compaction, including diffusion creep flow-laws and flow-laws rooted in detailed parameterizations of granular deformation, to compare the numerical outputs to the experiments. We find that rheological compaction laws that include particle-particle friction and account for the existence of jamming states are better suited to model compaction at intermediate crystallinities. Compaction calculations depend heavily on the given rheological compaction law and this work lays the foundation for developing more accurate phase-separation calculations given geological constraints.

426

Digital Twin Components in Volcanology

Professor Arnau Folch[1], Paolo Papale[2], Antonio Costa[3], Sara Barsotti[4], Leonardo Mingari[5], Deepak Garg[2], Giovanni Macedonio[6], Flavio Cannavò[7], Gilda Currenti[7]
[1]Geociencias Barcelona (GEO3BCN-CSIC), Barcelona, Spain, [2]Istituto Nazionale di Geofisica e Vulcanologia (INGV), Sezione di Pisa, Pisa, Italy, [3]Istituto Nazionale di Geofisica e Vulcanologia (INGV), Sezione di Bologna, Bologna, Italy, [4]Icelandic Meteorological Office, , Iceland, [5]Barcelona Supercomputing Center, Barcelona, Spain, [6]Istituto Nazionale di Geofisica e Vulcanologia (INGV), Osservatorio Vesuviano, , Italy, [7]Istituto Nazionale di Geofisica e Vulcanologia (INGV), Sezione di Catania, , Italy

Interdisciplinary digital twins are becoming able to mimic the different Earth system domains with unrivalled precision, providing analyses, forecasts, uncertainty quantification, and “what if” scenarios for natural and anthropogenic hazards from their genesis to propagation and impacts. The EU DT-GEO project (2022-2025) is deploying a prototype digital twin on geophysical extremes consisting of interrelated Digital Twin Components (DTCs), intended as self-contained containerised entities embedding simulation codes, Artificial Intelligence (AI) layers, large volumes of nearly-real-time data streams, data assimilation methodologies, and overarching workflows for deployment and execution of single or coupled DTCs in centralised High Performance Computing (HPC) and virtual cloud computing Research Infrastructures (RIs). These DTCs, actually a first step towards a digital twin on Geophysical Extremes integrated in the Destination Earth (DestinE) initiative, will deal with geohazards from earthquakes, volcanoes, and tsunamis by harnessing world-class computational (EuroHPC) and data (EPOS) Research Infrastructures, operational monitoring networks, and leading-edge research and academia partnerships. In particular, 4 DTCs of the 12 in DT-GEO will address different volcanic hazards. DTC-V1 will merge multi-parametric data from ground-based and remote observation systems (on-site monitoring networks and satellites) with global modelling of magma and rock dynamics and with AI approach. DTC-V2 will merge real-time geostationary satellite observations with the FALL3D model using the on-line data assimilation PDAF system to generate deterministic and ensemble-based probabilistic forecast products. DTC-V3 will merge real-time multi-parametric data from ground-based and remote observation systems with deterministic modelling of lava flow propagation and inundation areas including Bayesian modelling of vent opening. Finally, DTC-V4 will consider air-quality data and AI in a gas dispersal forecast context to improve our operational Early Warning Systems.

857

Volcanic unrest of Mount Pelée (Martinique, France)

Dr Fabrice Fontaine[1,2], Dr Jean-Christophe Komorowski[1], Dr Jordane Corbeau[1,2], Dr Arnaud Burtin[1], Dr Raphael Grandin[1], Mr Jean-Marie Saurel[1], Dr Jean-Bernard de Chabalier[1], Dr François Beauducel[1], Dr Pierre Agrinier[1], Dr Roberto Moretti[1,3], Dr Severine Moune[1,3,4], Mr Frederic Jadelus[1,2], Mr David Melezan[1,2], Mr Jean-Gilles Gabriel[1,2], Mr Cyril Vidal[1,2], Mr Benoit Zimmermann[1,2], Ms Doris Vaton[1,2], Mr Julien Koziol[1,2], Mr Jean-Marc Lavenaire[1,2], Ms Aurélie Filliaert[1,2], Ms Elodie Chilin-Eusebe[1,3], Dr Manuel Inostroza[1,3], Dr Jean-Philippe Métaxian[1], Dr Claudio Satriano[1], Dr Martin Vallée[1], Mr Anthony Potier[1], Dr David E. Jessop[1,3,4], Mr Vincent Robert[1,3], Mr Sébastien Deroussi[1,3], Mr Arnaud Lemarchand[1], Dr Guillaume Carazzo[1], Mr Sébastien Bonaimé[1], Dr Anne Le Friant[1], Dr Marc Chaussidon[1], Dr Audrey Michaud-Dubuy[1], Dr Steve Tait[5], Dr Lise Retailleau[1,6], Mr Arnaud Andrieu[1,2], Dr Andréa di Muro[1,6], Dr Patrick Allard[1], Dr Ivan Vlastelic[1,3]
[1]Université Paris Cité, Institut de physique du globe de Paris, CNRS, F-75005 Paris, France., , , [2]Observatoire volcanologique et sismologique de Martinique (OVSM), Institut de physique du globe de Paris (IPGP), 97250, Fonds Saint Denis, France., , , [3]Observatoire volcanologique et sismologique de la Guadeloupe, Institut de physique du globe de Paris, 97113, Gourbeyre, France., , , [4]CNRS, UMR 6524, Laboratoire Magmas et Volcans, OPGC, Clermont-Ferrand, France, , , [5]Observatoire Midi-Pyrénées, 31400 Toulouse, France., , , [6]Observatoire volcanologique du Piton de la Fournaise, Institut de physique du globe de Paris, La Plaine des Cafres, La Réunion, France., ,

Between 1999-01 and 2019-01 shallow volcano-tectonic earthquakes (down to 4 km depth) occurred at background mean rate of around 2/month beneath Mount Pelée. Following a marked anomaly in April 2019 (34 VT), monthly seismicity increased to attain 342 VTs in December 2020 with a maximum of 534 VTs in April 2021. Since unrest began, 41 hybrid and 25 long-period seismic signals were recorded, together with episodes of low-frequency volcanic tremor (November 8-9, 2020). In addition to the dominant VT family recorded since the 70s, several new families were detected and localized down to 6.9-9.5 km depth. Distal VT seismicity, 10-20 km bsl was recorded between December 2018 and January 2019. Cumulated seismic energy of shallow to intermediate depth VTs in 2022 is low but similar than in 2021. Four deep VT and 4 deep hybrids (12-33 km below the surface) were recorded in 2022 (magnitude between 0.6-1.9). No felt earthquakes were reported. Processing of continuous GNSS data reveal minor deformation from June 2021 to June 2022, best modelled as a source of inflation located about 1 km below and slightly SW of the summit, above the hydrothermal system. A zone of strongly degraded and dead vegetation observed in December 2020 on Mount Pelée's SW flank is associated with passive soil CO_2 degassing without fumaroles. It is located near active thermal springs and the 1851 phreatic eruption vents. There is no major change in the geochemistry of thermal springs. Nearshore, underwater CO_2 degassing with a magmatic isotopic signature and associated with a weak thermal anomaly and slightly acid pH is monitored since June 2021. The ongoing unrest features most likely reflect the ascent of a limited volume of deep magmatic fluids that reinvigorated the shallow hydrothermal circulation. On IPGP's recommendation, authorities set the volcano alert level to yellow (vigilance) on 2020-12-04.

734

An extended history of explosive volcanism in the Rungwe Volcanic Province, Tanzania

Dr Karen Fontijn[1], Mr Clément Massaert[1], Dr Emmanuel Kazimoto[2], Ms Joyce Mlay[2], Dr Alan Deino[3], Prof Cynthia Ebinger[4]

[1]Université Libre De Bruxelles, Bruxelles, Belgium, [2]University of Dar es Salaam, Dar es Salaam, Tanzania, [3]Berkeley Geochronology Center, Berkeley, USA, [4]Tulane University, New Orleans, USA

The Rungwe Volcanic Province (RVP) is the southernmost volcanically active region in the East African Rift (EAR), with three active-dormant volcanoes, and several extinct centres. Together, they represent a long history of magmatism and volcanism in a complex structural setting between the Malawi and Rukwa-Tanganyika Rifts, and the less seismically active or inactive NE-SW trending Usangu and Luangwa Rifts. Early possible carbonatite volcanism at ~ 24.5-26 Ma and emplacement of phonolite domes at ~ 17-18 Ma suggest prolonged thermal perturbation of the lithosphere well before initiation of rifting. The main episode of volcanism and rifting is thought to have initiated at ~9 Ma and continues to the present, apparently concentrated in three main pulses, including large-scale explosive eruptions of mostly phonolitic magma. These tuffs and other volcanic rocks provide constraints on the timing of rifting initiation and propagation in the southern EAR. However, they have been poorly described in terms of their physical volcanology and chemistry and have, in some cases, inconsistent chronology, in contrast with some of the youngest, Holocene deposits.

We revisit the long-term history of these large explosive eruptions in the RVP and present new field observations, providing descriptions and interpretations of emplacement mechanisms of the large-scale pyroclastic deposits. Chemical and mineralogical fingerprinting of tephra provides insights into the magmatic sources and will facilitate correlation and synchronization of volcano-sedimentary records locally within the RVP, and regionally. Anticipated geochronological studies will place constraints on eruptive rates throughout the developmental history of the RVP.

389

Volcanic history of a complex maar in a monogenetic field
(Waitomokia, Auckland Volcanic Field) and its implication to volcanic hazards

Mrs April Foote[1], Professor Károly Németh[2,3,4], Associate Professor Heather Handley[5,6]
[1]Department of Earth and Planetary Sciences, Macquarie University, Sydney, Australia, [2]Volcanic Risk Solutions, Massey University, Palmerston North, New Zealand, [3]Saudi Geological Survey, Jeddah, Kingdom of Saudi Arabia, [4]Institute of Earth Physics and Space Science, Sopron, Hungary, [5]Department of Applied Earth Sciences, Faculty of Geo-Information Science and Earth Observation, University of Twente, , The Netherlands, [6]School of Earth, Atmosphere and Environment, Monash University, Clayton, Australia

Waitomokia volcanic centre is a maar, tuff ring and scoria cone complex located in the lowlands of the southern end of the Auckland Volcanic Field. Based on historical accounts, a central maar was joined by at least four tuff rings, as well as three scoria cones in the central crater. Extensive quarrying and urban developments have resulted in the near-complete removal of the scoria cones and incision of the tuff ring rims. The remaining outcrops, however, allow us to reconstruct a volcanic history of this complex centre, with the assistance of volcanic stratigraphy and facies analysis, vent locations, fragmentation depths, drivers of eruptive styles and their transitions.

The volcanic history of Waitomokia can be simply split into four main phases, with early and late basal tuff phases, a transitional phase and a magmatic phase. Early tuff ring deposits represent intermittent high-energy vent clearing eruptions, discrete explosions forming ballistic curtain deposits followed by pyroclastic fall and delayed settling of fines, and concentrated pyroclastic density currents (PDCs) followed by dilute density currents and settling. Later tuff ring deposits represent multiple vent shifts to the northeast, and discrete explosions forming ballistic curtain deposits followed by proximal fall and settling of fines, dilute density currents followed by settling, common pyroclastic fall, and intermittent concentrated PDCs. Transitional deposits are juvenile-dominant tuff and represent high-energy vent clearing eruptions followed by settling of fines, discrete explosions forming ballistic curtain deposits followed by proximal fall and settling, and concentrated PDCs followed by settling. Magmatic deposits represent further vent movement and a lack of magma-water interactions.

The size, complexity and evidence of vent migration at Waitomokia enforces the importance of further understanding the volcanic history, eruption style drivers and transitions, and resulting hazards of these types of complex centres in monogenetic volcanic fields.

1011

Clastogenic textures recorded in an obsidian-plugged conduit at Hrafntinnuhryggur, Iceland

Miss Annabelle Foster[1], Dr Fabian Wadsworth[1], Dr Madeleine C S Humphreys[1], Dr Hugh Tuffen[2], Miss Holly E Unwin[2]

[1]Department of Earth Sciences , Durham University ,, United Kingdom, [2]The Lancaster Environment Centre, Lancaster University , United Kingdom

Silicic volcanoes can produce either destructive explosive eruptions or gently emit lava. Direct observations of silicic eruptions at Volcán Chaitén and Cordón Caulle in Chile (2008-09 and 2011-12 respectively) demonstrated that both effusive and explosive eruption styles can occur simultaneously from the same vent. However, the shallow subterranean structures feeding such eruptive complexity at the surface remain understudied. Here we examine an exceptionally preserved shallow volcanic conduit at Hrafntinnuhryggur, Krafla, Iceland, to reconcile rhyolitic eruption styles with models of magma transport processes from storage to surface. Hrafntinnuhryggur is ~2.5 km-long linear ridge parallel to the regional tectonic trend, which was emplaced during a 25 ka silicic fissure eruption. The ridge is composed of discrete and discontinuous dome-like rhyolitic outcrops, separated by scree patches containing a variable polymict mixture of pumice lapilli and obsidian fragments. The broad repetition of pumice lapilli to obsidian along the ridge crest is also reflected in the deepest deposits of the exposed conduit ($\gtrsim$ 70 m-depth), where the outer margin of the outcrop is lined by a ~15 cm-thick deposit of pumice lapilli which gradationally transitions from non-welded to welded pumice and then to dense obsidian. Obsidian-dominated parts of the lava-bodies contain heterogenous textures, such as healed micro-fractures, healed brecciated and flow-banded obsidian, and poorly sintered particles of obsidian in open-fracture systems. We interpret these textures to be closely associated with fragmentation and sintering. Therefore, we suggest that the plugged conduit at Hrafntinnuhryggur is recording a hybrid explosive-effusive eruption style,. With reference to examples elsewhere, such as Mule Creek (U.S.A.) and Husafell (Iceland), we suggest that other apparently effusive silicic lavas and plugs are the remnants of explosively erupted ash and pumice that sinter in an increasingly restricted conduit.

886

The missing: 87 hours of science advisory at the frontline and learnings from the 2019 Whakaari/White Island eruption

Nico Fournier, GeoNet Volcano Monitoring Group
[1]*GNS Science, , New Zealand*

At 14:11 on Monday 9 December 2019, Whakaari/White Island volcano erupted in New Zealand while visitors where on the island. 22 people were killed and many more injured. Beyond the initial reflex rescue operations, the hours and days following the eruption focused on the recovery operations for the 8 victims remaining in the active crater, when volcanic activity was still highly variable. This presentation is a tale of science advisory and communication at the coal face in the 87 hours that followed the eruption, until the first recovery operation of the missing was attempted. It is a tale of communicating highly uncertain science and forecasts, and guiding operations in a high-consequence, high-scrutiny and high-expectations environment. It is a tale of communicating facts that no one wants to hear to a wide audience, from police and military to recovery teams, from emergency managers and health specialists to ministers, from the media and the public to the families of the missing. Finally, it is a tale of empathy, humility and reflection, and of what we learnt from this tragedy.

This presentation is dedicated to the missing, and to anyone who has been affected by the 2019 eruption at Whakaari/White Island.

740

Late Pleistocene multiphase subglacial eruption at Gaussberg volcano, East Antarctica

Dr Jodi Fox[1,2], Dr Jacqueline Halpin[1], Associate Professor Rebecca Carey[3], Dr Felicity McCormack[4], Professor Fred Jourdan[5]

[1]Institute For Marine And Antarctic Studies, University of Tasmania, Hobart, Australia, [2]National Museum for Nature and Science, Tsukuba, Japan, [3]Centre for Ore Deposit and Earth Sciences, University of Tasmania, Hobart, Australia, [4]School of Earth Atmosphere and Environment, Monash University, Melbourne, Australia, [5]Western Australian Argon Isotope Facility, Curtin University, Perth, Australia

Subglacial volcanic eruptions can have significant impact on ice sheet behavior and/or volume via short-term melting of ice and longer time-scale effects on regional geothermal heat flow, surface uplift and subsidence through time. Gaussberg volcano, located on the coast of East Antarctica at 89°19'E is a glacially eroded, pillow-dominated, cone-shaped edifice ~1200 m high. The bulk of the edifice is concealed below ice and the sea, the part of the edifice that is exposed, is 1000-1150m wide and rises 370 m absl. Gaussberg is the only confirmed volcano within this sector. It is suspected to have erupted entirely beneath ice in single or multiple phase(s) of eruptive activity. Previously, the timescale of volcanism was uncertain as a broad range of ages for the lavas (~56 ka, 9 Ma and 20 Ma) have been produced by K/Ar isotopic techniques.

We constrain the age and environment of eruption of Gaussberg volcano using legacy samples collected by Sheraton and Ellis (ANARE 1977). The samples are ultrapotassic (11.7-12.1 wt. % K_2O) olivine-bearing lamproite lavas mainly comprising leucite, clinopyroxene and glass. We provide a new chronology of eruption using $^{40}Ar/^{39}Ar$ technique applied to leucite (20.5-21.7 wt. % K_2O). We measured the volatile contents (H_2O) of volcanic glass with Fourier-transform infrared spectroscopy to constrain the quench pressures of lavas and hence the thickness of overlying ice at time of eruption. Our results reveal at least two phases of volcanic activity at Gaussberg volcano, 24.7 ± 1.8 ka to 34.1 ± 2.6 ka and 51.7 ± 1.0 ka to 55.8 ± 2.9 ka and that the eruptions occurred beneath an ice sheet that was ~540m thicker than present day.

We expect these new constraints on phases of volcano growth and paleoenvironment can inform Antarctic heat flow and ice sheet models.

1245

Along for the ride: phenocryst and microlite antecrysts in the 2020-21 effusive and explosive eruptions of La Soufrière, St Vincent

Dr Holli Frey[1], Dr. Matthew Manon[1], Dr. Jenni Barclay[2], Dr. Bridie Davies[2], Dr. Paul Cole[3]
[1]Union College, Schenectady, United States, [2]University of East Anglia, Norwich, United Kingdom, [3]University of Plymouth, Plymouth, United Kingdom

La Soufrière stratovolcano (St. Vincent) began erupting effusively in December 2020 and became explosive in early April 2021. Detailed stratigraphy and sampling of units within the tephra-fall deposits has allowed us to do a comprehensive petrologic time-series study through the first 48 hours of the explosive eruption(s). Primary eruptive products include a crystal-rich (45-50 vol%) basaltic andesite vesicular scoria. The compositional ranges and relative abundances of the phenocrysts do not vary across the eruptive sequences, whereas the microlites, crystallinity, and vesicularity changed as the eruption progressed. There are two distinct microlite populations: 1) “inherited” - normally zoned high-An plagioclase (>An70) + olivine (Fo62-79) + clinopyroxene + titanomagnetite, inferred to have crystallized at depths >15 km and high water pressures; 2) “juvenile” - unzoned plagioclase (An45-65) + clinopyroxene + orthopyroxene + intermediate pyroxene (Wo15-37) + titanomagnetite, inferred to have crystallized upon ascent due to decompression. The initial eruptions were dominated by extensive groundmass crystallization and the inherited microlite population; the ascent of this water-rich magma from depth may have initiated the March 23rd volcano-tectonic earthquake swarm and increase in CO2 degassing (Joseph et al., 2022). Additional microlite crystallization occurred during shallow ascent and resulted in a viscosity inhibited eruption until the system became over-pressurized on April 9th, when a weak SO2 plume was detected and explosions commenced. Later explosions featured an abundant “juvenile” microlite population and lower crystallinity, consistent with more rapid ascent from depth after the system experienced deep deflation following the initial eruption. Various assessments of equilibrium suggest that the majority of phenocrysts, as well as the inherited microlites, were not in equilibrium with the carrier melt and likely represent discrete batches of mush that were entrained upon ascent.

References: Joseph et al. (2022) Nature Communications 13, 4129

780

The post-2016 long-lasting Vulcanian activity of Sabancaya volcano (Peru) and associated aeolian remobilisation of volcanic ash

Dr Allan Fries[1], Dr Lucia Dominguez[1], Dr Paul A. Jarvis[1,2], Prof Marco Pistolesi[3], Nelida Manrique Llerrena[4], Rigoberto Aguilar[4,5], David Valdivia Humerez[4], Dr Eduardo Rossi[1], Dr Stefano Pollastri[1], Prof Claire J. Horwell[6], Prof Costanza Bonadonna[1]

[1]Department of Earth Sciences, University of Geneva, Geneva, Switzerland, [2]GNS Science, Lower Hutt, New Zealand, [3]Dipartimento di Scienze della Terra, Università degli Studi di Pisa, Pisa, Italy, [4]Instituto Geológico Minero y Metalúrgico-INGEMMET, Observatorio Vulcanológico del INGEMMET, Arequipa, Peru, [5]Université Clermont Auvergne, Laboratoire Magmas et Volcans, Clermont-Ferrand, France, [6]Institute of Hazard, Risk and Resilience, Department of Earth Sciences, Durham University, Durham, United Kingdom

The characterisation of tephra deposits associated with almost simultaneous sedimentation and wind remobilisation is a complex task and multidisciplinary strategies are required in order to accurately constrain associated eruptive parameters and processes. We present a multifaceted study that aims to characterise the recent eruptive activity and the subsequent aeolian remobilisation of tephra deposits at Sabancaya volcano (Peru), which started erupting in November 2016 with frequent and relatively small explosions (plume heights < 5 km above the vent). First, we have estimated the dense rock equivalent (DRE) volume of tephra deposits produced between November 2016 and August 2018 at 0.02 ± 0.01 km³ ((9.1 ± 4.5) × 10^{-4} km³ per month). Second, continuous sampling in a dedicated vertical tephra collector network between April 2018 and November 2019 allowed estimation of a cumulative erupted volume of (5.8 ± 2.5) × 10^{-4} km³ DRE that corresponds to a monthly volume of (2.9 ± 1.3) × 10^{-5} km³, indicating a significant decrease in the tephra production rate since 2018. Third, the evolution of the pulsatory activity was studied based on the repose interval between explosions and magma property (i.e. viscosity) estimates, classifying Sabancaya activity within Vulcanian eruptive styles. Finally, we have studied aeolian remobilisation phenomena affecting surficial tephra deposits based on high-resolution videos, measurements of the airborne concentration of particulate matter with a diameter of 10 µm or less (PM_{10}) and particle physical characterisation. Regardless of negligible morphological differences with respect to primary deposits, we found that the grainsize of remobilised particles is consistent with different transport mechanisms, with particles preferentially moving by saltation and suspension, for particles collected at ground level and above 1.5 m, respectively.

781

New insights into the formation and characteristics of ash fingers descending from the base of volcanic clouds

Dr Allan Fries[1], Dr Jonathan Lemus[1,2], Dr Paul A. Jarvis[1,3], Prof. Amanda B. Clarke[4,5], Prof. Jeremy C. Phillips[6], Prof. Irene Manzella[7], Dr Simona Scollo[8], Prof. Costanza Bonadonna[1]
[1]Department of Earth Sciences, University of Geneva, Geneva, Switzerland, [2]Department of Computer Science, University of Geneva, Geneva, Switzerland, [3]GNS Science, Lower Hutt, New Zealand, [4]School of Earth and Space Exploration, Arizona State University, Tempe, United States, [5]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Pisa, Pisa, Italy, [6]School of Earth Sciences, University of Bristol, Bristol, United Kingdom, [7]Faculty of Geo-Information Science and Earth Observation, Department of Applied Earth Sciences, University of Twente, Twente, the Netherlands, [8]Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo, Catania, Italy

Ash fingers are downward-propagating particle-laden flows that often form below volcanic plumes and clouds, likely affecting the sedimentation and dispersal of fine volcanic ash in the atmosphere. In fact, fine tephra entrained within fingers can settle faster collectively than as individual particles. However, despite a potentially significant role in the deposition of volcanic ash, the formation and characteristics of ash fingers remain poorly described, especially in the field.

To overcome this gap we collected new visual observations of ash fingers formed below wind-bent plumes at Mount Etna (Italy) from 2012 to 2013, Sabancaya (Peru) in 2018 and Sakurajima (Japan) in 2019. The high-resolution video images obtained in the field were calibrated in order to quantify plume and finger properties, significantly increasing the number of measurements of volcanic ash fingers. In particular, given that only particles sufficiently coupled with the flow can settle within fingers, measurements of finger downward velocities are used to constrain the maximum particle diameter transportable by ash fingers for each plume. The video images also provide insight into possible mechanisms initiating and driving ash fingers. We conclude that ash fingers may have resulted from settling-driven gravitational instabilities (SDGIs) strongly influenced by the wind in the cases reported here.

We additionally performed laboratory experiments to define conditions favouring the development of fingers as a function of the particle concentration and size in a controlled setting and to confirm our conclusions from the field-based study. Lab results show that the ratio of the finger characteristic velocity to the velocity of individual particles adequately predicts the occurrence of settling-driven fingers, and confirm that particle size is a main factor controlling finger formation. The lab findings combined with our new field observations constrain important quantitative thresholds and provide critical insights into formation mechanisms and characteristics of ash fingers.

1189

Large-scale Geochemical Mapping and Influences of Local Volcanism on Seafloor Sediments: A Case Study of Bay of Plenty, Aotearoa/New Zealand.

Ms Grace Frontin-Rollet[1], Dr Richard Wysoczanski[1], Mr Vincent Rigalleau[2], Associate Professor Monica Handler[3], Dr Katie Maier[1]
[1] National Institute of Water and Atmospheric Research, Wellington, New Zealand, [2]Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany, [3] School of Geography, Environment & Earth Science, Te Herenga Waka–Victoria University of Wellington, Wellington, New Zealand

Seafloor volcanism processes and eruption products can have a significant effect on the immediate seafloor environment (e.g., erosional scouring and subsequent deposition from particle density flows to long term erosion of volcanic rock). However, the large-scale geospatial effects of volcanism on the surrounding seafloor surficial sediment chemistry have not yet been documented for volcanically active offshore areas of Aotearoa/New Zealand.

Here we present initial large-scale geochemical maps of the offshore Bay of Plenty area, situated on the northeast coast of Te Ika-a-Māui/North Island, Aotearoa/New Zealand, that utilise analyses of over 300 surficial sediment samples. Data for 6 major elements and 8 trace elements were collected using portable x-ray fluorescence (pXRF). Certified Reference Materials (CRM) and internal standards were used to calibrate the data. Internal standards and a subset of samples were verified using benchtop XRF by two laboratories with excellent agreement between results. For as accurate calibration as possible, several linear and weighted regression models were tested for each element using CRM analyses. With the increase in accuracy from raw to calibrated data being on average from ~+/- 15% to ~+/- 3-6% for most major elements, these methods enable rapid and cost-effective acquisition of semi-quantitative data. Geospatial interpolation and multivariate statistical analysis reveal the geochemical signatures of two major volcanic sources and maps the extent of their connection with the surficial sedimentary environment: Tūhua/Mayor Island and Whakaari/ White Island, characterised by variance in Nb-Zn-Rb and Ni-Cu-Cr, respectively.

A large-scale geospatial database of surficial sediment geochemistry has applications for research ranging from the effects of local volcanism on nearby marine sediment composition, to benthic habitat mapping, and ocean acidification research into the stability of minerals in an acidifying ocean.

739

Estimating erosion depth of the Gangdese orogenic belt (southern Tibet) using exposed porphyry alteration systems and whole-rock La/Yb ratios

先生 Hanze Fu[1], Dr Gabor Kerestuzri[2], Prof. Qiuming Cheng[1], Prof. Rui Wang[1]
[1]China University Of Geosciences, Beijing, Haidian district, China, [2]Massey University, North Palmerston, New Zealand

Composite volcanoes can host economically valuable ore deposits (porphyry Cu deposits). After the volcanism ceased, erosion and tectonic uplift can altogether exhume such ore bodies and associated hydrothermal alteration halos, which have formed under narrow pressure, temperature, and pH conditions. The alteration mineralogy can highlight the vertical stratigraphy within an extinct composite volcano and their plumbing systems and can consequently be used to estimate paleo-depths.

In this study, we have combined (1) ASTER multispectral imagery for identifying hydrothermal mineral associations, (2) SRTM-based drainage patterns analysis for topographic analysis and (3) whole-rock La/Yb ratios for estimating paleo-depths along the Gangdese orogenic belt, southern Tibet. The Gangdese orogenic belt is a particular area in which Moho depth is negatively correlated with elevation and exposes 35 composite volcanoes from the post-collisional period (26-10 Ma). Here, we evaluate the role of tectonic uplift and erosion on the E-W isostasy contrast through mapping hydrothermal alteration mineralogy using alteration indices. The combined results reveal the eastern Gangdese (the east of ~88°) dominated with potassic and propylitic alteration associated with deeply eroded (2-3±1.1 km) post-collisional composite volcanoes, while the western part (the west of ~88°) has widespread argillic and phyllic alteration, representing a shallow erosion environment (1.0-1.6±0.5 km). The geomorphology and climatic analysis illustrate the east is characterized by steeper topography, warmer and wetter climate, and higher channel steepness index, indicating that the eastern Gangdese underwent rapid uplift and erosion. We hypothesize both the surface response of slab dynamics (20-10 Ma) and intensified Yarlung river incision (8-3 Ma) control the contrasting erosion patterns, which decrease the elevation and remove more volcanic lithocaps to expose more porphyry intrusions in the east. The presented study exemplifies how tectono-magma, surface processes, and climate to reorganize the landscape and ancient volcanic systems through erosion.

1002

Volcaniclastic deposits generate by slope failure and submarine phreatomagmatic explosions from the Neogene Kakudayama volcanic rocks, Japan.

Dr Norie Fujibayashi[1], Kazuma Takizawa[1]
[1]*Niigata University, Niigata, Japan*

Neogene basaltic to dacitic lavas, hyaloclastites, and volcaniclastic rocks are distributed in Kakudayama area, Niigata Prefecture, Japan. They represent the products of emergent volcanism, and we found a series of stratigraphic successions of boulderly submarine debris flow deposits generated by slope failure and gravelly turbiditic flow deposits generated by phreatomagmatic explosions, in this order. The boulderly submarine debris flow deposits consist of stratified beds of volcanic breccia with each thickness of about 2.5 - 4.2 m. The beds generally have a reverse-graded structure, in which the upper part contains many huge lava blocks, occasionally up to 2-3 m large. Platy block up to 10 m long with thickness of c.a. 2 m are also found in the deposits, which lies parallel to the bedding plane. The lava blocks are aphyric dacite, and their reddish-brown color indicate the subaerial emplacement before collapse.

The gravelly turbiditic flow deposits are composed of altered volcanic breccia, tuff breccia, and lapilli stone beds, showing an upward thining and fining structures. The lowest layer is thick (2.5 m or 3.6 m thick) and consists of a variety of angular volcanic rock fragments, rich in 10 - 20 cm large. Occasionally, rounded clasts are contained. The uppermost part is stratified by internally thinly bedded (<10 cm thick) lapilli stone beds, rich in moderately to highly vesiculated essential lapilli (c.a. 45%). The vesiculated essential material is the glassy hornblende-bearing two pyroxene andesite with various degree of vesiculation, ranging from 30 to 70 %. The same essential materials are found throughout the gravelly turbiditic flow deposits, and are also present in small amounts in the boulderly submarine debris flow deposits, suggesting that the eruption triggered slope failure first and continued to underwater phreatomagmatic explosions.

902

Lava flow drill map: Spatial resolution and the application to volcanic hazard mitigation

Dr Eisuke Fujita[1], Dr Hiroyuki, A. Shimizu[1], Dr Tomofumi Kozono[1], Prof Haruhisa Nakamichi[2]
[1]NIED, Tsukuba, Japan, [2]Kyoto University, Kagoshima, Japan

Volcanic hazard map provides information on inundation area of lava flow as well as its arriving time, temperature, flow speed, etc. The spatial resolution in digital elevation map strongly controls the reliability of lava flow simulation. Numerical simulation using coarse meshes can offer quick evaluation about volcanic hazard, sometimes for real time evaluation. On the other hand, that using fine meshes can give us information on detailed physical mechanism of volcanic phenomena. This detailed numerical simulation is inadequate to contribute to quick evaluation, so the database from many case studies, which we call drill map, are necessary. Each volcanic hazard simulation of lava flow can be performed using many kinds of parameters, some of which are dominant, for example, lava effusion rate, vent location and temperature of lava are sensitive to the lava flow dynamics. For the probabilistic evaluation, we have to assume adequate ranges for these input parameters and to calculate a plenty of cases, but it is impossible in view of numerical simulation resources. Here, we propose example of lava flow drill map database, which are applicable in case of emergency. The spatial resolution is 5 m, in the same order of road width for vehicles. These lava flow simulation results can be coupled with evacuation simulation using multi-agent method. Application of volcanic hazard simulation result to countermeasure simulation can encourage more adequate planning for risk and emergency assessment.

234

Modeling magmatic unrest at oceanic and coastal volcanoes, implication of the topography and crustal heterogeneities

Séverine Furst[1], Morelia Urlaub[1], Francesco Maccaferri[2], Elisa Klein[1]
[1]GEOMAR Helmholtz Centre for Ocean Research Kiel, 24148 Kiel, Germany, [2]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Napoli - Osservatorio Vesuviano, Via Diocleziano 328, 80124, Napoli, Italy

Volcanoes are sources of numerous threats including lava flows, pyroclastic flows, ash dispersal, landslides or sector collapses. In addition to these common volcanic hazards, volcano-induced tsunamis can occur at island or coastal volcanoes, introducing a major hazard that can affect populations far away from the volcanoes. Precursory signals to these sector collapses are yet poorly known limiting the mitigation of associated risks. The historical record, and by that we refer to few hundred years of as human witnesses, may suggest a link between catastrophic flank collapses at coastal and island volcanoes and magmatic activity but studies have identified various collapse events on inland volcanoes that were not related to the magmatic activity, but to other triggers including gravitational spreading, hydrothermal activity, earthquake and climate. Here, we investigate the impact of magmatic system on sector collapse through numerical modelling of dyke propagation. We use a 2D Boundary Element approach to model the shape, trajectory and stress induced by the travel of a fluid-filled fracture in the crust, accounting for the interaction with the topography, which is usually not negligible at oceanic and coastal volcanoes due to the underwater part of the edifice. We also model the interaction of the propagating dyke with crustal heterogeneities and face the outcome with available information about stress changes in volcanic systems. With this study, we aim to test whether ground deformation induced by magma transport presents a potential precursory signal preceding sector collapse of coastal and oceanic volcanoes.

235

Analogue experiments on the generation of seismic signals during dyke propagation

Séverine Furst[1,2], Virginie Pinel[2], Jean Vandemeulebrouck[2]
[1]GEOMAR Helmholtz Centre for Ocean Research Kiel, 24148 Kiel, Germany, [2]Univ. Grenoble Alpes, Univ. Savoie Mont Blanc, CNRS, IRD, Univ. Gustave Eiffel, ISTerre, 38000 Grenoble, France

The propagation of magma through the crust can be accompanied by seismic signals and deformation at the surface which usually stand for precursors in early warning strategies for volcanic unrest. While surface deformation is associated with emplacement of magma in propagating fractures, seismic signal is thought to be induced by the fracturation of the medium, mostly at the propagating tip of the dyke. To explore the generation of seismic signal in such context, we used analog modeling which is a powerful tool to reproduce natural processes at laboratory scale with well constrained parameters and conditions. We built dedicated analog experiments involving the propagation of crack induced by the injections of finite volume of air in gelatin tanks. Crack shape, trajectory and velocity of propagation were imaged with one camera whilst a set of 16 high-frequency accelerometers placed on the gelatin surface recorded the seismic signal during the experiments. Crack propagation generated a few events characterized by a relatively low frequency corresponding to the resonance of the crack wall and located around the depth of the crack tail. We observed that the rougher the crack surface was, the more events were recording during the propagation. The propagation of the crack also induced displacements at the surface of the gelatin that were estimated using the video and compared with predictions from numerical modeling using COMSOL software. Finally, we noticed a correlation between the surface displacement, the velocity of propagation and the low frequency signal when the crack is approaching the surface that could be used to better understand the increase in the seismic rate during the last stages of dyke propagation.

849

Mathematical models for harmonic volcanic tremors

Professor Lorenzo Fusi[1,2], Dr Giordano Montegrossi[2,3]
[1]Dept. of Mathematics and Informatics - University of Florence (Italy), Firenze, Italy, [2]INSTM - National Interuniversity. Consortium for Material Science and Technology, Firenze, Italy, [3]CNR - Institute for Geosciences and earth resources, Firenze, Italy

Volcanic eruptions are often preceded and accompanied by low-frequency harmonic tremors that can persist for minutes to many months. The typical measured frequency is approximately between 0.5 and 10 Hz. Recently it has been speculated that harmonic tremors may be linked to oscillations of large gas bubbles entrapped in cavities or rock cracks in which vapor or gas bubbles are heated by magma. The idea is that vapor bubbles develop near the heat source and, under proper conditions, dissipate energy not only by conduction but also by performing mechanical work (i.e. oscillating). Using an experimental apparatus that mimics the natural phenomenon of harmonic tremors (a capillary adiabatic tube filled with water and heated from the bottom) we develop a mathematical model of the observed phenomenon. The aim of the model is to give a rigorous description of the oscillatory behavior of the experimental apparatus and to reproduce the range of frequencies observed in on-field measurements. Writing the overall momentum and energy balance we formulate the mathematical problem that consists of a system of nonlinear ordinary and partial differential equations coupled together. We solve the system numerically obtaining an oscillating period that falls in the range of the recorded-ones.

303

Volcano-climate impacts during the Medieval warm period: insights from the Greenland ice cores

Miss Imogen Gabriel[1], Dr Gill Plunkett[2], Dr Peter Abbott[1], Dr Joe McConnell[3], Dr Will Hutchison[4], Dr Andrea Burke[4], Dr Maria Hoerhold[5], Ms Melanie Behrens[5], Dr Eliza Cook[6], Dr Michael Sigl[1,7]
[1]Oeschger Centre for Climate Change Research/University Of Bern, Bern, Switzerland, [2]School of Natural and Built Environment, Queen's University Belfast, Belfast, UK, [3]Desert Research Institute, Reno, USA, [4]School of Earth and Environmental Sciences, University of St Andrews, St Andrews, UK, [5]Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung, Bremerhaven, Germany, [6]Physics of Ice, Climate and Earth, Niels Bohr Institute, University of Copenhagen, Copenhagen, Denmark, [7]Department of Geosciences, University of Oslo, Oslo, Norway

The period 750 to 1000 CE was a time of significant societal and climatic changes across the North Atlantic region, encompassing the Viking expansion to Greenland and Iceland and the transition into the Medieval Warm Period (Hughes and Diaz, 1994; Arneborg, 2008; Sigurðsson, 2008). Despite this, volcanism during this period is poorly understood, with this period previously considered to be volcanically quiescent (Bradley et al., 2016).

Preliminary analysis of several Greenland ice core records, where evidence of eruptions may be preserved through sulphate aerosols and tephra, has revealed that this was in fact a period of heightened volcanic activity. However, uncertainties persist over the nature of several of these eruptions, i.e. their total duration, plume height, and the responsible volcanic centre(s). This has ultimately hindered the construction of detailed eruption records and robust climate impact assessments of events throughout this period.

To address this, we adopted a multi-parameter approach across several Greenland ice cores. We (1) determined the total duration of these events using the annually resolved high-resolution ice core chronologies; (2) undertook targeted sampling for cryptotephra major and trace element geochemical analysis to pinpoint the source volcano; and (3) conducted high-resolution sulphur isotope analysis to determine plume height (tropospheric or stratospheric).

The adoption of this multi-parameter approach has allowed us to better understand and characterise volcanic activity during the period 750 to 1000 CE. Moreover, it provided us with the necessary information to assess the climatic impacts of these eruptions when utilised alongside paleoenvironmental archives (i.e. speleothems; Affolter et al., 2019, Fohlmeister et al., 2012) and historical written records from across Europe (McCormick et al., 2007; Newfield, 2013) and North Africa (Kondrashov et al., 2005). Ultimately, the wider application of this approach (i.e. other time-periods and regions) may facilitate the reconstruction of past volcano-climatic impacts.

247

Eruption at basaltic calderas forecast by magma flow-rate

Dr Federico Galetto[1], Prof. Valerio Acocella[2], Prof. Andrew Hooper[3], Dr. Marco Bagnardi[4]
[1]Cornell University, Ithaca, United States, [2]Università degli Studi di Roma Tre, Roma, Italy, [3]University of Leeds, Leeds, United Kingdom, [4]NASA Goddard Space Flight Center, Greenbelt, United States

Forecasting eruption is the ultimate challenge for volcanology. While there has been some success in forecasting eruptions hours to days beforehand, reliable forecasting on a longer timescale remains elusive. Here we show that magma inflow rate, derived from surface deformation, is an indicator of the probability of magma transfer towards the surface, and thus eruption, for basaltic calderas. Inflow rates ≥0.1 km3 per year promote magma propagation and eruption within 1 year in all assessed case studies, whereas rates less than 0.01 km3 per year do not lead to magma propagation in 89% of cases. We explain these behaviours with a viscoelastic model where the relaxation timescale controls whether the critical overpressure for dike propagation is reached or not. Therefore, while surface deformation alone is a weak precursor of eruption, estimating magma inflow rates at basaltic calderas provides improved forecasting, substantially enhancing our capacity of forecasting weeks to months ahead of a possible eruption.

246

Spatial and temporal quantification of subaerial volcanism from 1980 to 2019: products, masses and average eruptive rates.

Dr Federico Galetto[1], Prof Matthew E. Pritchard[1], Dr. Adrian J. Hornby[1], Prof. Esteban Gazel[1], Prof. Natalie M. Mahowald[1]
[1]*Cornell University, Ithaca, United States*

Volcanism is one of the main mechanisms exchanging mass and energy between the interior of the Earth and the Earth's surface and atmosphere. However, the global mass flux of each type of erupted product (effusive: lava; explosive: ash and pyroclastic flows) is not well constrained, especially on decadal time scales. Here we review published estimates of the mass of the erupted products from 1980 to 2019 by a global compilation. We identified from the Smithsonian Global Volcanism Program database 1471 eruptions occurred from 1980 to 2019. For each eruption, we reported both the total erupted mass and its partitioning into the different volcanic products. Using this new database, we quantified the temporal and spatial evolution of global subaerial volcanism and its products from 1980 to 2019. We found that 1.1-4.8*1013 kg of magma were erupted in each analysed decade. Lava is the main subaerial erupted product representing ~56% of the total erupted mass of magma. The products related to the biggest eruptions (Magnitude ≥6), with long recurrence times, can temporarily make the explosive products more abundant than lava (e.g. decade 1990-1999). At a global scale, the 10 and 40 years average eruptive rates match well with the long-term eruptive rates (millions of years), because in both cases rates are scaled for times comparable to the recurrence time of the considered eruptions, suggesting a stability of the volcanic activity over timescales spanning six orders of magnitude. Finally, we estimated the 10 and 40 years average eruptive rates of each magmatic province.

1429

Characterising ice-magma interactions during the final stages of the 1783–84 CE Laki fissure eruption, Iceland.

Dr. Catherine R. Gallagher[1], Dr. Magnús Tumi Guðmundsson[1], Dr. Thorvaldur Thordarson[2], Dr. Bruce F. Houghton[3], Dr. Birgir Vilhelm Óskarsson[4], Dr. Robert A. Askew[4], Dr. Rosie Cole[1], Dr. Guðrún Þorgerður Larsen[1], Dr. Valentin R. Troll[5]

[1]Nordic Volcanological Center, The University Of Iceland, Reykjavík, Iceland, [2]Faculty of Earth Sciences, The University of Iceland, Reykjavík, Iceland, [3]SOEST, University of Hawai'i at Mānoa, , USA, [4]Náttúrufræðistofnun Íslands, Garðabær, Iceland, [5]Department of Earth Sciences, Uppsala University, Uppsala, Sweden

Substantial parts of Iceland's active volcanic zones are presently ice-covered, and fissure eruptions beneath glaciers are common. It has been hypothesised that fissure eruptions at or within ice-marginal settings would be predominantly phreatomagmatic and generate jökulhlaups. However, globally, few historical examples have been directly observed.

Fissure 10 (F10), the final fissure opening phase of the 1783–84 CE Laki flood basalt event in the Síða highlands of South Iceland, formed as dry magmatic eruptive activity propagated under Síðujökull, an outlet glacier from the Vatnajökull ice-cap. The resultant, predominantly phreatomagmatic, 2.5 km-long shallow sub-glacially erupted formations offer a rare example of intraglacial eruptive vents from a known historical eruption. They provide a perfect natural laboratory to understand the dynamics of fissure eruptions in a shallow subglacial or intraglacial setting. Comparisons to dry magmatic activity along the rest of the Laki cone-row allows for the effect of the shallow-glacier to be isolated.

Field mapping and drone photogrammetry reveal a sequence dominated by phreatomagmatic tuff deposits, intercalated with hackly jointed lobate lava flows, hackly jointed intrusions, and debris flows suggestive of fluctuating water levels. Repeating units of agglutinated spatter and spatter-fed lava flows cap the sequence, indicating the decreasing influence of external water with stratigraphic height. A thin layer of glacial till coats the top of the eruptive sequences indicating Síðujökull re-advanced over the area after the eruption, though it has since fully receded. The morphology of the formation itself displays increasing degrees of lateral confinement when traced SW–NE. Micromorphology and EMP analysis of glassy tephra indicates rapid quenching of the melt, leaving F10 tephras significantly less degassed than their dry magmatic Laki counterparts.

Analysis of rare landforms like these is important for interpreting paleo ice-extents. This study suggests a new Little Ice Age extent for Síðujökull, and SW Vatnajökull, using F10.

1058

Reconstructing the growth of Kīlauea's Ahuʻailāʻau cone (Fissure 8) using ground penetrating radar and eruption monitoring data

Dr Elisabeth Gallant[1], Dr Carolyn Parcheta[1], Dr Sarah Kruse[2], Dr Hannah Dietterich[3], Dr Matt Patrick[1], Liliana Desmither[1], Dr Mel Rodgers[2], Robert Van Alphen[2], Dr Rocco Malservisi[2]
[1]United States Geological Survey - Hawaiian Volcano Observatory, Hilo, United States, [2]University of South Florida, Tampa, United States, [3]United States Geological Survey - Alaska Volcano Observatory, Anchorage, United States

Cinder cones are one of the most common volcanic features on Earth, but the dynamics and processes of their construction are poorly documented because very few have been extensively monitored during eruption. Data collection and observational monitoring are difficult to conduct in real-time during cone-building eruptions because the location of activity can be distributed, with multiple fissures and vents that may reactivate intermittently. Additionally, this rapid evolution often means that the deposits from the earliest eruptive phases become buried before they can be studied and that reactivated vents may be inconsistently monitored.

The growth of Ahuʻailāʻau (fissure 8) during the 2018 lower East Rift Zone eruption of Kīlauea, Hawaiʻi, provided an opportunity to link extensive monitoring data and observations with post-eruptive studies and methodology. The opening phase of fissure 8 built a spatter rampart before stalling out for several weeks. When activity resumed, oscillating fountain heights up to 75 m rapidly grew the cone to 55 m over a period of 3 weeks. We used ground penetrating radar (GPR) to image the upper 15-20+ m of surface deposits on Ahuʻailāʻau to improve our understanding of the dimensional growth of the edifice during the cone-building phase. We identify a distinct boundary between spatter and cinder deposition, the transition in deposit type between the open section of the cone and the downwind section, the influence of changes in wind direction on the tephra blanket, and evidence of small syn-eruptive granular flows of the tephra. The GPR survey results were augmented by data from syn-eruptive monitoring of the lava fountaining, remote sensing and time-lapse camera data, and aeromagnetic surveying to link the eruption dynamics and morphologic evolution with time. These results and the post-eruptive surveying provide a useful benchmark for studies of cones whose growth was not witnessed or documented.

818

Origin of the magma that fed the onset of the 2018 Lower East Rift Zone eruption at Kīlauea Volcano

Ms Rose Gallo[1], Ms Laurine Barreau[2], Dr. Nicolas Cluzel[2], Dr. Thomas Shea[1], Dr. Allan Lerner[3], Dr. Paul Wallace[3], Dr. Cheryl Gansecki[4]

[1]University Of Hawai'i At Manoa, Honolulu, United States, [2]Universite Clermont Auvergne, Clermont-Ferrand, France , [3]University of Oregon, Eugene, United States, [4]University of Hawai'i Hilo, Hilo, United States

Eruptions in Kīlauea's East Rift Zone often entail complex mixing between several magmatic end-members. The voluminous 2018 eruption in the Lower East Rift Zone (LERZ) involved at least three end-members: (1) an evolved high-Ti basalt (HTB) (MgO ~4.5 wt.%) and (2) an andesite (MgO < 2.3 wt.%), both thought to have been stored beneath the LERZ prior to eruption, and (3) more mafic basalt that may have originated from summit reservoirs ~40 km away. The persistence of eruptible magma for long periods beneath inhabited areas in the LERZ makes understanding the thermal history and longevity of these reservoirs crucial. The 2018 eruption began with the effusion of nearly pure HTB end-member for 6 days (phase 1a) before mixed magmas began to dominate. The HTB was hypothesized to originate from leftover magma from the late stage of the 1955 LERZ eruption (1955L) (MgO= 6.3 wt.%). We examine this hypothesis using a comparative study of the whole rock (WD-XRF), glass, mineral, and melt inclusion compositions (EPMA and SIMS) of 2018 stage 1 and 1955 early and late-stage magmas. Whole rock trace element data and mineral compositions suggest that early 1955 magma (1955E) is a better match to 2018 than 1955L magma, consistent with the proximity of 1955E and 2018 stage 1 vents. This requires that a portion of the 1955E magma survived unaffected by late-stage magma mixing and cooled by < 25°C in 63 years of storage before being remobilized. Melt inclusion trapping depths for HTB and the 2018 fissure 17 basaltic andesites reach 2.5-3 km and are indistinguishable from those of 1955E. These depths are also consistent with the depth at which a dacite was intersected during nearby drilling in 2005 (2488 m), confirming that the ~2.5 km-depth region of the rift is a preferred magma storage region.

819

Reconciling complex stratigraphic frameworks reveals temporally and geographically variable depositional patterns of the Campanian Ignimbrite

Ms Rose Gallo[1], Dr. Michael Ort[2], Dr. Kayla Iacovino[3], Dr. Aurora Silleni[4], Dr. Victoria Smith[5], Ms. Paige Laplant[2], Dr. Guido Giordano[6], Dr. Roberto Isaia[7], Dr. Joseph Boro[1]

[1]University Of Hawai'i At Manoa, Honolulu, United States, [2]Northern Arizona University, Flagstaff, United States, [3]Jacobs, NASA Johnson Space Center, Houston, United States, [4]Università di Napoli Federico II, Napoli, Italy, [5]University of Oxford, Oxford, United Kingdom, [6]Università Roma Tre, Roma, Italy, [7]Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Vesuviano, Napoli, Italy

The 39.8-ka Campanian Ignimbrite was emplaced during a caldera-forming eruption of Campi Flegrei near Naples, Italy, and resulted in an enigmatic and complex PDC deposit for which several stratigraphic schemes have been proposed. The ignimbrite is found up to 80 km from the caldera, and co-ignimbrite ash-fall deposits occur up to 3200 km away. The proximal and distal stratigraphy of the Campanian Ignimbrite has never been definitively correlated due to the dissimilar appearance of proximal and distal deposits, a lack of medial exposures, and the inconsistency and heterogeneity of the proximal stratigraphy. We use the major-element glass chemistry, matrix and lithic componentry and alteration mineralogy of the proximal and distal deposits of the ignimbrite in an effort to correlate particular units and interpret the eruptive sequence. We propose that the significant heterogeneities between outcrops previously identified as belonging to the same proximal units are due to the emplacement of these PDC deposits during the same phase of the eruption but from multiple vents with differing eruptive processes. Similarities shared between outcrops thus represent geologic facies rather than true stratigraphic units. In contrast, we observe two true stratigraphic units in the distal deposits, as well as two alteration facies, whose characteristics are the source for the long-established names of the units. However, the units are distinguished by changes in properties related to vent processes and the alteration is interpreted to be controlled by the effects of stratigraphic position on temperature and fluid conditions, and therefore the unit and facies boundaries do not coincide everywhere. We propose a correlation scheme for the eruptive sequence that uses the existing proximal and distal stratigraphic nomenclature but links outcrops to eruptive phases, from pre- to syn-collapse of the caldera, rather than fitting them into a strict scheme of stratigraphic units.

1035

20 YEARS OF GEODETIC MEASUREMENTS REVEAL THE DEGASSING/MAGMA COOLING PROCESSES UNDER THE ISCHIA RESURGENT CALDERA

Dr Alessandro Galvani[1], Dr Giuseppe Pezzo[1], Dr Vincenzo Sepe[1], Dr Guido Ventura[1], Dr Mirko Iannarelli[1]
[1]*Istituto Nazionale Di Geofisica E Vulcanologia, Rome, Italy*

The understanding of the mechanisms responsible for the deformation of volcanoes is of primary to decipher the dynamics of magmatic systems. Here we present twenty years (1997–2018) of geodetic GNSS and leveling data on Ischia Island (Italy), which include a caldera affected by resurgence, hydrothermal manifestations, and shallow seismicity. The data from the GNSS Network and the leveling surveys reveal a constant subsidence of the resurgent block with values up to −15 ± 2.0 mm/yr and centripetal, horizontal displacements with the largest values concentrated on the southern flank of the resurgent block. The inversion of GNSS and levelling data suggests a 4 km deep source deflating by degassing and/or magma cooling. Therefore, the Ischia deformation behavior is not linked to gravity or volcano-tectonic processes. The inferred depth of the deflating source agrees with independent geophysical data. The Ischia shallow seismicity, which concentrates along zones of active gas and hot water discharge, is due to the dynamics of the shallow hydrothermal system being neither temporally nor spatially related to the deflation.

1286

Repeated lava fountains at Etna: analysis of ground deformation for unveiling the underlying magma dynamics

Dr. Alessandro Bonforte, Dr. Flavio Cannavò, Dr Salvatore Gambino[1], Dr. Francesco Guglielmino, **Dr.ssa Laura Privitera**, Dr. Giuseppe Puglisi
[1]*Ingv, Catania, Italy*

Mt. Etna volcano is one of the most active volcanoes of our planet. It erupts very frequently, mainly from its four summit craters: Voragine (VOR), Northeast Crater (NEC), Bocca Nuova (BN) and South-East Crater (SEC). Eruptions at summit craters are usually characterized by Strombolian activity of varying intensity, up to the more energetic lava fountains and high-energy paroxysms.

In the last 30 years, more than 200 short-living lava fountains occurred mostly taking place at the SEC causing the formation of dispersal ash plumes and fall-out deposits. These events may entail severe aviation hazards and more generally for the population.

Between December 2020 and February 2022, Mt Etna experienced ca. 60 lava fountains evidencing two sequences of episodes between 16 February to the end of March 2021 and from May to October 2021. We analyzed the ground deformation recorded by using tilt, GNSS and DInSAR occurred in this period. Tilt signals allow detecting the single lava fountains recording changes generally less than 1.0 microradian with a duration comparable with the episodes.

Our analyses evidenced as tilt changes are generally similar for each episode and we report some estimates about the position of the source generating the tilt signal of the lava fountain episodes.
During the first sequence lava fountains repeated approximately every two days with tilt variations comprise between 0.10 and about 0.70 microradians. The second phase was characterized by more frequent events with smaller tilt variations particularly during the June episodes.

During the sequences of lava fountains, we measured high tilt values at summital ECP station that suggests that ECP is probably affected by an additional, shallower, ground deformation source.

Moreover, we propose a multi-temporal-scale analysis of ground deformation data using both high rate tilt, GNSS measurements and DInSAR in order to investigate the cumulated deformation over the two sequences.

1076

Dynamics of Pyroclastic Density Currents on Venus

Dr Indujaa Ganesh[1], Dr Lynn Carter[2]
[1]Geophysical Institute, University Of Alaska Fairbanks, Fairbanks, United States, [2]Lunar and Planetary Laboratory, University of Arizona, Tucson, United States

Synthetic aperture radar (SAR) mapping of the surface of Venus revealed a handful of relatively young deposits with distinct morphology on the gently sloping flanks of large volcano-tectonic structures. These deposits, extending for tens of kilometers away from the centers of their parent structures, do not show flow textures or sharp boundaries characteristic of lava flows on Venus. Previous workers have theorized that these deposits were emplaced by pyroclastic density currents (PDCs) fed by eruption column collapse (Campbell et al., 2017). The dynamics of PDC transport and deposition under Venus's ambient conditions are, however, not well understood. We address this problem by adapting established terrestrial mass transport models for simulating PDC transport on Venus. We investigate two end member scenarios — 1) ground-hugging, particle-rich flow, and 2) dilute turbulent current. Results from models of dense, particulate flows show that high degree of initial flow fluidization via pressurized interstitial fluid is critical for emplacing material across gently sloping volcanic terrains on Venus (Ganesh et al., 2021). We find that both instantaneous collapse of an eruption column (~1-1.5 km height) and fountaining episodes lasting ~5-10 mins with fountain heights of ~50 m could have produced the observed spatial extent of some of the smaller PDC deposits, provided the volumetric eruption rate is high (~10^7–10^8 m^3/s). Our ongoing work focuses on understanding the role of energetic, turbulent currents in forming the larger deposits. We are primarily interested in determining the concentration and size distribution of solids in dilute PDCs that are capable of emplacing material across large extents on Venus. Results from these two sets of models will help place constraints on the eruption conditions and flow properties, such as the possible ranges of eruption rate, PDC volume, velocity, and grain size distribution, that could have produced the observed PDC deposit extents.

1485

Petrology and Chemistry of the 2022 Mauna Loa Eruption: Insights into the magmatic plumbing system

Kendra Lynn[1], Frank Trusdell[1], Drew Downs[1], Julie Chang[1], Dr Cheryl Gansecki[1,2], Baylee McDade[2], Steve Lundblad[2], William Wooten[2], J. Michael Rhodes[3], Michael Vollinger[3], Benjamin Andrews[4], Magdalen Grismer[4,5], Johanne Schmith[1], Brett Walker[1], Erin Fitch[6], Natalia Deligne[1], Liliana DeSmither[7], Peter Dotray[1], Elisabeth Gallant[1], Katherine Mulliken[7], Tim Orr[8], Carolyn Parcheta[1], Matthew Patrick[1], Michael Zoeller[1], Ninfa Bennington[1], Patricia Nadeau[1], Peter Kelly[8], Laura Clor[9], Mike Cappos[1], Tamar Elias[1], Christine Sealing[9]
[1]USGS Hawaiian Volcano Observatory, Hilo, United States, [2]University of Hawaiʻi at Hilo, Hilo, United States, [3]University of Massachusetts at Amherst, Amherst, United States, [4]Smithsonian Institution National Museum of Natural History, Washington, United States, [5]New Mexico Institute of Mining and Technology, Socorro, United States, [6]University of Oregon, Eugene, United States, [7]Research Corporation of the University of Hawaiʻi, Hilo, United States, [8]USGS Alaska Volcano Observatory, Anchorage, United States, [9]USGS Cascades Volcano Observatory, Vancouver, United States

Mauna Loa began erupting ~11:23 pm HST, on November 27, 2022 within the summit caldera, Mokuʻāweoweo. Subsequently, a ~500-m-long fissure propagated towards the southwest, but remained mostly within Mokuʻāweoweo. By early morning on November 28, eruptive activity at the summit ceased and migrated into the Northeast Rift Zone (NERZ) at four fissures between 3755 and 3365 m asl (~700 m above 1984 vents), localizing to one cone-building vent by December 2. A network of channels fed ʻaʻā flows extending 19 km down the north flank before the eruption ended December 10. Air-quenched samples from summit fissures and molten samples collected almost daily from the NERZ vents provide the first glimpse into the volcano's plumbing system since 1984. ED-XRF analyses done in near-real-time were followed by WD-XRF and EPMA. Whole rock compositions are similar to other Mauna Loa eruptions since 1823 and are indicative of typical reservoir magmas. The samples have whole rock MgO of 6.2 wt%, slightly lower than any eruption in ~200 years. Near-vent samples have no phenocrysts, although plagioclase, clinopyroxene, olivine, and oxides increase in abundance and size with distance from the vent as flows cooled. Highly similar compositions were erupted over the duration of the eruption from all vents along the 17 km distance across the summit and upper NERZ, indicating that the two-week eruption was fed by a homogenous magma. This aphanitic, low-MgO eruption is not influenced by rift-stored magma left over from 1984, but instead reflects an intrusion from the main reservoir, consistent with seismicity 2-4 km beneath the summit prior to eruption. A multi-GAS monitoring station located in the caldera detected no precursory SO_2 or CO_2 anomalies, and syn-eruptive CO_2/SO_2 ratios were low; both are also consistent with magma storage in the shallow reservoir system, with CO_2 loss that significantly preceded pre-eruptive unrest.

396

Preliminary results of the late Pleistocene and Holocene evolution of Santa Ana volcano, El Salvador

Angela V. Garcia[1], Dennis Lemus[1], Christopher Harpel, Demetrio Escobar[1], Walter Hernandez[3], Luis E. Mixco[1], Jacqueline Rivera[1], Charles Lewis[2,4]
[1]Ministerio de Medio Ambiente y Recursos Naturales de El Salvador, San Salvador, El Salvador, [2]U.S. Geological Survey Volcano Disaster Assistance Program, Vancouver, United States, [3]Universidad de El Salvador, San Salvador, El Salvador, [4]College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, Corvallis, United States

Santa Ana is an active, hazardous composite cone, yet until recently scant details were known of the volcano's eruptions before the historical period. Our tephrostratigraphy and dating begins filling this knowledge gap. New ages suggest that about 40,000 cal BP, the southern flank of ancestral Santa Ana collapsed, triggering a 17±5-km3 debris avalanche. While the deposit now extends into the Pacific Ocean forming the Acajutla Peninsula, global sea level was sufficiently lower at 40 ka to infer that the deposit was emplaced subaerially. Modern Santa Ana grew within the collapse crater through a series of magmatic and phreatomagmatic eruptions. Our tephrostratigraphy and dating of the volcano's eastern flank suggests that at least eight mafic magmatic eruptions emplaced tephra-fall and pyroclastic-density-current deposits beginning before 7,700 cal BP and continuing until after 5,800 cal BP. The apparent lack of deposits from Santa Ana emplaced between 3,200 cal BP and 600 cal BP suggests a possible quiescent period. During this time, the Tierra Blanca Joven ash, a regional marker bed from Ilopango Caldera, and a tephra-fall deposit with rhyolitic pumice and obsidian were emplaced. The latter is correlated to a cluster of obsidian domes in nearby Coatepeque Caldera and forms a local marker bed erupted between 1900 cal BP and 1500 cal BP. After 600 cal BP, Santa Ana's activity appears dominated by at least five phreatomagmatic eruptions, which emplaced ash and pyroclastic-surge deposits. We infer that these eruptions were like the volcano's 2005 CE eruption, which produced tephra-fall, pyroclastic surges, and a destructive lahar. We preliminarily attribute the change in eruption style to an increase in water volume in the volcano's hydrothermal system. Eruptive behavior since the late Pleistocene suggests that edifice collapse, pyroclastic density currents and surges, tephra fall, and lahars are all potential hazards during future eruptions of Santa Ana.

1431

Variations of Copahue Volcano Crater Lake and its Relation with Gas and Ash Emission During 2019-2021

Mr Fabricio Carbajal[1], Mr Sebastian Garcia[1], Dr. Nicolas Vigide[1], Dr. Gabriela Badi[1], Dr. Mariano Augusto[2,3], Dr. Clara Lamberti[2,3]

[1]Observatorio Argentino de Vigilancia Volcánica (OAVV), Servicio Geológico Minero Argentino (SEGEMAR), , Argentina, [2]GESVA-IDEAN, Dpto. Cs. Geológicas, FCEN, Universidad de Buenos Aires (UBA), , Argentina, [3]IDEAN (UBA-CONICET), Dpto. Cs. Geológicas, FCEN, Universidad de Buenos Aires (UBA), , Argentina

Copahue volcano is located on the international border between Argentina and Chile. It is monitored by the “OAVV” (SEGEMAR, Argentina) and “OVDAS” (SERNAGEOMIN, Chile). Copahue´s lastest and ongoing eruptive cycle initiated in 2012. During 2019-2021, periodic vapor-gases and ash emissions were emitted through the crater, and the hot, acidic crater-lake (CL) presented a significant area variation, in some cases being completely dried. In this work, a correlation between SO2 emissions and changes in the active crater dynamics for the last 3 years is presented. CL area analysis were carried out between 2018-2021, using 3.7 m of resolution satellite images (http://www.planet.com). Additionally, SO2 emissions were studied through the GEE (Google Earth Engine) web platform and contrasted with average flux data from DOAS equipment. Both satellite and ground-based measurements were correlated for the maximum SO2 emission during 2019-2021. Satellite images and meteorological data were integrated, observing a gradual variation in the CL area for the period, reaching maximum values up to 60000 m2, also observing a seasonal component. During 2020 and 2021 winters, maximum SO2 values (up 14000 t/d or day with DOAS and 0,7 Dobson units with GEE) and ash-clouds heights (1700m acl) were identified together with the disappearance of the CL. In addition, an increase in seismic tremor activity was registered for the same time span.

This correlation of events allows us to hypothesize: i) during the colder months, the ambient temperature prevents the defrosting that feeds the shallower hydrothermal system, favoring evaporation and decrease of the CL, and consequently, ii) the CL brine generates a shallow chemical seal, from which gases and ash are emitted when the system reaches critical pressure, consistent with the increase in tremor activity. In summary, the activity of the Copahue CL during the 2019-2021 period suggests a seasonal control for gas and ash emissions.

1430

Community Volcanic Risk Reduction Strategies for Lanín Volcano in Argentina

Mr Sebastian Garcia[1], Ms. Soledad Mele[2]
[1]*Observatorio Argentino de Vigilancia Volcánica (OAVV), Servicio Geológico Minero Argentino (SEGEMAR), , Argentina,*
[2]*Coordinación de Gestión Integral del Riesgo, Administración de Parques Nacionales (APN), , Argentina*

Lanín Volcano is a pleistocene-holocene stratovolcano located in the border between Argentina and Chile. In Argentina the volcano is located within the limits of Lanín National Park (LNP), in the province of Neuquén. Lanín Volcano shows a dominantly effusive style characterized by the recurrent emission of basaltic and andesitic lava flows, in addition to a scarce record of explosive eruptions with dacitic products. It´s last eruption occurred less than a thousand years ago (ca. <1.000 years), while its maximum recorded VEI ≤4, associated to lava flows of variable extent, lahars related to ice or snow melting, and to a lesser extent pyroclastic fallout and pyroclastic density currents (ca. 3 ka).

Within LNP different territorial actors coexist, including Mapuche original Communities and Creole inhabitants that live on the footsteps of the volcano. Also this complex territory includes: private landowners, park rangers, concessioner, permit holders, security/defense organizations (Border Police, Army, Customs Agents), as well as thousands of tourists that visit the volcano for recreational and touristic activities.

During the 2017, volcanic alert level change and awareness over the activity of this volcano raised showing a very low degree of preparation from local authorities as well as the communities that inhabit LNP. Despite this event didn´t end in an eruption, it showed the necessity to advance in studies to determine Lanín volcanic hazards and risk, as well as the need to develop strategies and collective planning instances to create mechanisms for prevention, preparation and response in case a potential volcanic eruptive crisis occurs.

In this work we present the first community strategy attempt to develop a volcanic risk reduction plan from an intercultural approach, in a complex territory that combines a natural protected area of national jurisdiction, an original communities sacred place, national and provincial administration, the local communities and tourism.

463

An experimental approach to explore volcanic thermal anomalies driven by subsurface steam transport

Mr Noé García-Martínez[1], Dr Társilo Girona[2], Dr David Benavente[1]
[1]*Department of Earth and Environmental Sciences, University Of Alicante, Alicante, Spain,* [2]*Geophysical Institute, University of Alaska Fairbanks, Fairbanks, Alaska, United States*

Understanding the transport of gas from depth to the surface is fundamental to interpret many geophysical and geochemical signals recorded around volcanoes, and thus to better identify volcanic unrest and anticipate eruptions. A geophysical signal that is probably controlled by gas transport is the low-temperature (low-T) geothermal anomaly, a subtle warming that can emerge at volcanoes years prior to eruption (Girona et al., 2021; https://doi.org/10.1038/s41561-021-00705-4). However, the mechanisms generating low-T geothermal anomalies are unclear, and many questions remain open. For example, how does hot gas interact with the host matrix at pore scale? How do the physical properties of the shallow subsurface affect surficial thermal manifestations? To address these questions, we have developed a new experimental setup to inject hot steam (100-200ºC) at constant pressure (up to 6bar) at the bottom of silty soil columns (30cm height and 11cm diameter), and we monitor temperature variations along the top and walls of the column using thermometers and a thermal infrared camera. Our preliminary results reveal that, under appropriate permeability and column height conditions, the steam injected exchanges heat with the host soil at pore scale until generating a condensation front and releasing latent heat that migrates towards the surface via conduction. In addition, we found that the initial water content of the soil column plays a major, unexpected influence in our experiments, with 1ºC anomalies being detected at the top of the column hours earlier if the initial water content of the soil is between 5% and 7.5%. In ongoing experiments, we aim to explore the role played by the physical properties of the soils (e.g., permeability, porosity) and by the combination of impermeable and water-saturated subsurface layers, and to model gas and heat transport with physics-based, finite element simulations (COMSOL). This research is supported by a Spanish MCIN award (RTI2018-099052-BI00).

532

Upcoming Surface Investigations of Volcanic Terrains on the Moon through NASA's Commercial Lunar Payload Services (CLPS) Initiative

Dr. Brent Garry[1], Dr. Maria Banks[1], Dr. Heidi Haviland[1], Dr. Paul Niles[1], Dr. Susan Lederer[1], Dr. John Gruener[1], Dr. John Karcz[1], Dr. Cindy Young[1], Dr. Ryan Watkins[1], Dr. Debra Needham[1], Dr. Brad Bailey[1]
[1]Commercial Lunar Payload Services (CLPS) Project Office, National Aeronautics and Space Administration (NASA), Washington, USA

The NASA Commercial Lunar Payload Services (CLPS) initiative is ushering in a new era of robotic field geology and geophysics on the Moon. Beginning in 2023, U.S.-based commercial space companies will start to deliver NASA science and technology payloads to the lunar surface; many of these commercial missions are slated to land in a variety of lunar volcanic terrains. NASA's CLPS program has selected 50+ payloads to investigate areas on the Moon representative of a range of volcanic processes. The current list of CLPS Task Orders (TO) scheduled to land in lunar volcanic terrains are TO2-IM and 19D (Mare Crisium), TO2-AB (Lacus Mortis), CP-11 (Reiner Gamma in Oceanus Procellarum), CP-12 (Schrödinger Basin), and CP-21 (Gruithuisen Domes). Most of these landing sites are basaltic mare terrains, whereas the CP-21 payloads will investigate silicic, non-mare volcanic domes. The majority of the early commercial missions will be stationary landers only, but a few later missions will deploy small rovers and hoppers. One strength of NASA's CLPS initiative is the rapid cadence for payload deliveries over the next decade which will allow dozens of instruments to investigate a broad range of lunar volcanic environments directly on the surface at sites long studied remotely by the lunar community. Here, we will provide an overview of the mission timelines, payloads and science investigations, and characteristics of each volcanic landing site. Data collected by CLPS payloads will provide a range of data types that will be publicly available for comparison to terrestrial analogs and field instruments to better understand volcanic processes in our Earth-Moon system.

533

Characterizing the Morphology of Lava Tubes and Volcanic Systems with Lidar

Dr Brent Garry[1], Dr. Scott Hughes[2], Mr. Thomas Grubb[1]
[1]National Aeronautics and Space Administration (NASA), Washington, United States, [2]Idaho State University, Pocatello, United States

Lava tube caves are drained-out tunnels that form within flow fields during volcanic eruptions. While exploration of lava tube caves may be limited to partial segments of a full tube system, the morphology and preserved flow textures within these sections still provide information about their formation. The challenge is producing a map or model that captures the full three-dimensional morphology of the lava tube. Two-dimensional maps provide relevant details about the shape, interior textures, and dimensions, but are also static and limited by scale. Lidar surveys produce detailed three-dimensional models that show the morphology of the tube at the meter-scale and textural details at the centimeter-scale. Point cloud models of lava tubes created from lidar surveys provide continuous x,y,z coordinates of all regions in the tube to analyze the changes in morphology, the spatial relationship with the surface terrain, and the distribution of flow textures and hazards. Combining point clouds with advanced visualizations using Virtual Reality (VR) provides quicker and more intuitive understanding of the complex morphology and spatial relationships of lava tubes. We have conducted lidar surveys of the 250 m-long Indian Tunnel (Craters of the Moon, Idaho), the 1.25 km-long Lava River Cave (Flagstaff, AZ), and the 100 m-deep chamber Triple Vulcan (Sierra Negra, Galápagos), plus additional sites in Iceland and Hawai`i. The final point clouds are up to ~3.25 billion points and preserve the broad-scale morphologic changes and finer-scale textures within a single data set. Each one of these features has a unique geomorphology that reveals clues about the emplacement history. Here, we will review our field survey techniques, analysis tools for the point clouds, morphologic characteristics and emplacement of each feature, and visualization techniques, including the use of VR to explore these sites.

470

Volcanology and facies analysis of the youngest phreatomagmatic deposits on Oʻahu, Hawaiʻi.

Miss Natalia Gauer Pasqualon[1], Bruce Frank Houghton[1]
[1]*University Of Hawaii At Manoa, Honolulu, United States*

The area known as the Lānaʻi Lookout has Oʻahu's youngest and best exposures of deposits from pyroclastic density currents (PDCs), generated by explosions involving magma-water interaction. It is located on the southernmost, subaerial portion of the Koko Rift system and reveals complex stratigraphic relations that reflect coeval contributions of 3 nearby eruptive centers: Hanauma Bay-Koko Head, Kahauloa and Koko Crater. This work presents the first detailed volcanological analysis of the deposits at the Lānaʻi Lookout through lithofacies description, definition of facies associations, and their interpretation. This approach is fundamental to understanding the explosion mechanisms, post-fragmentation transport and depositional processes, and to unravel the eruptive history. The lithofacies identified include planar-bedded, low-angle, and megaripple cross-bedded ash to lapilli, accretionary lapilli-rich falls and isolated ballistic blocks and bombs. These features were interpreted as generated by dilute PDCs, co-PDC fall and sedimentation from eruptive clouds, and ballistic-charged jets. Overall, at least three eruptive stages formed the pyroclastic succession: (i) relatively strong eruptions at shallow fragmentation depths, with frequent, short episodes, and sedimentation dominantly from fallout and projectile trajectories sourced by Kahauloa and Koko Crater; (ii) weak explosions at shallower fragmentation depths, with a dominance of intermittent, short-to longer-lived PDCs, sourced mainly at Kahauloa. (iii) deeper fragmentation depths, but also dominated by intermittent, short-lived PDCs from weak eruptions, and ballistic clasts sourced by Kahauloa and Hanauma. In summary, the lithofacies analysis and stratigraphic relations of this complex multi-vent system provided important information about the dynamics, eruptive style, and frequency of eruptions of the previously poorly constrained late-stage Hawaiian volcanism.

1022

Long term multi-parametric assessment of activity from open vent volcano El Reventador: correlation of volcanic ash properties with geophysical data

Dr Helen Gaunt[1,2], Ms Mia Pique[3], MSc Stephen Hernandez[2], Dr Silvana Hidalgo[2], Mr Marco Cordóva[2], MSc Patricio Ramon[2], Dr Benjamin Bernard[2]

[1]University College London, London, United Kingdom, [2]Instituto Geofisico Escuela Politecnica Nacional, Quito, Ecuador, [3]Northern Arizona University, Flagstaff, United States of America

El Reventador volcano, Ecuador has been actively erupting since its reactivation in November 2002 with daily explosive activity interspersed with effusive periods and rare paroxysmal events. Shifts in activity at such open vent systems can be difficult to forecast as changes in monitoring parameters are often hidden within background activity. By combining traditional geophysical data with the analysis of samples of volcanic ash, changing data patterns can potentially be used to identify changes in magma and conduit dynamics.

Between November 2016 and March 2019, we collected 6 samples of ash from an ashmeter on the southern flank of El Reventador. Geophysical monitoring networks also recorded seismicity and SO2 emissions and satellite remote sensing provided ash column heights and thermal anomaly data.

Componentry analysis of the ash samples revealed that higher juvenile contents correspond to periods of lower daily seismic event rates, lower seismic energy release, lower thermal anomaly values and generally lower SO2 emissions. Meanwhile, samples with a higher vesicular juvenile contents correspond to periods with higher average ash column heights and longer seismic inter-event times.

Higher vesicular juvenile contents and increased ash column heights could suggest a larger input of gas into the shallow conduit while longer seismic inter-event times might suggest the conduit was able to form more efficient plugs between explosions. Magma ascent could also have been slower, increasing the time needed for sufficient pressure to build up and therefore increased gas accumulation resulting in more energetic ash ejection and incorporation of vesicular juvenile magma. Lower juvenile ash contents however suggest greater instabilities in the conduit and the incorporation of more conduit wall material into the ejected ash. This is consistent with increased daily seismic event rates and more registered ash columns but lower average heights suggesting higher magma ascent rates with more frequent but smaller explosions.

1012

A new automated system for volcanic ash collection and real-time ash fall data: AACE-IG

Dr Helen Gaunt[1,2], MSc Francisco Mejia[2]
[1]*University College London, London, United Kingdom,* [2]*Instituto Geofisico Escuela Politecnica Nacional, Quito, Ecuador*

AACE-IG (Automated Ash Collection Ecuador – Instituto Geofisico) is a new, automated system for the collection of volcanic ash samples, and the transmission of ash fall data in real-time. Petrological eruption monitoring is a powerful tool that is increasingly used by volcano observatories to complement and inform the interpretation of more traditional geophysical monitoring techniques. At present, obtaining a continuous record of tephra emitted during volcanic activity requires personnel to be onsite in potentially hazardous zones, traveling long distances, which is not feasible especially during extended periods of activity. In addition, the evaluation of ash fall hazard and production of fall out maps can take days to produce as data must be collected from large areas. Currently, there is very little equipment specifically designed for real-time tephra sampling and the collection and transmission of ash fall data. AACE-IG can collect up to 21 samples of ash, measures the weight of ash falling in real-time and takes images of the samples as they are collected. The weight and photos are stored on an internal memory but more importantly, are telemetered back to the observatory either by radio or internet connection, creating a digital record throughout the period of ash fall. AACE-IG can be programed to take samples at set time intervals and can be controlled or reconfigured via a web interface. The components of the system are designed to be 3D printed and the electronic components are standard and readily available in most electronics shops. The system is therefore cheap, lightweight and easy to construct without specialist knowledge and, the replacement of parts is quick and easy. This system will automate and streamline the collection of volcanic ash while also providing critical real-time data to the observatory, allowing for rapid hazard assessments and effective, timely communication.

1335

Comparing different methods to detect volcanic lightning

Franziska Heck[1], Mr Andre Geisler[1], Matthias Hort[1], Sonja A. Behnke[2], Harald E. Edens[2], Masato Iguchi[3]
[1]Universität Hamburg, Hamburg, Germany, [2]Los Alamos National Laboratory, Los Alamos, USA, [3]Sakurajima Volcano Research Center, Disaster Prevention Research Institute, Kyoto University, Kagoshima, Japan

The origin of volcanic lightning is still a matter of intense research because it may complement other monitoring techniques in detecting volcanic eruptions at remote or not well monitored volcanoes. Various methods have been used to detect electrical discharges over the last decades and here we use data of a multicomponent geophysical network which was operated in 2019 at Sakurajima volcano to compare different methods for lightning detection. Among others, the network included a lightning mapping array sensor (LMA, which detects VHF electromagnetic radiation), an electric field mill (EFM, which measures the static electrical field, 10 S/s (samples per second)), a thunderstorm detector from Biral (BTD, which also measures the static electrical field, 100 S/s), and a fast antenna (detects fast changes in electric field from current pulses in lightning, including return strokes, 180 MS/s). We picked a period of high activity (early Nov. 2019) to compare the signals detected by the different instruments. First, we briefly discuss the algorithms used to find electrical discharges in the EFM and BTD data sets. From this catalog we then picked eruptions with high discharge rates and compared the detection of discharges between all instruments available for discharge detection in our network. We discuss in detail the advantages and disadvantages of the different techniques in terms of detecting electrical discharges during volcanic eruptions. In order to do so, we also use data from a slow antenna (50 kS/s) that recorded eruptions at Sakurajima in 2015. First, we compare the amplitudes of BTD, EFM, and fast antenna data to constrain how well the amplitudes are resolved by the different instruments. Next, we discuss how the different instruments can be used to locate discharges as well as determine electric field changes due to discharges which is useful when modeling eruption cloud charging.

1331

Exploring the electrical signature of different vulcanian eruptions at Sakurajima volcano, Japan

Mr Andre Geisler[1], Matthias Hort[1], Sonja A. Behnke[2], Harald E. Edens[2], Masato Iguchi[3], Haruhisa Nakamichi[3]
[1]Universität Hamburg, Hamburg, Germany, [2]Los Alamos National Laboratory, Los Alamos, USA, [3]Sakurajima Volcano Research Center, Disaster Prevention Research Institute, Kyoto University, Kagoshima, Japan

The electrical charging of volcanic plumes and the associated discharges are an active field of research in volcanology. In order to make this a reliable monitoring tool the conditions under which discharges occur need to be explored. Here we use data of a multicomponent geophysical network which was operated in 2019 at Sakurajima volcano to constrain such conditions. The network included one vertically scanning Doppler radar to resolve the internal structure of the eruption column at a low temporal resolution and two fixed Doppler radar systems to resolve the dynamics of the eruption column at one point at high temporal resolution. A total of 5 infrasound stations was used to determine eruption onsets. Discharges were detected by three electric field mills (EFM), a thunderstorm detector from Biral (BTD), a lightning mapping array sensor (LMA) as well as a fast antenna. While the EFM and the BTD measure the static electric field, the LMA detects VHF electromagnetic radiation and the fast antenna is able to detect electric field changes of portions of lightning strokes. Meteorological conditions are monitored by a local weather station and radiosonde measurements and photos were taken at one minute intervals during daytime.

Each data set has been analyzed separately using specific algorithms to detect electrical discharges, extract eruption velocities, eruption volumes, precise plume heights, and eruption onsets among other things. From the data set spanning 7 month of activity between June and Dec, we select eruptions of different strength in terms of plume height and eruption velocities. Using this subset of eruptions, we analyze the temporal evolution of the electrical discharges with respect to eruption parameters, including the eruption onset, eruption velocities, and plume height.

916

Metals and volatiles in Brothers submarine volcano associated with hybrid seafloor massive sulfide deposits

Dr Ariadni Afroditi Georgatou[1], Dr. Cornel de Ronde[1], David Adams[2], Dr Bruce Charlier[3], Dr Ian Graham[4]
[1]GNS Science, Lower Hutt, New Zealand, [2]The University of Auckland, Auckland, New Zealand, [3]Victoria University of Wellington, Wellington, New Zealand, [4]University of New South Wales, Sydney, Australia

Recent technological advances in mining exploration have boosted the economic interest of sea floor massive sulfide deposits (SMS), thought to represent modern analogues of fossilised volcanic hosted massive sulfide (VHMS) deposits and known for containing high concentration of critical metals (e.g., Zn, Pb, Cu and Ag). One of the most well-studied submarine systems associated to SMS is Brothers active volcano, situated along the Kermadec arc, shown to have both a hydrothermal and a magmatic input reflected in the formation of the caldera and the resurgence of two younger central cones, respectively. Here we investigate the magmatic source and transport of metals and volatiles in Brothers, through major and trace element geochemistry of melt inclusions (MI) and silicate glass occurring in the matrix and interstitially within aggregates.

Considering the narrow compositional range of Brothers Cu-poor dacites (SiO_2=62-65 wt.%, Cu≤40 ppm), MI were also studied in the nearby associated Cu-rich basaltic ridges (i.e., mafic end member; SiO_2=50-53 wt.%, Cu≤150 ppm). Depending on the aspect of the MI (glassy, crystallised or devitrified) and on the host mineral phase (olivine, clinopyroxene, plagioclase or magnetite), preliminary EPMA and LA-ICP-MS in situ analysis indicate varying S, Cl, Cu and Au contents for MI found in the ridges (260-1120 ppm, 2820-4550 ppm, 4.4-14 ppm and ≤2-4 ppb) and those present in the caldera (90-190 ppm, 4410-5220 ppm, 1.5-30 ppm and 3-9 ppb). In order to decipher the extend of magma degassing prior to eruption and the nature of the exsolving immiscible volatile phase, these latter MI values will be compared to the S, Cl, Cu and Au contents (median) of the matrix glass of the same samples (ridges: 180 ppm, 2400 ppm, 100 ppm, ≤4 ppb and caldera: 70 ppm, 5200 ppm, 35 ppm, 5 ppb), and to previously published datasets on MI obtained from the cones.

285

Seismicity below the eastern flank of Piton de la Fournaise (la Réunion) explained with elasto-plastic models of magma inflation

Dr Muriel Gerbault[1], Ms Aline Peltier[2], Mr Fabrice Fontaine[2], Mr Jean-Luc Got[3], Mr Riad Hassani[4], Ms Valerie Ferrazzini[2], Ms Lydie Gailler[5], Mr Zacharie Duputel[2]
[1]GET, IRD, Toulouse, France, [2]OVPF, IPGP, Tampon, La Réunion, France, [3]ISTERRE, Université de Haute-Savoie, Chambéry, France, [4]Géozur, Université de Nice Sophia-Antipolis, Nice, France, [5]LMV, université de Clermont-Ferrand, Clermont-Ferrand, France

Flank destabilization of volcanic edifices can cause catastrophic events. The persistent, asymmetric "cup" shaped, seismicity recorded below the eastern flank of Piton de la Fournaise shield volcano (la Réunion), gives insight on its mechanical stability. Here its elasto-plastic behavior is modeled at crustal scale with the 3D FE code Adeli (tensile and Drucker-Prager shear failure). When considering first only the volcano's topography in the gravity field, deviatoric stresses attain about 35 MPa below the summit and displacements reach 30m in the horizontal east-west direction near sea-level. Plastic behavior produces a rather symmetric cup shape plastic domain around the volcano's summit, that extends at depth with reducing bedrock "effective" friction (a proxy for reduced friction due to pore fluid pressurization). When applying an internal overpressure to simulate either a distal dike located below the eastern flank of the volcano, or the inflating magma reservoir located at depth ca. 0 km below the summit, a cup-shaped shear zone forms below the eastern flank. The inflating dike produces a shear zone 1 km too shallow while the inflating magma reservoir produces a shear zone that extends down to -2 km depth and coincides with the observed seismic cup, when friction is <=5°. Hence, we propose that this structure is a mechanical consequence of continuous magma supply in the reservoir, coherent with previous interpretations. This means that at least originally it did not need to form as a pre-existing weak zone or a magma-filled structure. However, the stress state associated with this shear zone may promote the intrusion of magma sills. It also branches to the surface with planar radial shear zones comparable to some observed eruptive fissures. The 3D kinematics of this shear zone does not rule out the possibility of a giant flank slide, although it does not appear today as imminent.

837

Different styles of magma chamber decompression revealed by VEI 7 caldera-forming eruptions at Aira and Kikai calderas in Japan

Dr Nobuo Geshi[1], Dr Genji Saito[1], Dr Isoji Miyagi[1], Dr Chris Conway[1]
[1]*Geological Survey Of Japan, Aist, Tsukuba, Japan*

Aira and Kikai are two collapse calderas located in Kagoshima, Japan, which show contrasting styles of decompression during their VEI 7 caldera-forming eruptions. In the ~30 ka Ito eruption of Aira caldera, the water content in glass embayments of crystals in the initial Plinian-fallout pumice and minor ignimbrite decreased along the stratigraphic sequence to the main ignimbrite, suggesting decompression of the magma chamber occurred in the lead-up to collapse. The decrease of water content along the sequence corresponds to a drop in the magma chamber pressure from 140-260 MPa before the eruption to 90-190 MPa before the onset of collapse. In contrast, the ~7.3 ka Akahoya eruption of Kikai caldera shows no clear decrease of water content in glass embayments throughout the stratigraphic sequence, suggesting the pressure remained almost constant (40-90 MPa) throughout the eruption.
This difference in the depressurization process may reflect differences in the depth to the magma chambers at these caldera volcanoes. Assuming a piston-cylinder type structure with a cylindrical collapse block, caldera collapse occurs when the driving force that pulls the caldera block down into the magma chamber exceeds the friction on the caldera fault. Though Aira and Kikai calderas both have perimeters of ~50 km, the magma chamber at Aira is deeper (>5 km) than at Kikai (~3 km). This difference in magma chamber depth equates to a difference in the friction strength of the caldera faults, and as a result, a large underpressure was required for collapse onset at Aira caldera, whereas the collapse of Kikai caldera began with smaller underpressure. As the eruption of caldera-related ignimbrite is driven by the collapse of caldera block into the chamber, underpressure in magma chambers during caldera collapse is an important parameter for the variations in caldera-forming eruptions.

891

The influence of ash particles on volcano acoustics - comparing controlled experiments with real eruption data

Dr Julia Gestrich[1], Dr. Valeria Cigala[2], Dr. David Fee[1], Dr. Ulrich Kueppers[2], Mr. Markus Schmid[2], Dr. Alexandra M. Iezzi[3], Dr. Corrado Cimarelli[2], Dr. Caron E. J. Vossen[2], Dr. Jörn Sesterhenn[2], Dr. Maurizio Ripepe[6], Dr. Giorgio Lacanna[6], Dr. Jacopo Taddeucci[7], Dr. Juan José Peña Fernández[2], Dr. Laura Spina[7], Mr. Richard Buzard[1], Dr. Robin S. Matoza[4], Dr. Donald B. Dingwell[2]

[1]University Of Alaska Fairbanks, Fairbanks, United States, [2]Department of Earth & Environmental Sciences, Ludwig-Maximilians-Universität (LMU), Munich, Germany, [3]USGS Cascades Volcano Observatory, Vancouver, United States, [4]Department of Earth Science and Earth Research Institute, c, Santa Barbara, United States, [5]Universität Bayreuth, Bayreuth, Germany, [6]Department of Earth Sciences, University of Florence , Florence, Italy, [7]INGV Rome, Rome, Italy

Acoustic recordings, including infrasound, are powerful tools to analyze and interpret ongoing eruption dynamics. Despite recent rapid advances in the field, the effect of tephra particles in the volcanic jet and plume on acoustic recordings is poorly understood. Our aim is to improve this understanding by performing controlled analogue experiments and comparing those to eruption data recorded on Stromboli volcano. We carried out scaled laboratory experiments using a shock tube apparatus. A variety of experiments were performed outdoors to decrease artifacts from reflection and explored different starting conditions, including 1) particle content, 2) grain size, 3) temperature and 4) vent geometry. We find that the addition of particles generally reduces the overall acoustic amplitude, especially immediately after the decompression. A few milliseconds later, the particle-rich experiments show a higher amplitude compared to the gas-only experiments. Furthermore, the gas-only experiments show a broader spectrum generally, similar to fine-scale turbulence spectra, whereas the particle-rich experiments have a more narrow spectral shape similar to large scale turbulence spectra.

We compare these results and observations to data recorded on Stromboli volcano, Italy, from a deployment between May 9-14, 2022. During this time, one of the north vents produced short-duration jets with variable ash content, temporal spacing and directionality. Additionally, we integrate high-speed imagery and electric field data to help characterize the ash content and eruption dynamics. Lastly, we compare the acoustic amplitudes, spectral properties, and directivity between the experiments and volcanic data using scaling relationships to better relate the datasets. Initial results suggest that particle-rich volcanic jetting produces distinguishable characteristics compared to gas-rich jets, which may help inform eruption monitoring and hazard mitigation.

1406

Hunga Tonga-Hunga Ha'apai: GNSS-derived ionospheric disturbances over the Pacific Ocean following the January 2022 eruption

Jessica Ghent[1], Dr Brendan Crowell[1]
[1]*University Of Washington, Seattle, United States*

On January 15, 2022, the climactic eruption of Hunga Tonga-Hunga Ha'apai (HTHH) stunned the world with its power. The large explosion produced an acoustic wave that traversed the globe multiple times over the following days and contributed to global tsunami activity, all of which propagated acoustic-gravity waves up into Earth's ionosphere. It is well established that the ionosphere, an electrically charged layer of Earth's atmosphere, registers strong acoustic-gravity waves produced in natural events as perturbations to ions within this layer. These Traveling Ionospheric Disturbances (TIDs) offer valuable information about atmospheric and oceanographic behavior surrounding the Tonga event. In the past decade, the use of Global Navigation Satellite Systems (GNSS) data has increasingly been utilized to explore ionospheric activity during natural hazard events. Using GNSS, we focus our analysis on TIDs across the Pacific and highlight the superpositioning and separation of acoustic- and tsunami-generated TIDs approaching New Zealand. GNSS data were gathered from stations managed by UNAVCO, IGS, Geoscience Australia, and GNS New Zealand. Raw data were processed using the SNIVEL_ION algorithm, while filtered time series were manually inspected to remove gross outliers. Lastly, tsunami arrivals were validated using ocean buoy data where available. We find ionospheric perturbations up to ~7 TECu, a historically large value, proximal to HTHH. Furthermore, we detect supersonic TIDs traveling at 833 m/s, with Lamb wave- and tsunami-generated TIDs following at 310 m/s. We consider the source of another TID traveling at 463 m/s, with a shift in the frequency domain, that crosses the slower TIDs ~3000 km from HTHH. Back-propagation shows that it took one hour for this faster TID to generate after the main eruption. Finally, we find that acoustic- and tsunami-generated TIDs are fully superpositioned until ~1000 km from HTHH and are distinct by ~2200 km from the source.

1457

Pulling the plug: do silicic VEI 4-5 eruptions always progress from Plinian to Vulcanian, and finally to effusive activity?

Professor Thomas Giachetti[1], Joshua Wiejaczka[1], Kathleen Trafton[1], Thomas Shea[2]
[1]*University Of Oregon, Eugene, United States,* [2]*University of Hawaii, Honolulu, United States*

Silicic magmas have produced some of the most voluminous and explosive eruptions of the Holocene (e.g., Taupo, Mount Mazama, Novarupta). However, the first and only modern documentation of rhyolitic eruptions from Chaitén and Cordón Caulle (Chile) are just a decade old. These two VEI 4-5 eruptions progressed from an initial (sub-)Plinian stage to a less steady phase involving hybrid activity where the eruption was simultaneously explosive and effusive. Both eruptions ended with the emplacement of a rhyolitic lava flow. We conducted detailed field work and laboratory analyses on the explosive deposits of three other VEI 4-5 silicic eruptions at Medicine Lake (Glass Mountain, 1060 CE, USA), Newberry (Big Obsidian Flow, 640 CE, USA), and Mt Mazama (Cleetwood, 5.7 BCE, USA). We identified sub-units, measured grain size and componentry distributions, calculated volume and mass discharge rate, and characterized the progression of the eruptive style with time. Based on similarities in sedimentological characteristics of the deposits, we find that all three eruptions progressed in a manner like those of Chaitén and Cordón Caulle. In all cases, the proportion of juvenile pyroclastic obsidian and lithic material increase upwards throughout the fall deposit, especially in the uppermost layer. Combined with the presence of breadcrust bombs and tuffisitic material, this suggests that Vulcanian-like explosion(s) occurred between the stable explosive phase and the final effusive phase. We suggest that, after the initial (sub-)Plinian phase, all five eruptions experienced similar processes where syn-eruptive formation of obsidian by ash agglomeration and sintering along the conduit edges above the fragmentation level modulated the eruptive style by partly clogging the conduit, leading to Vulcanian-like behavior. This non-linear behavior in the upper part of the conduit may be related, at the base of the conduit, to decreasing magma supply rates below a critical value.

717

Formation of unusual glazed pyroclasts from the 2021 Fagradalsfjall eruption

Miss Janina Gillies[1], Professor Ed Llewellin, Dr Fabian Wadsworth, Dr Rich Brown, Professor Thorvaldur Thordarson
[1]*Durham University, Durham, United Kingdom*

The 2021 Fagradalsfjall eruption in Iceland included episodes of fountaining that produced unusual pyroclasts that have the appearance of glazed reticulite. Initial investigation of these clasts show that they have a smooth, dark grey or light brown glassy surface that is <0.3 mm thick, surrounding a light brown to dark grey interior that is highly vesicular. The vesicles range in diameter from <20 µm to >20 mm, with the majority <1 mm. Many of the vesicles are elongated and curve around the largest vesicles. Towards the centre of the pyroclasts the vesicles are irregularly shaped with “wrinkled” vesicle walls. We present the results of scanning electron microscope imaging of polished sections through the clasts, and x-ray computed tomography of whole clasts. Imagery was analysed to determine bubble size distributions, and to characterise the distinctive glazed surfaces and vesicle shapes.

In order to infer a formation mechanism for these various glazed pyroclasts, we consider the timescales of clast emplacement, clast cooling, bubble growth, outgassing, and capillary retraction and relaxation of melt films. Based on our observations and analyses, we interpret that the glazed pyroclasts spent a sufficient length of time within the fountain to keep the external faces of the pyroclasts hot for longer than is typical of fountain products. This allowed time for bubbles in the centre of the clasts to mature and collapse, and for bubbles near the edge of the clast to burst. Bubble burst at the clast margins led to liquid film retraction, forming a smooth, glazed surface that cooled once the clast left the hot fountain environment. These textures therefore inform on the nature of the fountain environment in which they formed.

715

Novel analogues for vesicular basaltic magma that capture non-isothermal processes

Miss Janina Gillies[1], Professor Ed Llewellin, Dr Fabian Wadsworth, Dr Rich Brown
[1]*Durham University, Durham, United Kingdom*

Products of basaltic volcanic eruptions are shaped by a variety of processes that occur as the lava cools. Often cooling plays an essential role in governing the physics of the process, such as in the formation of pyroclasts during explosive basaltic eruptions, and in all cases cooling and solidification are responsible for preserving the final textures. Here we introduce two novel analogues – bubbly molten sugar and bubbly art glass – that can be used for experimental investigation of non-isothermal processes in vesicular basalt. The analogues solidify as they cool, replicating behaviour in the natural system. These materials can help elucidate the relationship between bubbles, cooling timescales, and deformation processes during the formation of different types of basaltic pyroclasts.

The first analogue is produced by melting sugar mixed with sodium bicarbonate – similar to 'cinder toffee' confectionary. This analogue material is used at temperatures no greater than 150°C, allowing it to be used in a standard laboratory setting. The second analogue is produced by melting powdered art glass with sodium bicarbonate. This material is used at temperatures of around 800°C, requiring more specialist facilities. Bubbles are formed as the sodium bicarbonate thermally decomposes to produce carbon dioxide. The vesicularity of the material can be altered by varying the proportion of sodium bicarbonate. While still molten, both analogues can be manipulated to investigate how the proportion of bubbles affects the deformation and texture of the final product that is preserved as the material solidifies.

In initial experiments, these analogue materials have been used to recreate Pele's hair by pulling apart molten foam with varying vesicularities at a constant rate. We used this case study to illustrate how these novel analogue materials can inform the processes that form Pele's hair within a fountain environment, and how they are influenced by vesicularity.

1369

Active or not? A Volcano Activity Index to define the state of transcustal magmatic systems

Professor Guido Giordano[1], Prof Luca Caricchi[1]
[1]*Università Roma Tre, Roma, Italy*

The notion of active volcano is one of the least defined in science, relying on either eruptive records collected over arbitrary time-windows (e.g. Holocene), or on the comparison between the time lapse since last eruption and the average eruption recurrence. Recent years have seen a revolution in our understanding of magmatic systems, with volcanological, petrological and geophysical data reconstructing magmatic systems as transcrustal networks of transient, independent magma bodies immersed in hot crystal mushes, which may interconnect determining size and style of eruptions. A problematic aspect of this new model is that while the shallowest portions of the plumbing system are reasonably well imaged but ephemeral, the deepest portions are hard to characterize, despite potentially remaining long active and hot. Therefore, we do not know if long-dormant volcanoes are extinct or instead if eruptible magma is present throughout the plumbing system and is preparing for the next eruption. Understanding the interplay between long- and short-term and deep and shallow processes associated with accumulation and transfer of eruptible magma is essential for assessing the potential for future eruptions to occur and estimating their magnitude, which remains one of the foremost challenges in the Earth sciences. We review literature and use existing data for emblematic volcanic systems to identify the essential data sets required to define the state of activity of volcanoes and their plumbing systems. We explore global eruptive records in combination with heat flux and other geological and geophysical data to determine the evolutionary stage of plumbing systems. We define a Volcanic Activity Index applicable to any volcano that provides an estimate of the potential of a system to erupt in the future, which is especially important for long-quiescent volcanoes.

403

Gas-driven thermal anomalies on La Palma Island (Spain) before the 2021 Cumbre Vieja eruption

Professor Társilo Girona[1], Noé García-Martínez[2], Claire Puleio[1], Yan Zhan[3], Paul Lundgren[4], David Benavente[2]
[1]Geophyisical Institute, University Of Alaska Fairbanks, Fairbanks,, United States, [2]Department of Earth and Environmental Sciences, University of Alicante, Spain, , , [3]Earth System Science Programme, Chinese University of Hong Kong , , , [4]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA, ,

Identifying the observables that warn of volcanic unrest and eruptions is one of the greatest challenges in natural hazard management. Recently, Girona et al., 2021 (https://www.nature.com/articles/s41561-021-00705-4), discovered that volcanic edifices may slightly warm in the years leading up to both phreatic and magmatic eruptions. This slight warming, or low-temperature (low-T) geothermal anomaly, was found by analyzing ~16 years of long-wavelength (~11 µm) thermal infrared radiance data recorded daily by the moderate-resolution image spectroradiometers (MODIS) aboard NASA's Terra and Aqua satellites, and is probably driven by the subsurface circulation of fluids. However, many questions remain open. For example: What is the link between the spatiotemporal distribution of low-T geothermal anomalies, subsurface gas transport, and diffuse outgassing? We address these questions by updating the remote sensing-based methodology proposed by Girona et al. (2021), by testing different physics-based, finite element (COMSOL) simulations to model gas and heat transport through volcanic edifices, and by using the 2021 Cumbre Vieja (La Palma, Spain) eruption as a case study. Our remote sensing-based analysis reveals that the 2021 eruption of Cumbre Vieja was preceded by ~10 years of low-T geothermal anomalies in the crater and south/south-west flanks of Taburiente caldera, located 10-to-12 km to the north of the 2021 eruptive center. Moreover, our models suggest that the pre-eruptive, low-T geothermal anomalies in Taburiente were controlled by the heat transported by magmatic gases rising to the surface, and possibly by the latent heat released during the subsurface condensation of magmatic and/or hydrothermal H2O. The possibility of tracking the spatiotemporal distribution of low-T geothermal anomalies using satellite data opens new horizons to indirectly detect the pre-eruptive transport of hot gas towards the surface, anticipate volcanic unrest from space, and potentially better forecast eruptions. This research is supported by a NASA NIP award (80NSSC21K2074) and a NASA ESI award (NNH20ZDA001N-ESI).

561

Modelling mass balance and stress transfer at Krafla and Theistareykir geothermal systems, Iceland

Mrs Beatrice Giuliante[1], Philippe Jousset[1], Charlotte Krawczyk[1], Jacques Hinderer[2], Umberto Riccardi[3], Tania Toledo[4], Florian Forster[5], Anette Mortensen[6]

[1]GFZ, Potsdam, Germany, [2]University of Strasbourg, Strasbourg, France, [3]University of Naples "Federico II", Naples, Italy, [4]ETH Zurich, Zurich, Switzerland, [5]Hot Dry Rocks Pty Ltd, Melbourne, Australia, [6]Landsvirkjun, Reykjavik, Iceland

Structure analysis and geothermal field monitoring are mandatory to ensure sustainable exploitation of a reservoir. To assess subsurface mass and fluid displacement we use multi-parameter stations for field measurements, equipped with a gravity meter (superconducting or spring relative meters), a broad band seismometer, a GPS receiver, meteorological stations and other hydrological sensors. This setup is installed at the Krafla volcanic system for which we want to derive energy transfer models of the hydrothermal reservoir including the anthropogenic exploitation. Through the combination of absolute gravity measurements, the continuous signals measured with the multi parameter stations and seismic measurements we aim to also model mass and stress transfer.

We show results from previous and recent (June 2022) works at the Theistareykir geothermal field (North Iceland) as well as results from first continuous gravity records collected at the Krafla geothermal field. We present the first accurate Earth tide model of the Krafla area and present multi-parameter data analysis of the continuous signals. We aim at inverting, interpreting and finally assessing the anthropogenic contribution in the mass and energy transfer within the investigated geothermal field. The goal of the study is to verify the conditions for sustainable exploitation of the reservoir and understand the response of the geothermal system to changes in the production and injection rates in order to establish reservoir parameters, e.g. permeability.

1056

Seismicity during the 2021 Fagradalsfjall dyke intrusion, Reykjanes Peninsula, Iceland: Detailed evolution of a lateral dyke, and comparison to Bárðarbunga-Holuhraun

Miss Esme Glastonbury-Southern[1], Tim Greenfield[1], Tom Winder[1], Þorbjörg Ágústsdóttir[2], Bryndís Brandsdottir[3], Tomas Fischer[4], Jana Doubravová[5], Nick Rawlinson[1], Robert White[1], Egill Árni Gudnason[2], Gylfi Páll Hersir[2], Pavla Hrubcova[5], Conor Bacon[1,6]

[1]Bullard Laboratories, Department of Earth Sciences, University Of Cambridge, Cambridge, United Kingdom, [2]Iceland GeoSurvey, Reykjavík, Iceland, [3]Institute of Earth Sciences, Science Institute, University of Iceland, Reykjavík, Iceland, [4]Faculty of Science, Charles University, Prague, Czech Republic, [5]Institute of Geophysics, Czech Academy of Sciences, Prague, Czech Republic, [6]Columbia University, New York, United States

The 2021 Fagradalsfjall eruption on Iceland's Reykjanes Peninsula was preceded by more than 12 months of elevated activity, beginning around November 2019. This dominantly consisted of episodes of intense seismic swarms, but also featured inflationary episodes in both the Svartsengi and Krísuvík volcanic systems. On 24th February 2021, an exceptionally intense episode of seismicity covering the length of the Peninsula marked the initiation of a dyke intrusion, which continued to develop until the 19th of March, when melt first erupted at the surface. The fissure eruption lasted 6 months, ending on 18th September 2021.
During the intrusion, melt first propagated northeast towards Mt Keilir, then to the southwest, eventually forming a 10 km-long dyke. This was marked by more than 80,000 microearthquakes, recorded by a dense local seismic network and detected and located using QuakeMigrate[1].
We present high precision relative relocations of the seismicity, and tightly constrained focal mechanisms of earthquakes which are dominantly located along the base of the dyke. We compare the Fagradalsfjall seismicity to the 2014-2015 Bárðarbunga-Holuhraun intrusion and eruption seismicity [2], in the context of the contrasting tectonic settings, and markedly different precursory activity.

1: Winder, T., Bacon, C., Smith, J., Hudson, T., Greenfield, T. and White, R., 2020. QuakeMigrate: a Modular, Open-Source Python Package for Automatic Earthquake Detection and Location. https://doi.org/10.1002/essoar.10505850.1

2: Woods, J., Winder, T., White, R. S., and Brandsdóttir, B., 2019. Evolution of a lateral dike intrusion revealed by relatively-relocated dike-induced earthquakes: The 2014–15 Bárðarbunga–Holuhraun rifting event, Iceland. https://doi.org/10.1016/j.epsl.2018.10.032

1057

Ring Fault Slip Reversal at Bárðarbunga Volcano, Iceland: Seismicity during Caldera Collapse and Re-Inflation 2014–2018

Miss Esme Glastonbury-Southern[1], Tom Winder[1], Robert White[1], Bryndís Brandsdottir[2]
[1]Bullard Laboratories, Department of Earth Sciences, University Of Cambridge, Cambridge, United Kingdom, [2]Institute of Earth Sciences, Science Institute, University of Iceland, Reykjavík, Iceland

Microearthquakes reveal the kinematics of the Bárðarbunga caldera ring fault; during the 2014–2015 rifting event and gradual caldera collapse, and its subsequent, ongoing re-inflation. Tightly constrained focal mechanisms during re-inflation have reversed phase arrival polarities from events during the caldera collapse. Thus, the inner side of the steeply dipping northern caldera faults (averaging 81±8°) has been moving upwards during the post-eruptive period. Both precise relative relocations of the seismicity and fault plane solutions confirm that this is due to slip reversal on the same ring fault structure.

499

More Mantle, More Melt: Modeling the Mantle-Derived Causes of Heterogeneity in Volumetric Magmatic Flux at Arcs

Dr Andrea Goltz[1], Professor Christy Till[1], Professor Adam Kent[2]
[1]Arizona State University, School of Earth and Space Exploration, Tempe, United States, [2]Oregon State University, College of Earth, Ocean, and Atmospheric Sciences, Corvallis, United States

Estimates of volumetric magmatic flux vary significantly between arc volcanoes, both globally and between volcanoes in a given arc. A recent case study of the Cascades arc suggested that a root cause of heterogeneity in surface volcanic flux is variations in mantle magma flux entering the crust, which could relate to along-arc variations in fluid flux from the subducting oceanic lithosphere, changes in mantle thermal structure or composition, or subduction geometry.

In this study, we model the volumetric flux of magma from the mantle using a simplified 3-D box model of a subduction zone in order to constrain the physical factors with the greatest influence on the volume of magma produced in the mantle over time. In the model, we evaluate the relative importance the physical parameters of subduction (i.e., dip, convergence rate, thermal structure, lateral range of melting, and mantle grain size) have in controlling mantle magma flux, compared to the extent and type of melting (i.e., flux and decompression) in a Monte Carlo calculation.

Our results suggest that the lateral span of melting exerts the largest control on mantle magma flux calculated in our model. Although mantle thermal structure and flux of volatiles from the subducting plate exert first order controls on the degree of melting, they have relatively minor influence on total volumetric flux. In cases where calculated volumetric magmatic flux closely approximates published estimates, the average size of the melting footprint significantly exceeds the main edifice radius of volcanoes, suggesting that volcanoes likely harvest magma from larger regions.

The results of our modeling could explain volcanic features like monogenetic fields proximal to larger volcanic edifices. Our results may also help in the interpretation of geochemical features like similarity of primitive magmas at adjacent volcanoes and support the idea that mantle magma supply may control volcano spacing.

1119

Evaluating multi-decade time series of volcanic thermal features for potential eruption precursors using satellite ASTER data

Ms Andrea Gomez-Patron[1], Lin Way[2], Chloe Crothers[1], Abigail Downes[1], Laura Zapata[1,3], Rochelle Duato[1], Luke Jackson[1], Nell Nicastro[1], Dr. Matthew Pritchard[1], Dr. Kevin Reath[1]

[1]Cornell University, Ithaca, United States, [2]Nanyang Technological University, Jurong West, Singapore, [3]University of California, Los Angeles, Los Angeles, United States

Measurements of temperature changes at volcanic features can show trends that may potentially forecast eruptions. Previous work has shown that thermal precursors can be detected from space, and can include increases, decreases, or changes in variations in temperature. We evaluate how often these precursors are observed from 2000-2022 at 214 erupting volcanoes using nighttime Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) observations with a spatial resolution of 90 m/pixel. Initial review of 107 volcanoes finds that roughly 50% of them have sufficient nighttime cloud-free observations to make baseline temperature measurements. For instance, only 22% of Bulusan volcano's (Philippines) images are usable compared to 50% of the Dabbahu volcano's (Ethiopia) images. Where there is enough data to define baseline temperatures, we identify volcanoes that, within six to eight months of eruption, register temperature values that differ by at least two standard deviations from baseline values. Preliminary results indicate that the following volcanoes show increases in temperature: Sabancaya (Peru), Agung (Indonesia), Momotombo (Nicaragua), Kuchinoerabujima (Japan), Poas (Costa Rica), Kikai (Japan), Redoubt (Alaska); these register decreases in temperature: Lascar (Chile), Taal (Philippines); these experience increased temperature variance: Copahue (Chile/Argentina) and Klyuchevskoy (Russia). Moreover, volcanoes with multiple eruptions can exhibit different precursive activity each time. Interpreting thermal activity as a precursor is complicated by the fact that 25% of robust volcano time series have significant thermal activity, defined as absolute temperature changes of 30% or more, not associated with eruptions (as recorded by the Global Volcanism Program). Our study confirms previous work that found that thermal precursors can be seen from space, but more temporally dense cloud-free satellite observations at spatial resolution of 90 m/pixel or better are needed.

1146

The magmatic plumbing system of Kilauea Volcano, Hawai`i, during its 2018 eruption

Mr Helge Gonnermann[1], Gaetano Ferrante[1], K.R. Anderson[2], James F. Foster[3], Ingrid A. Johanson[4]
[1]Rice University, Houston, United States, [2]U.S. Geological Survey, Moffett Field, United States, [3]Universität Stuttgart, Stuttgart, Germany, [4]U.S. Geological Survey, Hilo, United States

We present a zero-dimensional model for subsurface magma transport and storage during the 2018 eruption of Kilauea Volcano, Hawai`i. Our objective is to identify the fundamental dynamical relations throughout Kilauea's summit and East Rift Zone (ERZ) magma storage and transport system, and to reconcile these with observations. For the latter we focus on Global Navigation Satellite System (GNSS) and earthquake data, as well as eruption rate estimates. Using the aforementioned model we identify the various components of Kilauea's shallow magma storage system, their storage capacities, and how they are interconnected. We are thus able to simulate the observed temporal evolution of deformation at Kilauea's summit and ERZ during the 2018 eruption with considerable detail. Our simulations predict the initial intrusion of magma into Kilauea's Lower ERZ, the subsequent evolution of magma pressures within Kilauea's summit and ERZ, as well as the transport of magma within the summit, from the summit to the ERZ, and within the ERZ to the 2018 eruptive vent. Simulation results suggest that magma storage within Kilauea's summit has a total capacity, expressed in terms of the compressibility-volume product, of about 100 cum/Pa. Magma storage tapped during the eruption within Kilauea's ERZ has a similar capacity. To what extent the latter is due to crystal-poor magma reservoirs, olivine cumulate mush, or some combination thereof is at this point not constrained by our simulations. The connectivities with Kilauea's summit, from summit to ERZ, and within the ERZ can be quantified in terms of conductances that vary somewhat, but are overall of the order of 1E-4 cum/(s.Pa)

1437

A NEW PATHWAY TO UNTANGLE THE QUESTION: WAS THE VOLCANIC ERUPTION TRIGGERED BY THE EARTHQUAKE?

Mr Gino Gonzalez[1,2,3], Eisuke Fujita[4], Alexander Garcia[2], Bunichiro Shibazaki[5], Takumi Hayashida[5], Dmitri Rouwet[2], Federico Lucchi[6], Roberto Sulpizio[1], Antonio Costa[2], Giovanni Chiodini[2], Rodolfo Castro[7], Karoly Nemeth[8], Aaron Moya[9], Joan Marti[10], Marco Viccaro[11], Gustavo Chigna[12], Adolfo Garcia[3], Raul Mora-Amador[3]
[1]Università degli Studi di Bari, Aldo Moro, Bari, Italy, Bari, Italia, [2]Istituto Nazionale de Geofisica e Vulcanologia, Sezione di Bologna, Bologna, Italy, Bologna, Italy, [3]Volcanes sin Fronteras, Costa Rica, San Jose, Costa Rica, [4]National Research Institute for Earth Science and Disaster Resilience, Tsukuba, Japan, Tsukuba, Japan, [5]International Institute of Seismology and Earthquake Engineering, Building Research Institute, Tsukuba, Japan, Tsukuba, Japan, [6]BIGEA, University of Bologna, Italy, Bologna , Italy, [7]MARN, El Salvador, San Salvador, El Salvador, [8]Institute of Earth Physics and Space Science, Sopron, Hungary, Budapest, Hungary, [9]Laboratorio de Ingeniería Sísmica (LIS-UCR), Universidad de Costa Rica, San José, Costa Rica, San Jose, Costa Rica, [10]Dipartimento di Scienze Biologiche Geologiche e Ambientali – University of Catania, Italy, Catania, Italy, [11]CSIC, Barcelona, Spain, Barcelona, Spain, [12]INSIVUMEH, Guatemala, Guatemala, Guatemala

"Was the volcanic eruption triggered by the earthquake?" The answer to this question usually is "maybe" or "a coincidence". A region like Central America, where the occurrence of earthquakes is frequently and where there are many active volcanoes, is an adequate area to find hints to answer this question. This research focuses on if the uncommon occurrence of three large earthquakes in the subduction zone of Central America, within a time span of ten weeks in 2012, triggered enhanced volcanic activity. The time window analyzed is from 2000 to 2019, during which 51 volcanic eruptions occurred. Before the 2012 earthquakes, 21 eruptions occurred. The Monte Carlo statistical method allowed to demonstrate that this increase in the number of volcanic eruptions after the three large earthquakes of 2012 it is not just a temporal coincidence. We analyzed the characteristics of each earthquake and suggested how these could disturb the volcanic system. Although Central America hosts 24 volcanoes with historical eruptions, only 11 of them erupted after the 2012 earthquakes. Why did only these volcanoes erupt? To answer to this question, we calculated the dynamic and static stress in each volcano and the level of volcanic unrest prior to after the earthquakes. We found that only volcanoes in a state of unrest before the earthquakes but, although, without large explosions previously, erupted after the earthquakes. This observation suggests that the earthquakes itself cannot have generated the volcanic eruptions, but that they could rather promote volcanic eruptions, given previous unrest. This research can be a tool for forecasting volcanic activity when a large earthquake hits a region, if volcanic activity is previously monitored. The findings of this study will help to communicate and prepare the population before the next volcanic eruption possibly triggered by a tectonic earthquake.

1419

NEW VIEWS OF THE NEAPOLITAN YELLOW TUFF ERUPTION, CAMPI FLEGREI, ITALY

Mr Gino Gonzalez[1], Dr. Roberto Sulpizio[1], Dr. Antonio Costa[2], Dr Federico Lucchi[3], Dr. Roberto Isaia[4], Dr. Biagio Giaccio[5], Dr. Jacopo Natale[6], Dra. Daniela Mele[1], Dr. Lorenzo Monaco[7]

[1]Università degli Studi di Bari, Aldo Moro, Bari, Italy, Bari, Italia, [2]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Bologna, Bologna, Italy., Bologna, Italy, [3]BIGEA, University of Bologna, Bologna, Italy, [4]Istituto Nazionale di Geofisica e Vulcanologia, Sezione Osservatorio Vesuviano, Naples, Italy., Napoli, Italy, [5]Istituto di Geologia Ambientale e Geoingegneria - CNR, Monterotondo, Italy, Rome, Italy, [6]Dipartimento di Scienze della Terra, dell'Ambiente e delle Risorse - Università degli Studi di Napoli Federico II, Italy , Napoli, Italy, [7]Dipartimento di Scienze della Terra, Università di Pisa, Pisa, Italy

Large volcanic eruptions are one of the most extreme geophysical phenomena that can occur in our planet. These events can spread ashes to regions and worldwide.

The Neapolitan Yellow Tuff (14.1 ky B.P.; NYT) is the largest eruption in the last 15 ky in Campi Flegrei, the most active caldera in Europe. The NYT spread ashes as far as Croatia, Slovenia and Austria. Naples city, whit a population of more than 3 million, is largely built over the deposits of this eruption.

The stratigraphy and eruptive mechanism of NYT were studied in the 90's.

Here, we propose a new assessment of the stratigraphy and eruptive mechanisms based on new fieldwork, grain size distribution, componentry analysis, geochemical data, SEM images and microtomography of juvenile particles.

We found that the sequence of the NYT lower member is characterized by fallout and diluted pyroclastic density current (PDC), with a primary magmatic fragmentation, revealing a fragile magma with the capacity to produce large amount of fine ash.

We calculated the volume of fallout deposits in the order of ~1 km3, while the volume of PDC is several km3, but less than the previously estimated. Numerical simulations will be performed to better constraint the erupted volume of NYT.

248

Characterization of flank deformation and concurrent volcanic unrest styles at Pacaya Volcano, Guatemala

Ms Judit Gonzalez Santana[1], Dr Christelle Wauthier[1,2]
[1]Department of Geosciences, Penn State University, , United States, [2]Institute for Computational and Data Sciences, Penn State University, , United States

At remote and/or poorly instrumented volcanoes, radar satellite interferometry (InSAR) has revolutionized the ability to monitor ground deformation and has facilitated the identification of transient and persistent flank slip at volcanoes globally. Pacaya is an active basaltic stratovolcano in Guatemala with evidence for an ancestral collapse, and where magma-driven flank instability was identified during major eruptions in 2010 and 2014, using InSAR. We leverage the availability of repeated SAR coverage over Pacaya from 2007 to investigate the links between ground deformation and eruptive unrest styles, to understand the conditions under which flank creep can be initiated, sustained, or halted at active volcanoes and to devise a conceptual model for the initiation of flank creep at Pacaya. We quantify flank deformation through InSAR time-series analysis, and describe concurrent eruptive behavior through volcanic activity reports, ash advisories, thermal anomaly time-series, and lava flow maps. The large transient flank instabilities coincident with vigorous eruptions in 2010 and 2014 are followed by months-long slower creep during the relatively quiescent 2010 to 2014 and 2015 to 2018 intervals, whereas times with similarly elevated eruptive activity in 2007 to 2009 and 2018 to 2020 are not accompanied by clear flank creep. Our analysis suggests that during times of elevated volcanic unrest with persistent thermal anomalies in the crater region and degassing, attributed to open-vent volcanism, as in 2007 to 2009 and 2018 to 2020, magma migrates in an open conduit with little associated deformation. Conversely, when new vents open outside the summit area, either at the start or during a transition in an eruption, transient flank creep can be initiated, as in 2010 and 2014. Therefore, the opening of new vents beyond the main summit cone, particularly in a north-northwest to south-southeast alignment, could forewarn an increased likelihood of new or accelerating flank creep at Pacaya.

1184

Architecture of orbicular textures from Karamea, New Zealand

Miss Charlotte Gordon[1], Dr David Wallis[1]
[1]*University of Cambridge, Cambridge, United Kingdom*

Crystal clusters are ubiquitous in igneous rocks, encoding valuable information about the history of the magma. To interpret them correctly, we must be able to discern between different cluster-forming processes such as synneusis, heterogeneous nucleation, growth twinning and mush disaggregation. This study focuses on orbicular textures, where crystals form concentric shells around a core, in layers defined by variations in mineralogy and texture. To date, there has been little quantitative investigation into the crystal morphologies and orientation relationships present in orbs, and no consensus on how they form.
Our samples are from Karamea, New Zealand, which has provided spectacular material to many of the world's major museums but has rarely appeared in the peer-reviewed literature. We apply electron backscatter diffraction (EBSD) analysis and QEMSCAN mapping to characterise the architecture of the Karamea orbs, providing new insights into their formation.

We focus on plagioclase, which forms monomineralic orbicular shells with either a dendritic or a granoblastic texture. If plagioclase grew freely in the melt then attached to the growing orb surface by synneusis, we would expect it to do so on the prominent crystal faces (010) or (001). However, our preliminary data do not reveal evidence of this behaviour. Instead, plagioclase orientations throughout the orbs are strongly controlled by the orientations of the substrate crystals on which they grew. This effect is particularly striking in one sample where all orientations present in the dendritic shell can be traced back to orientations in the core. Crystals in the granoblastic layers also frequently have systematic orientation relationships with their neighbours. Our preliminary data therefore support orb growth by the heterogeneous nucleation of crystals in substrate-controlled orientations, with variations in texture likely controlled by undercooling. Our findings could be applied to identify evidence of heterogeneous nucleation in crystal clusters from other magmatic settings.

1169

Mineral inclusions in K-feldspar megacrysts track mush mobility

Miss Charlotte Gordon[1], Dr David Wallis[1]
[1]*University of Cambridge, Cambridge, United Kingdom*

K-feldspar megacrysts are a common yet enigmatic feature in granitic and granodioritic plutons. Megacrysts have many characteristics typical of crystals grown in melt-rich magmatic conditions, for example euhedral shapes. However, experimental and modelling evidence indicates that K-feldspar grows late in the crystallisation sequence, when the magma is highly crystalline. This apparent paradox has been the subject of a long-running debate with extensive implications for our interpretation of igneous textures.
We provide a new perspective on this problem by examining the arrangement of mineral inclusions within K-feldspar megacrysts, using electron backscatter diffraction (EBSD) to quantify the crystal orientations. The plagioclase inclusions have systematic orientation relationships with their host megacrysts, and appear to have attached by synneusis, whereby crystals form separately in melt and then attach in low-energy orientations. These patterns demonstrate that during megacryst growth, surrounding crystals were able to rotate into favourable orientations. The driving forces for such rotations are extremely small, and to rotate on reasonable timescales, crystals require a mobile magmatic environment where unimpeded rearrangement can occur. Strong resorption zoning in the megacrysts suggest these conditions may have occurred episodically.

Beyond the euhedral bounds of the megacryst, K-feldspar is present as an interstitial network, but plagioclase crystals hosted within this network have non-systematic orientations. We interpret that this transition from systematic to non-systematic plagioclase orientations marks the point at which the mush became a static, interconnected framework in which crystals were no longer free to rotate relative to one another.

These relationships demonstrate that megacrysts must have grown predominantly in a mobile magma, and that the mush only became static and "locked-up" in the latest stages of K-feldspar crystallisation.

513

Drilling of a volcanic conduit beneath a Quaternary dacitic dome at Kuttara volcano, Hokkaido, Japan

Dr Yoshihiko Goto[1], Dr Jocelyn McPhie[1]
[1]*Muroran Instutute Of Technology, Muroran, Japan*

Hiyoriyama is a Quaternary dacitic dome located in Kuttara volcano, Hokkaido, Japan. We have drilled a 350-m-long, inclined hole passing beneath the Hiyoriyama dome, penetrating its volcanic conduit at 200 m below the ground surface. The Hiyoriyama dome (250–400 m across, 130 m high) consists of augite-hypersthene dacite ($SiO2$ = 70 wt.%) that contains abundant mafic enclaves ($SiO2$ = 59 wt.%). Drill cores, totalling 320 m in length, were recovered from the hole. The principal lithofacies of the drill cores are dacitic pyroclastic deposits (97 vol.% of total drill cores), coherent andesite (3 vol.%), and tuffisite veins (<1 vol.%). The dacitic pyroclastic deposits correspond to the Kt-ty, Kt-3, Kt-2 and Kt-1 tephras, which were erupted from Kuttara volcano. The coherent andesite (57–59 wt.% SiO2) is positioned below the summit of the Hiyoriyama dome, suggesting it is the volcanic conduit (feeder dyke) of the dome. The dyke width, calculated from the core length (9.8 m) and drill-hole angle (41°), is 6.4 m. Lithological difference between the conduit and the dome can be explained by magma ascent from a zoned magma chamber. The tuffisite veins occur within the coherent andesite and in the pyroclastic deposits. The total number of veins intersected is 28. The tuffisite veins are tabular, zigzag or Y-shaped, up to 20 cm wide, and composed of lithic and mineral fragments up to 2 cm across. Pyrite-rich alteration zones occur on both sides of the tuffisite veins. Some tuffisite veins grade into quartz veins that contain framboidal pyrites. The tuffisite veins are inferred to have formed by injection of high-temperature fluid and entrained particles into temporarily opened fractures. At 200 m below the ground surface, the conduit zone of the Hiyoriyama dome is 16 m in width and consists of a feeder dyke and associated tuffisite veins.

514

Eruptive history of Usu volcano, Hokkaido, Japan, revealed by multiple trench surveys

Dr Yoshihiko Goto[1], Mr Takamasa Takamasa[1], Mr Koudai Sato[1], Mr Hibiki Ito[1], Dr Akihiko Tomiya[1]
[1]*Muroran Instutute Of Technology, Muroran, Japan*

A complete tephra stratigraphy of individual volcano is essential to establish eruptive history of the volcano. We have studied tephra stratigraphy of Usu volcano, Hokkaido, Japan by multiple, hand-dig trench surveys. Usu volcano is one of the most active volcanoes in Japan. The trench surveys were carried out at eleven locations in and around the Usu volcano area. Most trenches were dug at not-easy-access locations, including the summit of the Higashi-Maruyama cryptodome, and the summit of Donkoroyama scoria cone. Each trench was <3.7 m in depth. Tephra layers, which were produced by the historic eruptions from AD 1663 to 2000, were described at each trench. The trench surveys revealed that: (1) the Higashi-Maruyama cryptodome, which was previously undated, was formed in AD 1663; and (2) the pre-1769 eruption, which was thought to be a minor eruption, is a large-volume explosive eruption as well as the 1769, 1822 and 1853 eruptions. Combined with previous studies, we have established the entire eruptive history of Usu volcano as follows. Eruptive activity of Usu volcano commenced at 19 ka with andesitic explosive eruptions. Subsequent extrusions of andesitic lavas produced a stratovolcano. The summit of the stratovolcano largely collapsed at 16 ka, resulting in generation of a debris avalanche, and producing an amphitheater 2 km across. Summit collapse was followed by a dormant period of ~15 ky. During this hiatus in volcanic activity, the composition of erupted magma changed from mafic to silicic. Historical eruptive activity commenced with a rhyolitic Plinian eruption and cryptodome formation at Higashi-Maruyama in AD 1663. In <1769 a large silicic explosive eruption occurred in the summit area of Usu volcano. This eruption was followed by dome-forming eruptions in 1769, 1822, 1853, 1910, 1943–1945, 1977/78, and 2000, which occurred in the summit area and foothills of Usu volcano.

454

Noisy neighbors: how do you get non-explosive mingling next to explosive interactions?

Dr Alison Graettinger[1], Kadie Bennis[2], Aaron Galletly[1], Hannah Grachen[1], Dr. Richard Hanson[3], Dr. Brittany Brand[4]

[1]University of Missouri Kansas City, Kansas City, United States, [2]Global Volcanism, Smithsonian Institute, Washington DC, USA, [3]Texas Christian University, Fort Worth , USA, [4]Boise State University, Boise, USA

Magma rising to feed eruptions must first move through near-surface materials, which commonly include unconsolidated and wet sediments. Field work documenting mingled non-explosive textures such as peperites as well as experiments with molten materials indicate that the presence of water itself is not enough to trigger explosive interactions, and that explosive and non-explosive textures can occur together in eruptive products or in subsurface feeder conduits.

Eroded small volume mafic volcanoes provide excellent opportunities to investigate diverse near-surface intrusions into unconsolidated sedimentary deposits and their relations with eruptive products from explosive and non-explosive processes. Eroded Plio-Pleistocene volcanoes in the Western Snake River Plain, ID, USA and Eocene hypabyssal intrusive complexes in Big Bend National Park, TX, USA display a range of mafic non-explosive intrusive deposits proximal to or cross-cutting diatreme-like phreatomagmatic structures. Evidence of magma mingling with unconsolidated wet sediment includes peperite, pillowed and billowed dikes, sediment melting and vesiculation, centimeter-thick glassy margins, and incorporation of significant amounts of quartz sand into a dike. Individual sites display textural diversity of mingling from millimeter to meter scale reflecting highly heterogenous processes. At the same time, many of structures occur commonly across disparate sites; e.g. billowed structures on intrusive margins occur at multiple sites from pre-eruptive depths of ≤500 m to ≤10 m but have similar geometries and amplitudes.
The scale of the variability in textures and the proximity between explosive and non-explosive textures reflects a spatial variation in the interactions between magma and sediment, while the recurrence of the types of textures across different volcanic settings reflects the commonality of processes involved. The physical evidence from outcrops of the types described here provide useful constraints for experimental and numerical investigations of the thermal and mechanical interactions between magma and wet sediment as an important step to defining conditions favorable for explosive interactions.

521

Volcanic Field Sites for Artemis Testing and Training

Mr Trevor Graff[1,2], Dr Kelsey Young[1,3], Dr Cindy Evans[1], Mr Scott Wray[1], Mr David Coan[1,4], Artemis Geology Training Team, Joint EVA Testing Team
[1]NASA Johnson Space Center, Houston, USA, [2]Jacobs, Houston, USA, [3]NASA Goddard Space Center, Greenbelt, USA, [4]Aerospace Corp, Houston, USA

The Artemis Program will reestablish human presence on the Moon and lead to a new era of scientific discovery and exploration. Led by the National Aeronautics and Space Administration (NASA), the Artemis Program is a collaboration of space agencies and companies around the world. An integrated effort between various disciplines of science, engineering, and mission operations is currently developing methods, facilities, and analog field locations to train astronauts and test hardware and concepts of operations. These efforts aim to best prepare for the next steps of human exploration on the lunar surface and beyond.

Numerous terrestrial volcanic field sites were evaluated and selected for their unique roles in helping to prepare for the lunar surface mission phases. This effort heavily leveraged the comprehensive academic research conducted at these field sites, as well as the tremendous Apollo heritage. The currently selected volcanic field sites include the San Francisco Volcanic Field in Northern Arizona, the Potrillo Volcanic Field in southern New Mexico, the highlands of Iceland, and the Southwestern Nevada Volcanic Field. Within each of these volcanic field sites numerous specific testing and training locations are being further developed utilizing the analogous terrain and unique features in these regions. Recent Artemis testing and training events have been conducted at a number of these volcanic field sites by both a dedicated Artemis Geology Training Team and a Joint Extra Vehicular Activity (EVA) Testing Team. This presentation will highlight the selected sites as well as the objectives and accomplishments of some of the recent field-testing events and training courses. Additionally, we continually strive to pursue additional sites, locations, data sets, collaborations, and partnerships in this endeavor and welcome knowledge transfer and community input.

333

Carbon Isotope Composition of Basalts from Loihi Seamount: Evidence for Recycled Carbon in the Hawaiian Mantle Plume

Dr David Graham[1], Dr. Peter Michael, Thi Truong, Dr. Michael Garcia
[1]*Oregon State University, Corvallis, United States,* [2]*The University of Tulsa, Tulsa, United States,* [3]*Oregon State University, Corvallis, United States,* [4]*University of Hawaii at Manoa, Honolulu, United States*

We analyzed the carbon isotope composition of vesicle CO_2, plus He isotopes and He and CO_2 concentrations in the vesicle and glass phase of 37 submarine basalts from the summit, north and south rifts, and east flank of Loihi Seamount, the youngest volcano in the Hawaiian hotspot chain. Tholeiites and transitional basalts lie in a narrow range of vesicle $\delta^{13}C$ = -0.9 to -4.6‰, while alkali basalts range from -2.1 to -7.2‰. Calculated total (vesicle+glass) $\delta^{13}C$ in tholeiites and transitional basalts ranges from -2.5 to -6.0‰ for a vapor-melt isotope fractionation factor Δ = δvapor - δmelt = +2 to +4‰. We estimate that total $\delta^{13}C$ = -3 to -5‰ for most lavas. This range resembles mantle source values deduced from gas-rich MORBs and Iceland basalts, and for Kilauea deduced from its fumarole gas. However, this similarity is a conundrum because Loihi basalts degassed >97% of their initial CO_2 based on CO_2-trace element systematics and crystal fractionation modeling. Loihi primary magmas (MgO=18 wt.%) had initial CO_2 concentrations of 0.6 to 1.8 wt.%. Most tholeiitic and transitional basalts followed a quasi closed-system degassing trajectory. Correcting for degassing indicates that $\delta^{13}C$ = -0.5 to -3.0‰ in Loihi undegassed primary magma. This primary magma estimate is based on Δ=+2‰ during degassing; larger values of Δ, as measured experimentally, and/or open-system degassing, lead to even higher estimates of $\delta^{13}C$ for a primary magma. The Hawaiian plume source therefore seems to be characterized by $\delta^{13}C$ that is higher than the values of -4 to -6‰ commonly found throughout Earth's mantle. This may be explained by the presence of a small mass fraction (much less than 1%) of recycled calcium carbonate in the Loihi mantle plume source.

895

Roles, Rules & Relationships: Lessons from the Caribbean science-management interface

Mr Omari Graham[1], Mrs. Stacey Edwards[1], Prof. Richard Robertson[1]
[1]*The University Of The West Indies Seismic Research Centre, St. Augustine, Trinidad and Tobago*

During periods of volcanic unrest, civil authorities around the world depend on information from scientists to guide their decision making. In some instances, limited experience among these authorities cause scientists to take on decision-making responsibility usually reserved for non-scientists. These actions increase the managerial risks faced by scientists as they can lose credibility and could be legally liable for the negative outcomes. Working in disaster risk governance structures at varying stages of development can also present unique challenges. Using semi-structured interviews and content analysis we sought to understand how scientists at The UWI Seismic Research Centre (UWI-SRC) managed interactions at the science-management interface during volcanic emergencies in the Eastern Caribbean. Our analysis yielded two major themes: (1) communication practice and (2) stakeholder relationships. Our findings indicate that strong relationships between volcano scientists and authorities coupled with purpose driven communication methods can improve decision making capacity among public officials, reducing public vulnerability. To reduce managerial risk, we propose the prioritisation of situation awareness when communicating volcanic hazard information. We use this opportunity to present some of the lessons learnt from stakeholder collaborations leading up to and during the 2020 – 2021 eruption of the La Soufrière Volcano, St. Vincent. We also highlight the role of routine science-emergency management interaction during inter-eruptive periods in facilitating more effective disaster risk reduction, especially in small island developing states (SIDS).

899

Toward Integrated Volcano Early Warning: Issues and Opportunities for the Caribbean Region

Mr Omari Graham[1], Mrs. Stacey Edwards[1], Prof. Richard Robertson[1]
[1]*The University Of The West Indies Seismic Research Centre, St. Augustine, Trinidad and Tobago*

Volcanic Alert Level Systems (VALS) enable volcano scientists to quickly and simply communicate the activity at volcanoes to other stakeholders. This early-warning system (EWS) can vary in form and function in different countries. Some alert level systems only describe activity while others prescribe mitigation actions for each level of alert. In some countries, volcano alert levels are assigned by scientists, while in other jurisdictions emergency management agencies ultimately decide on alert levels. This study investigated the effect of VALS design on stakeholder interaction at the Eastern Caribbean science-management interface and describes how the alert level system influenced risk management decision-making and public preparedness during the 2020 – 2021 eruption at La Soufrière volcano, St. Vincent and the Grenadines. National focus groups conducted with stakeholders in six Caribbean territories and interviews with key local stakeholders after the La Soufrière eruption allowed for detailed exploration of the current realities faced by regional scientists, government officials and relief agencies. Our findings indicate that a lack of accountability among VALS sub-systems can impact stakeholders' ability to reduce risk to vulnerable populations. Additionally, it was found that while the current VALS provided adequate guidance on actions for civil authorities, advice on personal preparatory and mitigation action at each stage of alert was not readily available. Here we present a stakeholder perspective on scientists' contributions to complex, socially driven early warning processes. We also highlight opportunities for the advancement of more inclusive disaster risk science in developing regions of the world routinely threatened by multiple hazards.

331

Synthesizing experiments and geochemistry to understand magma storage conditions: rhyolitic Rotoiti and Earthquake Flat Pyroclastics (Okataina Volcanic Center, New Zealand)

Ms Elizabeth Grant[1], Dr Dawnika L. Blatter[2], Dr Thomas W. Sisson[2], Dr Kari M. Cooper[1], Dr Darren M. Gravley[3], Dr Chad D. Deering[4], Dr Adam J.R. Kent[5]

[1]University Of California Davis, Davis, United States, [2]US Geological Survey, Menlo Park, United States , [3]University of Canterbury, Christchurch, New Zealand , [4]Michigan Technological University, Houghton, United States , [5]Oregon State University, Corvallis, United States

Understanding how crystal-rich bodies mobilize to eruption requires robust assessment of the crystal mushes themselves. The nature of crystal-rich bodies is revealed by determining mineral crystallization ages, magmatic compositional variations, and other intensive parameters. Further, these combined observations lead to more nuanced interpretations of how magma mushes evolve through time. We conducted H2O-saturated phase equilibrium experiments on the rhyolitic Earthquake Flat Pyroclastics (EQF) at fO2 = NNO and upper crustal pressures. The high crystallinity of the EQF Pyroclastics (40%) and the presence of large (>2mm) euhedral grains, as well as the lack of resorption and other disequilibrium textures suggest that the mush was crystallizing immediately prior to eruption. Our experimental determination that the erupted melt is co-saturated with quartz, plagioclase, and biotite at 140 MPa and 755 °C, strongly suggests those were the magma storage conditions immediately prior to eruption. These conditions would then require a rapid mobilization mechanism prior to eruption. We also present crystallization ages and trace element concentrations of zircon interiors and surfaces. EQF zircon average higher U concentrations, and lower Eu/Eu* values than zircon from adjacent, penecontemporaneous Rotoiti eruptives. This suggests that EQF zircon crystallized from more evolved melts, which had also experienced greater plagioclase fractionation than the Rotoiti magma body. The EQF zircon are also more diverse in some geochemical indices indicating they were more compositionally heterogeneous. Based on these observations, we propose that high crystallinity inhibits wholesale reservoir mixing and homogenization, such that individual zircons record local compositionally distinguishable melts.

742

Recording the time interval between twin caldera-forming eruptions during a geomagnetic excursion: a paleomagnetic study in the Taupō Volcanic Zone

Dr Darren McClurg Gravley[1], Dr Takeshi Hasegawa[2], Dr Nobutatsu Mochizuki[3], Dr Chie Kusu[2], Dr Makoto Okada[2]

[1]University of Canterbury, Christchurch, New Zealand, [2]Ibaraki University, Mito, Japan, [3]Kumamoto University, Kumamoto, Japan

Determining the duration of >VEI 7, un-witnessed caldera-forming eruptions remains elusive, with most estimates coming from qualitative geologic observations. We utilise a novel approach to quantify the paleomagnetic secular variation recorded in a tephra sequence that includes airfall units and two caldera-forming ignimbrites (Mamaku and Ohakuri) that were erupted ~240 ka and ~30 km apart. The lack of an intervening soil and minimal erosion led previous researchers to suggest only days to months elapsed between these two eruptions.

Non-welded, fine-grained samples from five tephra units were collected utilising a specifically-engineered apparatus to precisely guide a small cube into an outcrop and accurately measure the sample orientation. We also used more traditional oriented drilling for the welded Mamaku ignimbrite. Paleomagnetic directions were measured by spinner magnetometer with thermal or alternating current demagnetization, and uncertainties for mean paleomagnetic directions range from 2.5 – 10°. We report a series of interesting results: 1) the Mamaku ignimbrite paleomagnetic direction falls within a published geomagnetic excursion; however, the Ohakuri ignimbrite and airfall units also plot within this excursion, 2) because the changing rate of secular variation is assumed to be an order of magnitude faster during an excursion (0.1 to 0.2°/year), we estimate a time break of centuries between the caldera-forming eruptions, and 3) compared with a previous paleomagnetic study, the welded Mamaku mean direction correlates very well with the earliest pyroclastic flow material to be deposited, and it is possible that the entire thickness of Mamaku ignimbrite (>100 metres) may have been deposited over a period of one century. Despite not resolving time breaks down to years or less, conversely, from our data it is possible the Ohakuri-Mamaku eruptions were much longer than days to months apart. We are encouraged by our findings and the possibility of refining timescales for large caldera-forming eruptions.

738

Shallow conduit processes and volatile behaviour in the phreatomagmatic stages of the 1210-11 CE Younger Stampar eruption, SW-Iceland

Ms Jacqueline Grech Licari[1], Dr William M. Moreland[1], Prof. Thor Thordarson[1], Assoc. Prof. Enikö Bali[1], Prof. Bruce F. Houghton[2]
[1]*Faculty of Earth Sciences, University Of Iceland, Reykjavík, Iceland,* [2]*Department of Earth Sciences, SOEST, University of Hawai'i at Manoa, Honolulu, USA*

The 1210-11 Younger Stampar eruption opened the 1210-1238 Reykjanes Fires with an offshore Surtseyan eruption that constructed the ≃0.006 km³ Vatnsfell tuff cone, featuring a short-lived, dry final phase. A second offshore phreatomagmatic stage produced the ≃0.044 km³ Karl tuff cone. Later, activity migrated onshore onto a 4 km-long fissure with an effusive eruption that generated the Yngri-Stampar crater row and lava flow fields. Vatnsfell and Karl cones are tholeiitic basalt deposits and comprise alternating dilute pyroclastic density current (d-PDC) and tephra fall units, intercalated with units from simultaneous deposition by d-PDC and fall. Chemical analysis reveals that both cones contain olivine phenocrysts (Fo80-83), and oscillatory-zoned feldspar macrocrysts, with core and rim compositions of An88-91 and An75-79, respectively. Three groups of plagioclase- and olivine-hosted melt inclusions were identified, indicating that erupting magma originated from a deeper, crystal-mush-dominated storage zone. Original and residual sulfur contents of ≃1430 ± 15 ppm and ≃430 ± 15 ppm per stage, indicate that a total of ≃1.16 ± 0.03 Tg of SO_2 were released into the atmosphere during the two stages. This corresponds to ≃66% of degassing at the vents. Vesicularity measurements reveal unimodal, left-skewed distributions with modes of 90% and 95% for Vatnsfell and Karl cones, respectively. Analysed juvenile clasts contain sharp-bound domains of contrasting vesicularity, with boundaries oblique to clast margins. This suggests early mingling of melt batches with different histories of ascent/stalling in the shallow conduit. Regions of contrasting vesicularity were analysed separately to create two vesicle size and number distribution datasets. Number densities for modal clasts ranged from 3460/mm³ to 10900/mm³. The evidence suggests that expansion of exsolved magmatic gases drove initial dry fragmentation even in the 1210-11 phreatomagmatic stages, whereas external water was responsible only for secondary quench granulation. Additional micro-textural and geochemical results shall also be presented.

1285

Lower crustal earthquakes reveal the trans-crustal magma plumbing systems of Icelandic volcanoes (II): temporal evolution & magnitude distributions

Dr Tim Greenfield[1], Dr Tom Winder[1]
[1]*University Of Cambridge, Cambridge, United Kingdom*

A new earthquake catalogue has found lower crustal earthquakes to be present beneath all the currently active central volcanoes in central Iceland. These earthquakes (which span 6 – 40 km depth) occur in a region where the crust should be ductile and no brittle failure should occur. In this study (and in a companion presentation – Winder & Greenfield – same session) we present the temporal evolution and magnitude distributions of these deep earthquake clusters; identifying persistently active clusters which exhibit hours- to days-long swarms as well as swarms associated with eruptions or intrusions. Many of these events have a lower frequency content than their upper-crustal cousins and can be classified as deep long-period (DLP) events, although importantly some swarms exhibit more "normal" frequency content.

We identify exceptionally intense swarm episodes punctuating background activity in some lower crustal clusters, while others show relatively stable, low rates of seismicity over more than 15 years. During some swarms, the event waveforms remain identical other than their amplitude, which appears to scale with inter-event time. However, the magnitude distributions appear truncated, possibly reflecting a spatial constraint on the region available for brittle failure. Other clusters, including those with more "normal" frequency content, have more usual magnitude-frequency distributions.

These observations clearly reflect a diversity of processes driving seismicity in the lower crust. We take a systematic look at potential mechanisms which might explain these enigmatic earthquakes, and how they can be used to illuminate the magmatic plumbing system within the Icelandic crust.

881

Deep long period earthquakes beneath Fagradalsfjall, Iceland reveal the magma plumbing system through the lower crust

Dr Tim Greenfield[1], Dr Tom Winder[1], Prof Nicholas Rawlinson[1], Prof John Maclennan[1], Prof Robert S White[1], Dr Thorbjörg Ágústsdóttir[2], Dr Conor A Bacon[3], Prof Bryndís Brandsdóttir[4], Dr Eva P S Eibl[5], Ms Esme Glastonbury-Southern[1], Dr Egill Árni Gudnason[2], Dr Gylfi Páll Hersir[2], Prof Josef Horálek[6]
[1]University Of Cambridge, Cambridge, United Kingdom, [2]Iceland Geosurvey, Reykjavik, Iceland, [3]Columbia University, New York, USA, [4]University of Iceland, Reykjavik, Iceland, [5]University of Potsdam, Potsdam, Germany, [6]Institute of Geophysics, Prague, Czech Republic

Deep long period earthquakes (DLPs) are enigmatic seismicity detected beneath some volcanoes around the world. Using a dense network of seismometers on the Reykjanes Peninsula, Iceland, we detect a cluster of these DLPs close to the location of the 2021 Fagradalsfjall eruption site within the lower crust (i.e., below the brittle ductile transition) and 5 km shallower than available petrological estimates of where the Fagradalsfjall lava was stored. The DLP seismicity occurs within swarms starting from March 2020. No DLP earthquakes are detected beneath Fagradalsfjall in the previous 7 years. DLP swarms continue until the onset of the dyke intrusion, three weeks before the eventual eruption, although the high seismicity during the dyke intrusion may have masked the small signals from DLPs in the lower crust. During the eruption, DLP earthquake swarms returned 1 km southwest of their original location during periods when the nature of the eruption changed. The DLP seismicity is therefore likely to be linked to the magma plumbing system beneath Fagradalsfjall. We suggest that the DLP seismicity was triggered by the exsolution of CO_2-rich fluids or the movement of magma at a barrier to the transport of melt in the lower crust. Increased flux through the magma plumbing system during the eruption likely adds to the complexity of the melt migration process, thus causing further DLP seismicity, despite a contemporaneous magma channel extending to the surface. Finally, we use the data recorded between August 2021 and August 2022 to investigate the link between DLP seismicity, the end of the 2021 eruption and the subsequent 2022 dyke intrusion and eruption.

465

Forecasting volcanic unrest and eruption potential through thermomechanical modeling and geodetic data assimilation

Dr Patricia Gregg[1], Dr. Yan Zhan[2], Dr. John Albright[1], Dr. Matthew Head[1]
[1]University of Illinois at Urbana-champaign, Urbana, United States, [2]Chinese University of Hong Kong, Hong Kong, Honk Kong (SAR)

Combining multiphysics numerical models with observations of volcanic unrest using robust statistical data assimilation is critical for evaluating the evolution of magma systems, their potential for eruption, and eruption triggering mechanisms. In particular, thermomechanical finite element method (FEM) models provide estimates of the magma system stress evolution and stability through time, while data assimilation provides a statistical framework for assessing model results and forecasts. Here we present recent advancements in using statistical data assimilation to link geophysical observations of ground deformation and seismicity with thermomechanical FEMs to provide forecasts of magma chamber evolution and stability. We illustrate how the Ensemble Kalman Filter (EnKF) has been adapted to assimilate geodetic observations of surface deformation into multiphysics FEMs and track the evolution of stress in volcanic systems. Stability and eruption potential is evaluated using model estimates of magma reservoir overpressure, tensile stress and failure along the calculated magma reservoir boundary, and Mohr-Coulomb failure in the host rock. We discuss recent successes implementing the approach to hindcast the 2008 eruption of Okmok Volcano, Alaska (Albright et al., GRL, 2019), and forecast the 2018 eruption of Sierra Negra Volcano, Galápagos (Gregg et al., Sci. Adv., 2022) as well as applications at other active volcanoes. We find that the EnKF approach not only provides a robust framework for evaluating near-real time volcanic unrest, it also allows for investigating historical eruptions via hindcasts to determine precursors and triggering mechanism. Our findings demonstrate the potential for utilizing the EnKF – FEM approach to investigate eruption potential and triggering mechanisms at restless volcanoes worldwide.

586

Incremental development of a voluminous, stratified rhyolite: Evidence from post-collapse volcanism at Valles Caldera

Magdalen Grismer[1], Dr. Laura E. Waters
[1]*New Mexico Institute Of Mining And Technology, Socorro, United States*

Valles Caldera (VC) is a resurgent caldera system that has sourced voluminous, explosive (Bandelier Tuff) and smaller, effusive (post-collapse) eruptions of rhyolite, offering an opportunity to compare petrogenesis in caldera cycles. We present a petrologic study of the post-collapse rhyolites, including high-silica (HSR) and low-silica rhyolites (LSR) that erupted from 1,200-69.3ka, to understand the evolution of the VC magmatic system since the eruption of the Upper Bandelier Tuff (UBT). Through application of models to minerals in the rhyolites, the pre-eruptive temperatures, fO_2, and H_2O contents range from 728-826°C, –0.4 to +1.4 ΔNNO, and 4.4-6.2wt% respectively. Minimum storage pressures (PH_2O) are 90-210 MPa. The post-collapse rhyolites with eruptive ages ≤1Ma have lower temperatures, are more oxidized and hydrous than most of the UBT, and have a trend of increased eruptive temperatures, oxidation states and a decrease in PH_2O values with age and geographic location.

The storage conditions, whole rock and isotopic compositions, and erupted volumes of the rhyolites all covary, suggesting a relationship between the post-collapse rhyolites, which can be explained by two methods of petrogenesis. (1) The rhyolites originate from the same source, which becomes more refractory through time as HSRs are extracted, where biotite and chevkinite melting influence $^{87}Sr/^{86}Sr_i$ and $^{143}Nd/^{144}Nd$ patterns respectively. (2) There is a change in source lithology from the east to the west side of the caldera, where biotite and chevkinite still influence the radiogenic isotopes, but a change in the underlying lithology that is subject to melting beneath VC explains the geographic locations of HSRs and LSRs. The past ~1.2 Ma of post-collapse volcanism could have produced up to 380km³ of rhyolite in the plutonic record, which would share the same geochemical characteristics as their erupted components, representing a rhyolitic body stratified in whole rock and isotopic composition and fO_2 from east to west.

1110

Morphometry of lava domes from the Central Andes: quantifying the impacts of growth and degradation on lava dome shape

Dr Pablo Grosse[1], Dr. Gabriel Ureta[2], Dr. Daniel O'Hara[3], Dr. Matthieu Kervyn[3]
[1]CONICET and Fundación Miguel Lillo, San Miguel De Tucumán, Argentina, [2]Millennium Institute on Volcanic Risk Research - Ckelar Volcanoes, Universidad Católica del Norte, Antofagasta, Chile, [3]Department of Geography, Vrije Universiteit Brussel, Brussels, Belgium

Lava domes are common landforms in continental volcanic arcs. They can be spatially and genetically related to larger stratovolcanoes or collapse calderas, part of monogenetic fields, or found as individual, isolated edifices. The morphology and growth of lavas domes has been investigated with analogue experiments and numerical modelling, but few studies have focused on quantifying their shapes in nature. Here we analyze the morphometry of ~100 lava domes from the Central Volcanic Zone of the Andes, an arid region that contains hundreds of well-preserved domes with ages spanning from Miocene to Recent. Morphometric parameters are computed using TanDEM-X 12 m DEMs and applying an expanded version of the MorVolc algorithm. We investigate two sets of lava domes: (1) Late Pleistocene-Holocene pristine domes with variable morphologies that reflect different growth processes; and (2) Miocene to Recent simple, variably-degraded domes that reflect erosional processes with time.

Recent lava domes can be classified into three types: (1) simple domes with one stable vent and one main effusive phase, which can be subdivided into flat-topped (or torta), intermediate and pointy; (2) complex, irregular domes with one relatively stable vent but several overlapping effusive phases; and (3) multiple, irregular, often elongated domes with several vents. These morphometric types only partially correlate with existing typologies based on experimental studies. Comparisons between the morphometry of natural lava domes and theoretical/experimental models allow inferring some of the factors controlling their shapes, such as effusion rate and yield strength.

Simple, variably-eroded lava domes have morphometric parameters such as flank slope, roughness, irregularity, drainage density and intensity of the slope-breaks along their basal outlines that show different degrees of correlation with age. Further analysis of these parameters allow estimating dome age based on morphometry and infer a degradation model for this type of landform in arid climates.

1114

Quantifying the degradation of composite volcanoes in arid climates: morphometric analysis of Miocene to Recent volcanoes from the Central Andes

María Luisa Ochi Ramacciotti[1], Dr. Pablo Grosse[1], Roos M. J. van Wees[2], Dr. Daniel O'Hara[2], Dr. Matthieu Kervyn[2]

[1]CONICET and Fundación Miguel Lillo, San Miguel De Tucumán, Argentina, [2]Department of Geography, Vrije Universiteit Brussel, Brussels, Belgium

The morphology of composite volcanoes is controlled by the interplay of aggradational and degradational processes. Once a volcano becomes extinct, erosion becomes the dominant shape-modifying process, gradually degrading the edifice. The type and intensity of erosion with time depends on the initial or pristine edifice morphology, its lithology and climate. Morphometric analyses allow quantifying volcano morphologies and their degradational patterns, and infer the controlling factors. Here we analyze the morphometry of ~100 composite volcanoes from the arid Central Volcanic Zone of the Andes, using the TanDEM-X 12 m spatial resolution digital elevation models and applying an expanded version of the MorVolc algorithm. The selected volcanoes have relatively simple, conical morphologies, and andesitic-dacitic lava-dominated compositions. About half of the analyzed volcanoes have radiometric age constraints between 20 and < 1 Ma, whereas the other half only possess rough relative age estimates. We compute a set of morphometric parameters that quantify the morphology of the edifices, including shape (e.g., ellipticity, irregularity) and slope parameters. We also apply a qualitative ranking that considers the degree of preservation of craters and lava flows, as well as gully density and amount of incision. Several parameters show different degrees of correlation with age, suggesting that they are susceptible to erosional processes and hence can be used to infer patterns and intensity of degradation and to estimate the ages of un-dated volcanoes. Analysis of these parameters as a function of volcano age allows to establish a preliminary quantitative evolutionary model of volcano degradation for andesitic-dacitic composite volcanoes in arid climatic regions.

1206

Deep magmatic sources feeding eruptions from Red Crater, Tongariro

Miss Kerstin Gruender[1], Dr Simon Barker[1], Dr Michael Rowe[1], Dr Esteban Gazel[1]
[1]*Victoria University Of Wellington, Wellington, New Zealand*

Andesite volcanoes are characteristic features of subduction zones that are ultimately driven and sustained by magma recharge from the mantle. However, crustal magmatic systems are complex and primitive magma compositions are mostly overprinted by mixing processes before eruption, obscuring signatures of deeper crustal levels and the mantle. Geochemical analysis of crystal cargoes of erupted magmas, especially early-formed minerals like olivine, can provide insights into deep magmatic processes. Tongariro is a large composite andesite volcano located in one of New Zealand's most volcanically active areas at the southern end of the Taupo Volcanic Zone (TVZ). We present new data on the magmatic driving force behind young (<1.8 ka) eruptions from Red Crater, one of Tongariro's currently active vents that last erupted in the early 1900s. Sampled basaltic andesite scoria contains rapidly quenched primitive olivine (Fo85-90) with abundant glassy melt inclusions which we have analysed for major, volatile and trace element concentrations. We identify at least three olivine and two melt inclusion populations, with compositions that are amongst the most primitive melts reported in the TVZ. Our initial interpretation supports the pre-eruptive recharge of primitive Mg-rich magma from a deep mantle source, interaction with at least one mid-lower crustal magma reservoir, followed by rapid ascent and eruption, as recorded by crystal and melt inclusion populations, mineral textures and zoning. This research provides insights into Tongariro's deeper volcanic magma system and will help to improve our knowledge about magma sources feeding eruptions in this area and contribute to our general understanding of andesite petrogenesis at continental subduction zones.

841

Explosive and effusive silicic volcanism leading to opening of the South Atlantic: Evidence from the Paraná Large Igneous Province, Brazil

Guilherme Gualda[1], Lydia J. Harmon[1,2], Darren M. Gravley[3], Edenilson do Nascimento[4]
[1]Vanderbilt University, Nashville, United States, [2]Arizona State University, Tempe, United States, [3]University of Canterbury, Christchurch, New Zealand, [4]Universidade Federal do Paraná, Curitiba, Brazil

Following copious basaltic volcanism within the Paraná LIP, magma compositions shifted abruptly, leading to extensive deposits of silicic rocks. Studies in Africa have suggested primarily pyroclastic deposition, while rocks in Brazil have been interpreted as resulting from extensive effusive volcanism. Poor exposures and extensive welding and alteration in Brazilian rocks obfuscate original features. We aim to better document the geological evolution of Paraná silicic volcanism using cliff-forming and surface exposures near the Serra do Mar escarpment in Southern Brazil.

We characterize in detail the surface rocks and surface morphology in the vicinity of the escarpment. We access the first 100-150 m of the cliffs using ropes and rappelling techniques and high-resolution drone imaging to characterize the geological evolution exposed along the escarpment.

In some areas, surface morphology is characterized by rolling hills, and localized ramp-like features that indicate inclined flow morphologies. Cross sections reveal units that pinch and swell, and imbricated units that suggest onlap of lava flows on pre-existing units – such morphologies are indicative of effusive volcanism. In other areas, units are tabular, flat-topped, and they extend for several to tens of kilometres, suggesting infilling of any pre-existing topographic irregularities - such features are suggestive of explosive volcanism. Onset of silicic volcanism is characterized by 3-4 effusive units, followed by a distinctive explosive unit characterized by blob-like pyroclasts, capped by another lava flow unit. Effusive domes are exposed at the top surface, from which lobe-like lava flows emanate. The last volcanic manifestations are obsidian dikes and domes, whose compositions suggest they are fed by different magma bodies than those that fed previous units.

Our study opens the door for proper assessment of the volumes of individual units, and it helps elucidate the magmatic evolution leading to continental breakup at the nascent stages of the Southern Atlantic Ocean.

839

The Rhyolite Factory: Integrating plutonic and volcanic perspectives using rhyolite-MELTS

Guilherme Gualda[1], Calvin F. Miller[1], Blake W. Wallrich[1]
[1]*Vanderbilt University, Nashville, United States*

The largest and most devastating eruptions on Earth involve rhyolite, making it important to understand the architecture of the silicic portions of magmatic systems. While it is commonly accepted that magmatic systems span much of the crust, little direct evidence is available for the vertical continuity of such systems. We focus on Miocene plutonic and volcanic units from the Colorado River Extensional Corridor (Southern Nevada, USA).

Studied plutons consist primarily of coarse-grained granitoids rich in feldspar that can be credibly considered cumulates. However, plutons include fine-grained marginal facies and dikes, as well as leucogranite units, that have been interpreted to record melt compositions. Volcanic units record compositions extracted from these magmatic systems.

We use whole-rock compositions to calculate extraction pressures, and glass compositions in volcanic rocks to calculate storage pressures using rhyolite-MELTS. We seek pressures consistent with an assemblage containing quartz+2 feldspars±magnetite±ilmenite.

Our dataset reveals 3 main clusters of compositions and pressures: 72.5-74.5 wt% SiO_2, 440-370 MPa (Q2F extraction); 75.9-77.3 wt% SiO_2, 250-190 MPa (Q2FMI extraction and storage); 77.4-77.9 wt% SiO_2, 160-120 MPa (Q2FMI extraction and storage). Compositions attributed to cumulates do not yield extraction pressures, suggesting that rhyolite-MELTS can weed out cumulatic compositions.

We infer the distribution of magma in a magmatic column spanning from the middle crust to the surface. Our data show well defined gaps in pressure between the three groups: a magma mush was located in the middle crust (~400 MPa, ~15 km depth), from which magmas that fed the studied plutons were derived. Remaining extraction pressures reveal two mush magma zones from which eruptible magma fed eruptions to the surface. The leucogranite corresponds to eruptible magma that failed to erupt. We conclude that magma distribution is vertically discretized – i.e., magma accumulates in specific horizons, while much of the crust remains melt-free.

652

Early stages of volcanic activity at Hekla volcano, Iceland

Professor Esther Ruth Gudmundsdottir[1], Bergrún Arna Óladóttir[1,2], Olgeir Sigmarsson[1,3], Gudrún Larsen[1]
[1]Institute of Earth Sciences, University of Iceland, Reykjavik, Iceland, [2]Icelandic Meteorological Office, Reykjavík, Iceland, [3]Laboratoire Magmas et Volcans, CNRS and Université Clermont Auvernge, Clermont-Ferrand, France

Mount Hekla is the most active and prominent volcano in Iceland producing silicic tephra. The history of the Hekla volcano is often considered to have begun with its first large silicic eruption forming the Hekla-5 tephra layer, approximately 7100 years ago. To further understand the early activity of the Hekla volcano over 320 tephra units have been sampled from eight soil sections around the volcano, and over 280 analyzed for major element composition. In these soil section sequences up to 50 tephra layers have been identified beneath the Hekla-5 tephra, most with Hekla, Vatnafjöll and Katla affinity. The early Hekla tephra layers include both primitive and evolved basalt and a few basaltic andesites. The basaltic tephra demonstrate that the early activity of Hekla was characterized by mafic volcanism before the production of silicic magma. This concurs with the basement of hyaloclastite formations of relatively primitive basalt composition up on which the volcano has been constructed and early Holocene effusive activity of the Hekla volcanic system. After the Hekla-5 eruption the production of intermediate magma increased, resulting in at least two large tephra layers (H-DH and H-Ö, about 6700 and 6100 years old respectively) both with a significant basaltic component. This phase ended with the Plinian Hekla-4 eruption 4200 years ago. The tephra stratigraphy obtained in the project will improve the regional tephrochronology of southern Iceland.

1314

Volcano-ice interaction: Empirical evidence of the rate and style of ice melting in recent eruptions in Iceland

Professor Magnús Gudmundsson[1], Thórdís Högnadóttir[1], Eyjólfur Magnússon[1], Hannah I. Reynolds[1], Gudrún Larsen[1], Finnur Pálsson[1]
[1]*Institute of Earth Sciences, University of Iceland, Reykjavik, Iceland*

Since the second decade of the 20th century, the record of volcanic eruptions in Iceland is reasonably complete, as it includes minor eruptions in remote, glacier covered areas. The average interval between eruptions in this period is three years. About 10% of Iceland is ice covered, with some of the most active volcanoes located within glaciers. Including 1918, 13 eruptions have occurred with significant volcano-ice interaction. The period since 1996 has been particularly active, with six confirmed eruptions within glaciers, all of which displayed intense ice melting in the initial phase. Since 1996, all eruptions have been monitored with contemporary observations from the air, involving surveying of developing ice cauldrons and other effects on the glaciers. As a result, considerable empirical data exists on all these events. Some observational data also constrains ice melting that occurred in the eruption of Katla in 1918. The dominant style of melting in all but two of the 13 eruptions since 1918 was subglacial heat release with magma fragmentation being the dominant style of subglacial activity. In the 11 eruptions with initial subglacial phase, the volume of subglacially-erupted material varied from ~0.001 to 0.45 km3 (DRE), compositions ranged from basalt to trachyandesite, initial ice thickness from ~100 m to 750 m and the volume of ice melted ranged from 0.01 km3 to 4 km3. The resulting penetration rates of the ice overlying the vents ranged from a few tens of meters per hour to over 100 m/hour. In two cases (Hekla 1947 and 1980), melting was mainly supraglacial, caused by pyroclastic flows. Some eruptions caused major jökulhlaups. However, the link between flooding and eruptions is not always simple. It depends on the hydrological conditions such as subglacial storage potential in pre-existing subglacial lakes, as has been the case for Grímsvötn.

778

Magnitude analysis of the Canary Islands volcanoes through Energy based Probability Density Functions (E-PDFs)

Miss Alejandra Guerrero[1], Professor Arnau Folch[1], Professor Joan Martí[1]
[1]*Geoscience Barcelona. Csic, Barcelona, Spain*

The characterisation of the past behavior of a volcanic system (e.g. eruption magnitude, recurrence, location, etc.) is a necessary first step in volcanic hazard assessment and evaluation of related uncertainties of future events. These records are obtained in different ways: field-based geological studies, in case of ancient and preserved deposits, historical observations, for more recent events, or multi parametric geophysical monitoring, which provides in situ eruption information. The multiplicity of data sources yields to heterogeneous information from the past, not only in the number of the events and their characteristics but also in the completeness of records across the timeline. Additionally, the reconstruction of past events based on the actual ranking of explosivity, becomes challenging in volcanoes considered effusive. The current classification of the eruptions links volumes and column height in a proportional-incremental relation, which means, if volume increases, the column height escalates as well. Additionally, the size of the plume height could be linked to more than one classification, diffusing the clear frontier between effusive-dominated or explosive-dominated events. The Canary Islands volcanoes are examples of environments where the big volumes of ejected material are not always associated with big ash plumes. A study based on the eruption energy balance and partition and the use of volcano analogues to complement record gaps can provide an alternative approach in volcanic settings displaying combined effusive and explosive events. The energy balance and partition can be converted into energy-based Probability Density Functions (EPDFs). Likewise, the EPDFs are capable of being fragmented into energy released by different volcano products. In the case of volcanoes with limited historical record, such as Canary Islands (Tenerife, La Palma, El Hierro, Lanzarote), the EPDF of one or many analogue volcanoes can be used and adjusted to describe the volcano's expected behavior.

1274

Long term volcano tectonics of Mt. Etna from twenty-five years of SAR interferometry

Dr Francesco Guglielmino[1], Dr Alessandro Bonforte[1], Dr Giuseppe Puglisi[1]
[1]*INGV - Istituto Nazionale di Geofisica e Vulcanologia - Sezione di Catania, Osservatorio Etneo, Catania, Italy*

Mt. Etna was one of the first volcanoes in which SAR was used for structural studies (Borgia et al., 2000; Bonforte et al, 2011). Particularly fruitful for the structural studies are the techniques based on the interferometric analysis of time series of SAR passes for two main reasons: fist, because the time series analysis allows reducing or removing the most common atmospheric or geometric artefacts in the SAR interferometric images and second, because long lasting subtle deformations along faults are optimally defined (Ferretti et al, 2001; Lanari et al., 2007). In this presentation, the results of twenty-five years of interferometric SAR analysis on Mt. Etna are presented and discussed to update the earlier studies. This study allows to accurately detail the geometry and dynamics of the active faults and to propose interpretations about the link between magmatic activity, local and regional tectonics.

References

Bonforte, A., Guglielmino, F., Coltelli, M., Ferretti, A., & G. Puglisi (2011): Structural assessment of Mount Etna volcano from Permanent Scatterers analysis, Geochem. Geophys. Geosyst., 12, Q02002, doi:10.1029/2010GC003213.
Borgia A., Lanari R., Sansosti E., Tesauro M., Berardino P., Fornaro G., Neri M., Murray J.B. (2000): Actively growing anticline beneath Catania from the distal motion of Mount Etna's decollement measured by SAR interferometry and GPS. Geoph. Res. Lett., vol 27. 3409-3412
Ferretti, A., Prati, C., & Rocca, F. (2001): Permanent scatterers in SAR interferometry, IEEE Trans. Geosci. Remote Sens., 39, 8 – 20, doi:10.1109/36.898661.
Lanari, R., Casu, F., Manzo, M., Zeni, G., Berardino, P., Manunta, M., Pepe, A. (2007): An overview of the small baseline subset algorithm: A DInSAR technique for surface deformation analysis. In Deformation and Gravity Change: Indicators of Isostasy, Tectonics, Volcanism, and Climate Change; Birkhäuser: Basel, Switzerland; pp. 637–661.

291

Monitoring volcanic carbon dioxide flux by remote sensing of vegetation on Mt. Etna

Nicole Guinn[1], Craig Glennie[1], Marco Liuzzo[2], Jennifer Lewicki[3], Giuseppe Salerno[2]
[1]University Of Houston, Houston, United States, [2]Instito Nazionale di Geofisica e Vulcanologia Sez. Palermo, Palermo, Italy, [3]U.S. Geological Survey California Volcano Observatory, Moffett Field, United States

Carbon dioxide is one of the most abundant volcanic gases, and changes in its emissions can act as a precursor to volcanic activity; however, volcanic CO2 is difficult to differentiate from atmospheric sources through remote sensing. CO2 exsolved from magma can migrate into the soil and atmosphere on volcano flanks and can impact the health of vegetation. This study investigates the beneficial impacts of diffuse CO2 degassing by fertilization of plants and the potential for changes in vegetation health to act as a proxy for the diffuse CO2 degassing signal. Vegetation health was quantified through normalized difference vegetation index (NDVI) using platforms such as Landsat 8, MODIS, Sentinel-2, and VIIRS with Google Earth Engine.

Mt. Etna has one of the highest rates of volcanic degassing in the world. Monitoring includes the EtnaGas network, which is comprised of 14 automatic stations that continuously measure soil CO2 flux, temperature, pressure, humidity, rain, wind speed and direction. The stations were installed in 2002 near volcanic structures with strong CO2 emissions. We compared timeseries of soil CO2 and the NDVI signal of vegetation within a 1000 m radius of each station. Both NDVI and soil CO2 flux were normalized to filter out seasonal and environmental factors. Over a 2-year period, the soil CO2 flux peaked 156 ± 50 days before NDVI on the first peak and 142 ± 37 days for the second peak. These offsets may be related to soil and atmospheric exchanges of degassed CO2, and it provides a proof of concept that changes in CO2 emissions can be associated with changes in vegetation health. Additional work includes minimizing the radius around each EtnaGas station, looking for patterns in plant health with distance from the CO2 degassing areas and associated with prevailing wind direction, and expanding the time period of analysis.

1370

Geological Hazard Mitigation Portal of Indonesia

Mr Hendra Gunawan[1], Mr Hery Kuswandarto[1], Dr Hendra Gunawan[1], Mr Ahmad Barnes[1]
[1]*Center for Volcanology and Geological Hazard Mitigation (CVGHM), Geological Agency, Ministry of Energy and Mineral Resources, Bandung, Indonesia*

Located along the "Pacific Ring of Fire", Indonesia faces high seismic, tsunami, landslide and volcanic risk. As the government-mandated agency to perform geological hazard mitigation, CVGHM has duty to do monitoring, evaluating, reporting, mapping, perform analysis and providing technical recommendations of geological hazards in Indonesia. We continuously strategizing and establishing an efficient and optimal infrastructure and data management system to improve mitigation that allow contingency planning, effective emergency preparedness, timely assessment, warning and action during crisis. Multi-hazard disaster mitigation action requires functioning disaster mitigation information systems that can provide reliable and timely data, statistics and analysis. For this reason, we created geological hazard mitigation portal, an open access interactive graphical user interface allowing users to search and download various geological hazard maps (earthquake, tsunami, landslide, volcanic), volcano geological maps and and rain-induced landslide susceptibility maps. This map can be visualize interactively based on area of interest following administrative boundary and kept up-to-date with the most recent recommendation. Given that we are also dealing with large amounts of volcano monitoring data that are complex and of various types and formats, a robust and efficient data management platform is crucial for CVGHM. We are using PostgreSQL, an open-source relational database management system emphasizing extensibility to GIS-based data type and SQL compliance. To make an efficient data archiving, we developed a system that able to automatically input low-rate processed data into the database. This system also allows data display in near real-time through web application. All of these efforts aimed for quick assessment, timely evaluation, and better decision to provide early warning to the community.

1353

The catastrophic explosive event of Semeru volcano, Indonesia

Dr Hendra Gunawan[1], Mr Oktory Prambada[1], Dr. M. Nugraha Kartadinata[1], Mr Ahmad Basuki[1]
[1]*Center for Volcanology and Geological Hazard Mitigation (CVGHM), Geological Agency, Ministry of Energy and Mineral Resources, Bandung, Indonesia*

Semeru has been the most active volcano in Java manifested by periods of intermittent explosion and lava effusion occurred at the summit crater. This eruption episode took place continuously for years without ceasing. Semeru presented a wide range of eruptive style, e.g. fissure eruption in 1941 and large explosive lava dome failure that had been reported in its eruptive history. The 4 December 2021 explosive eruption at Semeru volcano, producing 16km PDC and syn-eruptive lahars that took 58 lives of local peoples and sand miners, destroyed settlements area and public infrastructures along the Besuk Kobokan river channel at the southeastern flank. This was the first monitored explosive eruption of Semeru that produced partial column collapse PDC, its deposit characterized a more energetic PDC compare to the usual gravitational cone collapse. Another catastrophic event in the past occurred in April 1885, when the south crater wall collapsed southward producing 26M m3 PDC deposit. Semeru PDC events are not the only destructive hazards, lahar also posed catastrophic impacts that can extend farther and cover wider area. The most catastrophic hazard of Semeru was the rock avalanches that occurred during heavy rainfall in 1909 and 1981. In between the large explosive event, frequent small to moderate lava cone collapse due to the shallow overpressure produce PDC with maximum of 5km runout distance. We will focus to better understand the mechanism driven such catastrophic event that occurred less frequent but catastrophic that is important for future hazard mitigation, optimising monitoring infrastructure capable to detect anomalous behavior leading to significant events, advise stakeholders on optimizing land use planning in the proximal hazard area, and together with local community and civil authorities to better prepare of all range of possible hazard scenarios of Semeru and for better management and response during crisis.

1337

Anatomy of a submarine past volcanic explosion east Mayotte: quantification of primary fragmentation

Professor Lucia Gurioli[1], Professor Jean-Christophe Komorowski[2], Dr Carole Berthod[2,3], Dr Etienne Medard[1], Mr Tristan Lacombe[1], Mrs Pauline Verdurme[1], Mrs Valentine Puzenat[2], Professor Patrick Bachèlery[1], Dr Saptarshee Mitra[1], Dr Simon Falvard[1], Dr Raphael Paris[1], Dr Emmy Voyer[1], Professor Andrea Di Muro[4], Dr Besson Pascale[2], Dr Elodie Lebas[2], Dr Fabien Paquet[5], Dr Cecile Cathalot[6], Mr Sylvain Bermell-Fleury[6], Dr Carla Scalabrin[6], Dr Emmanuel Rinnert[6], Professor Nathalie Feuillet[2], Dr Isabelle Thinon[5]

[1]Université Clermont Auvergne, CNRS, IRD, OPGC, Laboratoire Magmas et Volcans, 6 avenue Blaise Pascal, 63178 , Aubière, France, [2]Université Paris Cité, Institut de Physique du Globe de Paris, CNRS, F-75005, Paris, France, [3]Observatoire volcanologique et sismologique de la Guadeloupe, Institut de Physique du Globe de Paris, F-97113, Gourbeyre, France, [4]Laboratoire de Géologie de Lyon : Terre, Planètes, Environnement, CNRS, UMR 5276, Ecole Normale Supérieure de Lyon, Université de Lyon, Université Claude Bernard Lyon 1, Villeurbanne, Lyon, France, [5]BRGM, BP 36009, 45060 Cedex 2, Orléans, France, [6]IFREMER, Centre de Bretagne, –Unité Géosciences Marines, 1625 Rte de Ste Anne, 29280 , Plouzané, France

Contrary to subaerial counterparts, explosive submarine eruptions suffer from a critical lack of physical understanding. We show that magmatic primary fragmentation occurred at more than 1350 meters under sea level within the Horseshoe volcanic structure located 10 km far from the Mayotte Island eastern coast. The limited dispersion of deposits, dominated by lapilli-sized fragments with scattered breadcrust bombs and blocks (as imaged by in-situ video-cameras), the unimodal grain-size distribution of the matrix (sampled by dredges and multi-tube corer), and the coexistence of vesicular and dense juveniles phonolite fragments, indicate an emplacement process by gas-decompression–driven jets immediately above the vent, similar to subaerial vulcanian and/or dome-driven explosions. Transition from tubular pumice, with elongated vesicles (up to 60 % in vol.), to dense fragments with more rounded, sparse vesicles (up to 20 % in vol.), indicate high ascent rates in a conduit dominated by a parabolic profile typical of subaerial eruptions. The pervasive bimodal vesicle size distribution in all clast types, their relatively high-number density (X-ray tomography), the presence of fine ash and the increase of the juvenile fraction in the fine matrix, are indicative of a magmatic/phreatomagmatic primary fragmentation. The Horseshoe edifice is strongly linked with the 2018-2021 seismo-volcanic crisis that produced the new Fani Maoré volcano. The area is characterized by an expanding field of active submarine CO_2-rich fluid emissions, and lies exactly above the main, 30 km-deep, cluster of ongoing seismicity and the region where active magmatic reservoir is inferred. Intense past volcanic activity affected this area with > 100 volcanic cones of explosive and effusive origin. The implications of this work are paramount for understanding explosive submarine volcanism and underscore the need for continuing to expand multiparameter monitoring of this active area where resumption of volcanic activity could lead to new explosive eruptions and / or caldera collapse.

280

Characteristics and origins of erupted volcanic ash particles: Insights from maar complex deposits at Lamongan Volcanic Field, East Java, Indonesia

Mr Andriansyah Gurusinga[1], Prof. Tsukasa Ohba[1]
[1]*Akita University, Akita, Japan*

The eruptions of maar complex at Lamongan Volcanic Field (LVF) in East Java, Indonesia produced several distinct of ash particles: primary ash (black non-vesicular [bnv]; black vesicular [bv]; pale-brown [pb]; and clear-brown [cb]) and accessory ash (orange-brown [ob], free crystal [fc], and altered ash [alt]). All types of ash were found on the outcrops; however, we excluded fc and alt particles from determining the origin of the ash particles. Primary ash is typically equant to sub-equant in shape, sub-angular (bv+bnv) to sub-rounded in outlines (cb+pb), incipient to poor in vesicularity, relatively smooth bubbles (bv+bnv), and irregular bubbles (cb+pb). In contrast, accessory ash (ob) has an irregular shape, characterized by rugged outlines, smooth bubble shape, and poorly vesicular. The black and brown particles were crystal-rich (18-63 %) with similar mineralogy (pl+px+opq±ol). In contrast, orange particles were crystal-poor (<15 %) with pl+opq minerals. Their chemical composition ranges from picrobasaltic to basaltic andesitic at 41.40-52.93 wt.% SiO_2 and 0.25-1.63 wt.% K_2O. Our results suggest that heterogeneities in textures and morphologies of ash particles in the maar deposits are related to the variation of texture and magmatic properties during eruptions. The blocky black ash (bv+bnv) suggests that maar deposits were predominantly fragmented from relatively small (4-63 µm, bnv; 6-250 µm, bv) and rounded bubbles of high silica content magma (avg. 50.7 wt.%), whereas the slightly elongated brown ash (cb+pb) were fragmented from bigger and irregular bubbles of low silica content magma (avg. 47 wt.%), both are high crystallinity magma. However, the fluidal shape of orange ash (ob) was related to the rounded bubbles of low crystallinity magma with the highest silica content (avg. 52.6 wt.%). We also conclude that the crystal and bubble characteristics are closely relevant to the morphology and shape of ash particles regardless of eruption types rather than its magma composition.

311

Unusually fast and large tsunami generated by the 2022 Hunga Tonga – Hunga Ha'apai volcano eruption

Dr Aditya Gusman[1], Dr Jean Roger, Dr Chris Noble, Dr Xiaoming Wang, Dr William Power, Dr David Burbidge
[1]GNS Science, Lower Hutt, New Zealand, [2]Meteorological Service of New Zealand, Wellington, New Zealand

The Hunga Tonga – Hunga Ha'apai volcano eruption on 15 January 2022 generated a tsunami that was unusually fast and large, particularly at large distances from the source. Here we use an observation-calibrated air-wave model to simulate the tsunami generation process in a numerical model. We used pressure data observed at 94 stations in Niue, the Cook Islands, and New Zealand's main and outer islands to obtain a simple air-wave model. The modelled air-wave travels at an approximated constant speed of 317 m/s with an amplitude that decays proportional to the inverse square root of the distance from the volcano. We then simulated the generation and propagation of the tsunami due to the propagating air-wave in the atmosphere above the ocean. The leading sea surface displacement excited by the pressure disturbances travels at the same speed as the air-wave. This leading wave is then followed by subsequent water waves that travel in the same direction as the leading wave but at the conventional tsunami propagation speed (Figure 1). We found that the air-wave was more effective at generating tsunami-waves when it travelled over a deep bathymetric feature like the Kermadec-Tonga Trench. The tsunami amplitudes observed at gauges do not decay as rapidly with distance from the volcano as would be expected for a localized tsunami source. This is due to the continuous excitation of the tsunami as the air-wave propagates across the ocean. In shallow water, the leading water surface displacement can often be much smaller than the later waves that were most likely to have been generated in the deep ocean. A better understanding of the complexities of tsunami generation and propagation from sources of this type is important for improving tsunami disaster mitigation in future events.

921

Geological Insights into the Eruptive History of the World's Largest "Dirty" Geyser: Waimangu Geyser 1900-1904, Waimangu Volcanic Valley, New Zealand

Miss Annahlise Hall[1], Professor Shane Cronin[1]
[1]*The University Of Auckland, Auckland, New Zealand*

The Waimangu Volcanic Valley of the Taupo Volcanic Zone in New Zealand was activated following the 1886 Tarawera eruption. Among its first geothermal features was the 1900-1904 Waimangu Geyser. At the time, this was the world's largest geyser, producing atypically vigorous and unusually ash-rich eruptions, which make it unclear whether the activity represented geothermal or magmatic processes. Geyser deposits were examined alongside historical imagery to interpret the geyser's origins. A 2.5 m-thick sequence of poorly sorted geyser tuffs ~80 m NE of the geyser vent were identified stratigraphically above the 1886 Rotomahana mud. Twenty-one samples of tuff/lapilli-tuff beds were analysed for grain-size distribution and lithologic characteristics. XRD and SWIR spectroscopy revealed that clay minerals were dominated by mixed-layered illite-smectite, suggesting a formation at ~150-220°C within alkali chloride waters below the geyser site. A lack of fresh magma/glass suggests the eruptions were not phreatomagmatically induced. Grain-size results imply the geyser began vigorously, ejecting more coarser (>1 mm), mainly recycled 1886-derived particles. Contrarily later geyser activity ejected a greater proportion of finer (<1 mm) rhyolitic fragments from deeper horizons. Fining and lithological deposit changes demonstrate a deepening eruption locus and waning particle ejection energy through the geysers' lifetime. Geyser deposits and historical imagery express hybrid behaviour between hot spring "geysering" and intermittent small hydrothermal explosions, with the most violent explosions producing steam-rich pyroclastic surges. Hydrothermal eruptions were driven by ejecta fall-back and intermittent collapse of the surface crater walls and/or the subterranean hot-spring plumbing system. Each vent-blocking episode trapped heated meteoric waters that induced excess fluid overpressures. We propose a new category of hybrid geyser behaviour caused when a hot spring cannot maintain a stable plumbing system in thixotropic and/or unstable fine substrate sediments. Changes in vent structures within geothermal fields should be monitored for possible initiation of similar hazardous hybrid eruptions.

1382

Bubble interaction and evolution through a basaltic lava flow: insights from the Ahu'ailā'au lava field of the Kilauea 2018 eruption.

Ms Brenna Halverson[1], Dr. Alan Whittington[1], Dr. Julia Hammer[2]
[1]University Of Texas at San Antonio, San Antonio, United States, [2]University of Hawaii at Manoa, Honolulu, United States

Bubbles are an important factor in lava flow behavior, especially for the 2018 Kilauea eruption, which recorded maximum in-channel vesicularities of 82% (Patrick et al 2018). Here, we present a micro-CT analysis of bubbles, to evaluate their formation, evolution, and interaction through the Ahu'ailā'au flows of the 2018 Kilauea eruption. Bubble fraction, size and shape distribution affect lava viscosity and emplacement, and must be accommodated by dynamical models.
Surface-cooled samples collected along the flow field retain textures as similar to those of the moving material as possible. Those close to the vent record the high-vesicularity, low-viscosity regime from channel and overflows, while ooze-out samples from the a'a' sections record the high-viscosity end of an actively moving lava flow, where textures are captured near the ductile/brittle transition. These provide vesicle data for the upper and lower viscosity bounds of the flows, which encompass the full range of flow behaviors.
Three-dimensional textural characterization shows distinct vesicle size and shape systems through the flow field, related to emplacement structure and cooling rate. Vesicularities within the first 2 km of the vent vary from 60-85 vol.%, and tend to be bimodal, consisting of very large subangular vesicles surrounded by very small sub-spherical vesicles residing in the interstices between them. Further along the channel, vesicles form sub-equant frameworks of moderately sized vesicles, with vesicularities ranging from 40-65%. The distal reaches of the flow record much lower vesicularities, 15-25%, with large, sparse, vesicles with high aspect ratios and en-echelon fin-like shapes. These varied characteristics record and/or influence flow behavior and viscosity along the flow, as a function of concentration and capillary number. Finally, preliminary investigation of inter-bubble interactions suggest complex bubble evolution within a flow. Apparent rheological thresholds result in promotion and suppression of bubble nucleation and growth, respectively, modifying viscosity further than current models encapsulate.

196

Evolution of magma plumbing system beneath a submarine caldera after the 7.3-ka caldera-forming Akahoya eruption at Kikai volcano, SW Japan

Dr Morihisa Hamada[1], Dr Takeshi Hanyu[1], Dr Iona McIntosh[1], Dr Maria Luisa Tejada[1], Dr Qing Chang[1], Professor Katsuya Kaneko[2], Dr Jun-Ichi Kimura[1], Dr Koji Kiyosugi[2], Dr Takashi Miyazaki[1], Dr Reina Nakaoka[2], Dr Kimihiro Nishimura[2], Mr Tomoki Sato[1], Dr Nobukazu Seama[2], Dr Keiko Suzuki-Kamata[2], Dr Satoru Tanaka[1], Dr Yoshiyuki Tatsumi[2], Dr Kenta Ueki[1], Mr Bogdan Vaglarov[1]
[1]Japan Agency for Marine-Earth Science and Technology, Yokosuka, Japan, [2]Kobe University, Kobe, Japan

Kikai submarine caldera in SW Japan has repeated caldera-forming eruptions. After the 7.3-ka caldera-forming 'Akahoya' eruption, basaltic and rhyolitic subaerial eruptions and fumarole activity have been identified at subaerial Inamura-dake, Iwo-dake and Showa-Iwojima on the caldera rim. Although the huge central lava dome (~32 km^3) and satellite volcanic cones are observed inside the caldera, their formation processes are not well understood because they are submerged. Herein the geochemical composition of whole-rocks and minerals are investigated to constrain the magma conditions forming submarine volcanic edifices. Most rhyolites from the central lava dome and the western satellite volcanic cones are distinct from those of the Akahoya eruption and the old Iwo-dake volcanic stage (5.2–3.9 ka). However, the chemical compositions of these rhyolites are consistent with those of the young Iwo-dake volcanic stage since 2.2 ka, suggesting that the central lava dome formed contemporaneously with volcanism of the young Iwo-dake. By contrast, the eastern satellite volcanic cones may be older volcanic edifices because the corresponding rhyolites overlap with those of the old Iwo-dake volcanic stages. Fe-Ti oxide thermometry and two-pyroxene thermometry provide consistent temperature estimates of submarine rhyolitic magmas, ranging from 750 to 1000°C with an average of 880°C throughout the caldera. A magmatic hygrometer estimates that the water content of the melt ranges from 1 to 6 wt% H_2O. Polybaric crystallization from H_2O-saturated melts may occur beneath the submarine caldera at a depth of 1–8 km. Additionally, the lack of mafic inclusions, which are commonly observed in the subaerially erupted rhyolites at Iwo-dake and Showa-Iwojima, implying that direct interaction between basaltic and rhyolitic magmas is limited beneath the submarine caldera. We argue that present Kikai volcano is in the recovery stage of caldera evolution cycle and that a large volume of magma has been refilled within several thousand years beneath the caldera.

541

Temporal changes in scattering and attenuation characteristics at Taal volcano, Philippines, estimated by inversion of envelope widths of volcano-tectonic earthquakes

Ms Miki Hamamoto[1], Professor Hiroyuki Kumagai[1], Mr Rudy Lacson[2], Doctor Ma. Antonia V. Bornas[2], Doctor Renato Solidum[2]
[1]Nagoya University, Nagoya City, Japan, [2]PHIVOLCS, Quezon City, Philippines

We developed a method to estimate temporal changes in seismic scattering and intrinsic attenuation characteristics at volcanoes, which are described by the mean free path (l0) and intrinsic attenuation (Qi), respectively, based on inversion of envelope widths of volcano-tectonic (VT) earthquakes. The envelope width (p) is defined as the ratio of cumulative to peak amplitudes of envelope seismograms in 5−10 Hz. In this method, the partial derivatives of p values with respective to l0 and Qi perturbations in individual anomaly regions are calculated from envelope waveforms synthesized by the Monte Carlo method. We solve the damped least-squares problem for the residuals between observed p values and those calculated with 1D models for individual events to estimate temporal variations in l0 and Qi values in the regions. We performed synthetic tests using actual hypocenter locations and the seismic network at Taal volcano, Philippines. We used two-layer 1D models and set two anomaly regions in the surface layer near the summit and the eastern flank of Volcano Island. Our inversion showed that at least ten events are required to stably estimate l0 and Qi values in the two regions. We analyzed 535 VT earthquakes at Taal in 2011−2020 before Taal's eruption on 12 January 2020. We set a moving time window of one week and performed the inversion if more than ten events were observed in each window. Our results displayed systematic increasing trends in l0 and Qi values in the region beneath the eastern flank of Volcano Island just before the eruption. This region has been interpreted as an actively degassing magma conduit. Our estimated variations suggest that the conduit was filled with magma containing less bubbles and/or crystals before the eruption. Our inversion method is applicable to other volcanoes, but seismicity must be active for a higher temporal resolution.

542

Inversion of envelope widths of volcano-seismic events for scattering and attenuation structures beneath at volcanoes

Professor Hiroyuki Kumagai[1], Ms Miki Hamamoto[1]
[1]*Nagoya University, Nagoya City, Japan*

To investigate scattering and attenuation structures beneath volcanoes, which are fundamental to image magma and hydrothermal systems but are less known compared to velocity structures, we developed a new method for inversion of envelope widths measured from high-frequency (5−10 Hz) envelope seismograms of volcano-tectonic earthquakes. Using space-weighting functions or energy distributions between source and station locations calculated from Monte Carlo envelope waveform simulations for 1D models of the scattering mean free path and the quality factor of medium attenuation for S waves, we performed inversion of residuals between observed envelope widths and those calculated with the 1D models. Our inversion results at Taal in the Philippines and at Nevado del Ruiz and Galeras in Colombia displayed areas of stronger scattering and weaker attenuation near the summit craters at these volcanoes. We found that these areas correspond to low P-wave velocity regions in their tomographic images. These results together with the fact that the P-wave velocity decreases with increasing porosity in porous media suggest that unconsolidated volcanic sediments with cracks or pores filled with gas produced strong scattering in these areas. We also found areas of stronger attenuation in the eastern flank of Volcano Island at Taal, which were matched with an S-wave attenuation region that has been interpreted as an actively degassing magma conduit. Our study demonstrates that inversion of envelope widths is useful to improve our understanding of scattering and attenuation characteristics at volcanoes.

1073

Volcanic Degassing: A Potential Source of Water Ice on Mars

Ms Saira Hamid[1], Dr. Laura Kerber[2], Dr. Amanda Clarke[1,3]
[1]Arizona State University, Tempe, United States, [2]Jet Propulsion Laboratory, Pasadena, United States, [3]Istituto Nazionale Di Geofisica E Vulcanologia, Pisa, Italy

Mars is in many ways a periglacial planet and contains overwhelming evidence of surface and subsurface water ice at present day and throughout history. But where did this water come from? Volcanism provides a pathway for volatile species, mostly water, to outgas from the planet's interior into the atmosphere. Persistent, non-eruptive activity, known as passive degassing, is a common characteristic of terrestrial volcanoes and was likely a key source of water vapor on Mars, as indicated by the presence of magmatic water in melt inclusions in Martian meteorites.

Here we model the way in which passive degassing from Martian volcanoes would have contributed to the ice budget on Mars. We use the Laboratoire de Météorologie Dynamique Generic global climate model to simulate passive degassing with a self-consistent water cycle, in which water ice and vapor are advected by the atmosphere, mixed by convection, and subjected to phase changes. We explore the depositional patterns of water ice from known volcanic sources and the sensitivity of our resulting distributions to volcanological, atmospheric, meteorological, and orbital parameters. We find that the rate and duration of degassing are the primary controls on ice deposit thickness. We further find that the atmospheric pressure largely influences how long water vapor and ice lingers in the atmosphere, whereas differences in obliquity primarily control the ice distribution. The effect of eccentricity, seasons, dust opacity, and the longitude of perihelion on the surface ice distribution are second-order compared to obliquity variations. Assuming a present-day obliquity, passive degassing can cover the planet in an ice-rich veneer before it eventually sublimates everywhere except in the mid- to high-latitudes, the Tharsis rise, and the polar ice caps where it remains until ice-loss processes outpace ice accumulation.

290

In situ melt inclusion analysis of water-rich magmas: Volatile content inferences of magma depth and production of continual radio frequency

John Hamilton[1], Tobias Fischer[1], Robert Bodnar[2], Lowell Moore[2], Sonja Behnke[3], Armando Saballos[4]
[1]University Of New Mexico, Albuquerque, United States, [2]Virginia Tech, Blacksburg, United States, [3]Los Alamos National Lab, Los Alamos, United States, [4]INETER, Managua, Nicaragua

Melt inclusions (MI) from the 1992 eruption of Cerro Negro Volcano, Nicaragua and various eruptions from Sakurajima Volcano, Japan indicate melts were H2O-rich. Due to the H2O-rich nature of the melts and pressure in the MI during cooling, vapor in equilibrium with the melts are a mixed H2O-CO2 fluid dominated by H2O with vapor bubbles in the MI containing up to ~90 mol% H2O at ambient conditions. Our approach analyzes H2O-rich MI "as found", removing rehomogenization, reconstructing H2O and CO2 contents of MI based on Raman analysis of the vapor bubble, SIMS analysis of the glass and the NEWTWO mixed fluid model to estimate composition and thermodynamic properties of the exsolved H2O-rich fluid in the vapor bubble. Based on our modeling, recalculated H2O and CO2 contents of the vapor bubble leads to significantly lower CO2 concentrations of the undegassed melt and, concomitantly, lower MI trapping pressures inferring shallower trapping depths, compared to estimates based on pure CO2 vapor phase. Accurate calculations of magmatic H2O and CO2 concentrations are necessary in determining their contribution to the production of continual radio frequency (CRF) impulses. CRF is a burst of radio frequency impulses caused by swarms of "vent discharges" that can accompany the onset of a volcanic eruption, differing from lightning due to the duration of the radio signal. Given this type of electrical activity cannot be the result of charge separation due to ice collisions, fractoemission and triboelectrification drive CRF events. Higher volatile content in magma results in increased magma fracture, the key to determining when CRF events occur at eruption. Use of our model to analyze MI from CRF and non-CRF events from various eruptions at Sakurajima will help determine if there is a minimum threshold of volatile contents resulting in an ideal amount of magma fractionation to produce CRF events.

1149

Insights into the 15 January 2022 Hunga eruption (Kingdom of Tonga) through non-juvenile pyroclasts

Mr Kyle Hamilton[1], Dr Jie Wu[1], Professor Shane Cronin[1], Dr Ingrid Ukstins[1], Mr David Adams[1], Dr Joa Paredes Marino[1]

[1]*University Of Auckland, Auckland, New Zealand*

To understand the geological and hydrothermal properties of pre-eruption submarine Hunga volcano, we examined the mineralogy, petrology and geochemistry of non-juvenile "lithic" pyroclasts within ash from the catastrophic 15 January 2022 eruption. The lithics make up ~10 vol% of the ash deposit. Lithic lithologies include (in order of abundance): pale grey dense lava (~43%), highly crystalline lava (24%), altered lava (21%), dark grey glassy lava (10%); red/oxidised scoria (~2%). Lithics show a broad spectrum of textures from pure glasses to aphanitic and porphyritic rocks, some with near 100% crystalline intergranular texture. The rocks are mainly andesitic, containing plagioclase and pyroxene (cpx>opx) with rare Fe-oxide. Hydrothermal alteration is common; secondary minerals include anhydrite/gypsum, pyrite, chalcopyrite, quartz. Plagioclase/feldspar composition is skewed towards a mode at An_{89-90}, but spans a wide range with a long tail of low-An numbers, compared with the 2022 primary products. Pyroxene Mg numbers from the lithics occupy a lower range (Mg# 15-87 vs ~35-93 for 2022), and glass has larger variations and higher concentrations in SiO_2 (52-68 vs 53-66 wt%). Estimates of crystallisation conditions using pyroxene pairs and melt Sr-Ba in equilibrium with plagioclase, indicate significant shallow ponding and crystallisation before eruption of these edifice rocks. Thus, the rocks represent the mainly evolved/upper parts of the whole system. Collectively, the lithics include shallow cumulates, lavas, and related pyroclastics erupted below sea level. These products are consistent with samples collected from the islands spanning the last 2000 years of activity from Hunga. They suggest that the edifice has built up slowly from successive small-magnitude eruptions from the shallow magmatic system. The upper edifice collapsed in the catastrophic 2022 eruption, which sampled deeper components of the magmatic system not seen since pre-2022 materials.

1472

The Rover–Aerial Vehicle Exploration Network (RAVEN): Field-testing the next generation of Mars mission design in Iceland

Dr Christopher Hamilton[1], Joana Voigt[1], The RAVEN Team
[1]University Of Arizona, Tucson, United States

The Rover–Aerial Vehicle Exploration Network (RAVEN) project, funded through the NASA Planetary Science and Technology Through Analog Research (PSTAR), has the aim of developing and field-testing new technology and science operation workflows for exploring on Mars using a rover and an Unoccupied Aircraft System (UAS). In July and August 2022, the RAVEN team performed baseline mission simulations to evaluate the performance of rover- and UAS-only missions by examining the 2014–2015 Holuhraun lava flow in Iceland as a Mars analog environment. The rover mission simulations involved the Canadian Space Agency's Mars Exploration Science Rover (MESR) with a suite of instruments, including wide-angle, narrow-angle, micro-imager, and navigational cameras; Visible to Near-Infrared (VIS–NIR) Spectrometer; Laser Induced Breakdown Spectrometer (LIBS); and sampling system. The UAS mission simulation utilized four UASs, which together simulated the capability of a future Mars Helicopter, with multiple camera systems as well as VIS–NIR, LIBS, and sampling instruments. Our objective was to simulate ten operational cycles (i.e., days on Mars, which are referred to as sols). With MESR we simulated 14 sols and with the UAS we simulated 12 sols. Technology demonstrations were also made for UAS-based samplers, which included drill and claw designs. These samplers were tested on a range of natural target materials (basaltic lava, basaltic sand, and palagonitized hyaloclastite) and for fetching cached sample tubes, which is highly relevant for future Mars sample return missions. This work summarizes the results for the two baseline missions to illustrate the capabilities of the two robotic systems working independently and inform the design of a combined mission architecture using rover and UAS.

1140

Estimating the distribution of melt beneath the Okataina Caldera, New Zealand: An integrated approach using geodesy, seismology and magnetotellurics

Dr Ian Hamling[1], Dr Geoff Kilgour[2], Dr Sigrun Hreinsdottir[1], Dr Edward Bertrand[1], Dr Stephen Bannister[1]
[1]Gns Science, Lower Hutt, New Zealand, [2]GNS Science, Wairakei Research Centre, Taupō, New Zealand

The inversion of geodetic data to estimate the position and depth of an inflating or contracting magmatic body is inherently non-unique. A priori information and complementary datasets (e.g. as Magnetotellurics (MT) and seismicity) are often used to fix the depth and position of the source prior to inversion. However, these datasets are typically used in isolation and in a qualitative manner. Here we use geodetic (InSAR and GNSS), seismological and MT data acquired over the Okataina Caldera, New Zealand, and perform a joint inversion where MT data are directly included in the inversion of surface deformation data. Geodetic data acquired over the last ~20 years have shown subsidence across the Okataina caldera and surrounding areas of up to ~15 mm/yr focussed beneath the two geologically active linear vent zones (i.e., Haroharo and Tarawera) and within the northern Ngakuru graben. Assuming the subsidence is largely being driven by the ongoing cooling and contraction of melt, we estimate the distribution of contraction beneath the region. With the inclusion of MT data in the inversion, we estimate an annual volume loss of 0.007 km3/yr, less than half the volume predicted by unconstrained inversions. We suggest that the observed seismicity in the vicinity of the caldera is driven by the long-term stressing from the contracting magma as well as periodic fluid and gas release into zones of increased permeability surrounding the cooling intrusion. Furthermore, we show that simple cooling models can explain long-term, near-linear, subsidence rates for periods of tens to hundreds of years.

391

DYNAMIC VENT AREA CHANGES AT WHAKAARI/WHITE ISLAND DERIVED FROM STARING SPOTLIGHT SATELLITE

Dr Ian Hamling[1], Dr Geoff Kilgour[2]
[1]GNS Science, Lower Hutt, New Zealand, [2]GNS Science, Wairakei Research Centre, Taupō, New Zealand

The driving mechanisms behind phreatic eruptions make them challenging to forecast. Typically, pressurization occurs over a range of timescales, due to the injection of hydrothermal fluids or by the release and ascent of magmatic gas into a sealed hydrothermal system. In either scenario, the area of deformation is often restricted to an area of 10's of m2, making direct measurements difficult. Furthermore, the presence of hydrothermal features such as crater lakes and high temperature fumaroles often prevent clear views of the vent area. Standard satellite radar measurements return data from pixels that have an area of ~10 m, making it near-impossible to identify fine-scale topographic changes. Here we present analysis from new high-resolution (0.25-1 m) Synthetic Aperture Radar data acquired over Whakaari White Island since 2021. By using these radar data, it is possible to see through cloud and steam, enabling us to track small-scale changes in and around the vent area. Our results show the highly dynamic nature of the vent area, including the formation of new sub-vents and fine-scale fluctuations in the lake level. In addition, deformation timeseries allow us to track subtle displacements associated with changes in the shallow hydrothermal and magmatic systems, and active landslide. Following the 2019 eruption, deformation around the vent area has largely been dominated by subsidence with small-scale changes in displacement rates often correlated to other observable changes. We also observed renewed downslope motion of the SW crater wall with ~300 mm of subsidence along its head scarp. Together, these data provide a case study for utilizing new satellite measurements to assess detailed changes at hazardous and remote volcanic systems, helping to supplement the array of monitoring tools available to volcanologists.

1092

Evolution of crystallinity during the 2018 Kīlauea lower East Rift Zone eruption

Professor Julia Hammer[1], Brenna Halverson[2], Hannah Dietterich[3], Einat Lev[4], Justin Baur[4], Alan Whittington[2], Joseph Boro[5], Eric Hellebrand[6], Matthew Patrick[7], Janine Birnbaum[4], Brett Carr[7,8], Carolyn Parcheta[7]
[1]University of Hawaiʻi, Honolulu, United States, [2]University of Texas San Antonio, , , [3]USGS Hawaiian Volcano Observatory, , , [4]Columbia University, , , [5]Sandia National Lab, , , [6]Utrecht University, , , [7]USGS Hawaiian Volcano Observatory, , , [8]University of Arizona, ,

We quantify the crystallinity of quenched samples from the main fissure 8 lava flow of the 2018 Kīlauea lower East Rift Zone eruption by analyzing 27 post-eruptive samples constrained in time and space by syn-eruptive video observations, thermal imagery, and geologic mapping. Metadata include emplacement date, distance along-channel from the Ahuʻailāʻau (fissure 8) cone, lava effusion rate, and the emplacement context (e.g., main channel overflows, flow fronts, ponded section overflows, ʻaʻā delta). Three sample subsets, emplaced over narrow time windows from May 28 to June 11, represent a period of relatively low and steady effusion rate (≤160 m^3 s^{-1}); a fourth set (July 7-11) captures a period of high effusion rate and a transition to unsteady flux (≥230 m^3 s^{-1}). Samples are further subdivided to one of five distance bins: 0-1 km, 1-2 km, ~6 km, 8.5-10 km, and 12-14 km.

We determine the abundances of plagioclase, clinopyroxene, and olivine crystals from RGB images constructed from Al, Ca, and Mg wavelength-dispersive x-ray intensity maps of entire standard thin sections. This methodology reduces segmentation bias and effectively excludes the smallest crystals (<30 µm) that likely form after emplacement.

With only one exception, there is no change in overall crystallinity, phase abundances, or the proportions of phenocrysts (>150 µm) and microphenocrysts (30-150 µm) with respect to distance from vent. The exception is a tripling of the crystallinity of July lava as it transited the ʻaʻā delta. Even considering this increase, July samples are less crystalline (4-12 v.% DRE) than the May and June samples (10-20 v.%). Olivine abundance, dominantly as phenocrysts in all cases, is similar (3-5 v.%), so the reduced crystallinity of the July samples is attributable to their lower plagioclase and clinopyroxene abundances. Contextualized crystallinity data will be used to test numerical models of suspension rheology.

1280

Past impacts and future risk of volcanic hazards to Australia

A/Prof. Heather Handley[1,2], Andrew Tupper[3], Ray Cas[2], Susanna Jenkins[4]
[1]Department of Applied Earth Sciences, University of Twente, Enschede, Netherlands, [2]School of Earth, Atmosphere and Environment, Monash University, Melbourne, Australia, [3]Natural Hazards Consulting, Melbourne, Australia, [4]Earth Observatory of Singapore, Nanyang Technological University, , Singapore

Australia and the Australian people are at risk from volcanic hazards from future eruptions of domestic and international volcanoes, but our understanding of the characteristics, extent and magnitude of the risk has until now been very poor. This limits our ability to accurately forecast future eruptive activity and impacts, potentially leading to delayed, costly and/or ill-informed decision-making, with associated consequences. In this study we improved our understanding of the wide range of direct and indirect impacts to Australia from volcanic hazards and identified possible future risks by considering information from volcanological and geological studies, the media, government organisations, monitoring authorities and traditional sources of knowledge of volcanic eruptions. Australia has been directly impacted by volcanic ash from historic eruptions in countries such as Chile, Indonesia, The Kingdom of Tonga, Papua New Guinea and New Zealand (Kermadec Islands), with volcano-triggered tsunami and pumice rafts previously washing ashore and presenting a range of social, economic and environmental risks. Significant numbers of Australian nationals have encountered volcanic risk when overseas. The 2019 Whakaari/White Island eruption led to the tragic deaths of 17 Australian tourists. Less well known and appreciated are the risks posed to Australia from active volcanic regions in mainland Australia. Based on the known ages of eruptions, there are at least two volcanic provinces in the southeast and northeast Australian mainland still considered active and that could see a future eruption. The presence of mantle rock fragments (xenoliths) carried by the magma and erupted in both regions, alongside oral records of volcanism witnessed by Indigenous peoples, suggest that warning times prior to an eruption may be short with little precursory activity. This improved knowledge now needs to be translated into proactive emergency management and preparedness so that Australia can respond to volcanic risks from a future eruption at home or abroad.

960

Public Perceptions of Volcanic Hazards and Risk in Australia

A/Prof. Heather Handley[1,2,3], Jennifer Bratchell[3], Katharine Haynes[4], Carmen Solana[5], Christina Magill[6]
[1]Department of Applied Earth Sciences, University of Twente, Enschede, Netherlands, [2]School of Earth, Atmosphere, Environment, Monash University, Melbourne, Australia, [3]School of Natural Sciences, Macquarie University, Sydney, Australia, [4]Natural Hazards Research Australia, , Australia, [5]School of Earth and Environmental Sciences, University of Portsmouth, Portsmouth, United Kingdom, [6]GNS Science, Avalon, New Zealand

Effective response to volcanic hazards is greatly dependent on public awareness of the hazards and risk. Australia is at risk from volcanic activity both at home and abroad as exemplified by the 2022 Hunga Tonga-Hunga Ha'apai eruption and Holocene-dated volcanic eruptions occurring in mainland Australia. This study undertook scholarly enquiry to determine a baseline of knowledge and understanding of volcanic hazards and risk among the general population in Australia through a nation-wide quantitative survey, receiving 303 responses. The relative ranking of volcanic and other natural hazards amongst a range of social, economic and environmental concerns revealed that people were most concerned about the risk from climate change on their wellbeing or livelihood, followed by drought, bushfire and housing affordability. Respondents were less concerned about volcanic activity, although, 83% somewhat agreed, or strongly agreed, that Australia could be impacted by volcanic activity in other countries. Respondents showed a good understanding of potential precursory volcanic activity and the impacts of volcanic eruptions. Around a third of respondents were not sure when the last eruption occurred in mainland Australia and 27% neither agreed nor disagreed that there were parts of Australia that were still volcanically active. Very few of the participants (5%) agreed that Australia is well prepared for dealing with volcanic eruptions, with just 6% of residents aware of any preparedness, emergency management plans or warning systems for volcanic events, and almost 80% of people were unaware of the procedures they would need to follow in the event of an emergency related to volcanic activity. While the average recurrence interval of volcanic eruptions occurring in mainland Australia is on the order of thousands to tens of thousands of years, we recommend improved assessment, planning and communication of the risk to Australia from large-scale volcanic eruptions in the Asia-Pacific region and South America.

597

How We Do Volcano Data at GeoNet

Dr Jonathan Hanson[1], Steven Sherburn[2], Nico Fournier[2], Gill Jolly[1], Cameron Asher[2], Agnes Mazot[2], Jackson Shanks[2], Richard Johnson[2], Elisabetta D'Anastasio[1], Joshua Groom[1], Mark Chadwick[1]
[1]GNS Science Te Pū Ao, Avalon, Aotearao New Zealand, [2]GNS Science Te Pū Ao, Wairakei, Aotearoa New Zealand

The GeoNet programme at GNS Science Te Pū Ao, Aotearoa-New Zealand is responsible for collection and management of multi-hazard data sets, including for volcanoes. The collection, transportation, management, and data access are the responsibilities of specialised teams within the GeoNet programme. For volcano data, these teams work on behalf of, and supported by, the GNS Science's Volcano Monitoring Group (VMG). This multi-hazard data management programme has both strengths and weaknesses, some of which will be explored here.

GeoNet's key data principles are openness and FAIRness for all data and associated dataset meta-data, to facilitate research into hazards and assessment of risk. GeoNet stores all its data in the cloud (AWS) and provides a range of data access mechanisms (including mechanisms aimed at request-driven and bulk access) and documentation to facilitate access to, and use of, our data.

We focus on some recent data acquisition, management and access initiatives at GeoNet as examples: webcam images, scanDOAS SO2 emission rates, low-rate data collection platform, and low-rate data API. We will illustrate how these initiatives are impacting volcano data.

1372

Searching for traces of Heard Island volcanism in the Mount Brown South ice core

Margaret Harlan[1,2,3], Tessa Vance[1,2], Delphine Lannuzel[2], Jodi Fox[2], Helle Astrid Kjær[3,2], Eliza Cook[3], Anders Svensson[3], Mount Brown South Project Team

[1]Australian Antarctic Program Partnership, Hobart, Australia, [2]Institute For Marine And Antarctic Studies, University Of Tasmania, Hobart, Australia, [3]Physics of Ice, Climate, and Earth; Niels Bohr Institute, University of Copenahgen, Copenhagen, Denmark

The Kerguelen Plateau region is home to substantial annual phytoplankton blooms which contribute to the biological productivity of the Southern Ocean. The contribution of atmospheric fallout from Heard and McDonald Islands (HIMI) volcanism, primarily from Mawson Peak on Big Ben, Heard Island (53.106°S, 73.513°E), is a poorly characterized but potentially significant source of iron across the Kerguelen Plateau, driving primary productivity and accounting for the high inter-annual variability of blooms seen in the region. Assessing the impact of HIMI volcanism is complicated by the limited recorded eruption history, owing to the remoteness of the location and persistent cloud cover, which hinder observations of eruption events both in-situ and via satellite imagery. Here, we employ East Antarctic ice core archives to increase our understanding of the role of volcanism in the region's ecosystem.

We propose that due to its relative proximity to HIMI and favorable atmospheric transport conditions, the Mount Brown South ice cores (MBS, 69.111°S, 86.312°E) have the potential to contain preserved volcanic signals, including cryptotephra, from HIMI eruption events. Preserved tephra in MBS ice cores would extend the HIMI volcanic record and allow investigation of the iron fertilization potential of the volcanic fallout. Using the existing Heard Island volcanic record together with HYSPLIT air parcel trajectories and atmospheric river data as a guide, we have performed targeted sampling of the satellite era MBS Alpha core and successfully isolated volcanic glass shards. We geochemically characterize the cryptotephra using electron probe microanalysis to identify the likelihood of HIMI provenance. Further analysis using x-ray fluorescence microscopy at the Australian Synchrotron will allow quantification of trace iron concentrations and bioavailability. Together the data collected will inform our assessment of the iron fertilization potential of HIMI volcanic aerosols in the Kerguelen Plateau region.

825

Shallow magma storage of rhyolite magma in extensional tectonic settings using rhyolite-MELTS

Lydia Harmon[1,2], Guilherme Gualda[2], Blake Wallrich[2], Calvin Miller[2]
[1]*Arizona State University, Tempe, United States,* [2]*Vanderbilt University, Nashville, United States*

Identifying where eruptible magma bodies form and are stored in the crust is critical for understanding magma transport, eruption hazards, and magma body longevity. We shed light on previously under-reported magma bodies stored at the shallowest crustal depths (defined here as < 4 km) prior to eruption, and on a new approach to identify their existence beneath modern and ancient volcanic centers. Rhyolite-MELTS has been used effectively to calculate storage pressures for silicic magma bodies at moderate crustal depths, but its precision and accuracy in very low-pressure systems (<100 MPa) has not been sufficiently investigated.

During the recent Krafla IDDP-1 drilling project, magma was surprisingly intersected at 2.1 km depth. Here, we ground truth the use of rhyolite-MELTS geobarometry for very low pressures using natural Krafla IDDP-1 compositions. We input the composition of the melt (preserved as glass) and search in pressure and temperature space at a range of oxygen fugacity (fO2) to model the storage conditions of the Krafla magma. For an average composition of the drilled melt, rhyolite-MELTS yields a pressure of 42 MPa (1.6 km) for ΔNNO = -0.75 and 46 MPa (1.7 km) for ΔNNO = -1; these calculated depths are only 0.6 km and 0.4 km different from that of the intersected magma, showing that rhyolite-MELTS provides excellent estimates for very shallow magma storage.

The agreement between rhyolite-MELTS pressures and the drilled depth of the Krafla magma removes doubts about previously calculated very shallow storage pressures. For instance, results from the Taupō Volcanic Zone demonstrate that caldera-forming ignimbrite eruptions can be partly fed by magma bodies at < 4 km depth. This shallowest storage zone of eruptible magmas has significant implications for modeling caldera unrest and calculating geothermal resource potential.

822

Untangling the magmas and timing of the Whakamaru Group Ignimbrites, Taupō Volcanic Zone, New Zealand

Lydia Harmon[1,2], Guilherme Gualda[2], Darren Gravley[3], Sarah Smithies[3], Chad Deering[4]
[1]Arizona State University, Tempe, United States, [2]Vanderbilt University, Nashville, United States, [3]University of Canterbury, Christchurch, New Zealand, [4]Michigan Technological University, Houghton, United States

The Whakamaru eruptions are the largest known eruptions in the modern Taupō Volcanic Zone. The complex field relationships of the ignimbrites have thus far obscured the timing of their eruption(s). We present corroborating evidence from the ignimbrite record and associated fall deposits to determine how many magma bodies fed the Whakamaru eruptions and how they erupted through time. We also elucidate the pre-eruptive magmatic storage and extraction conditions of the magmas to understand the crustal conditions leading up to the largest volcanic eruptions in TVZ history.

We focus on erupted pumice clasts and use a combination of petrologic techniques, including: 1) field relations of pyroclastic fall and ignimbrite deposits; 2) SEM-EDS and LA-ICPMS major- and trace-element matrix glass compositions; 3) XRF whole rock geochemistry from the ignimbrites; 4) rhyolite-MELTS storage and extraction calculations.

Four main magma types (Types A-D) fed the Whakamaru eruptions and are interpreted to represent four individual magma bodies. Types B and C are compositionally related; they are not immediately related to Types A and D.

The tephras record the eruption timing. Eruptions commenced with type A only, prior to incorporating Type B. Only the final tephra horizons contain Types A, B, and C. Combined with the mapped distribution of pumice types within the ignimbrites, we can determine the history of the ignimbrite eruptions.
The storage conditions of the eruptible magma bodies are consistently shallow (~75-125 MPa). In contrast, the extraction conditions differ. Types B and C are likely extracted from a quartz-feldspar source at ~250 MPa, while Types A and D are likely extracted from a plagioclase-orthopyroxene±quartz source. Not only are there multiple magma bodies that fed the Whakamaru eruptions, but we find there are two distinct magmatic subsystems that coexisted and led to the eruption of different magma types at the same time.

210

Large-scale lava dome fracturing as a result of concealed weakened zones

Dr Claire Harnett[1], Prof Michael Heap[2], Prof Valentin Troll[3], Dr Frances Deegan[3], Prof Thomas Walter[4]
[1]University College Dublin, Dublin, Ireland, [2]Université de Strasbourg, CNRS, Institut Terre et Environnement de Strasbourg, Strasbourg, France, [3]Department of Earth Science, Natural Resources and Sustainable Development (NRHU), Uppsala University, Uppsala, Sweden, [4]GFZ German Research Centre for Geosciences, Potsdam, Germany

Mechanically weakened alteration zones in lava domes are thought to jeopardize their stability. Such zones can be hazardous when concealed within the dome, either because they formed by subsurface hydrothermal circulation or they formed on the surface but were subsequently buried by renewed lava extrusion. We present a new suite of computational models showing how the size and position of a weakened brittle zone within a dome can affect large-scale fracture formation, displacement, and collapse mechanism. By combining recent laboratory data for the mechanical behavior of dome rocks with discrete element method models, we show: (1) the presence of a weak zone increases instability, which is exacerbated when the size of the zone increases or the zone is positioned off-center. (2) The position of the weak zone changes the deformation mechanism from slumping-type slope deformation when the zone is positioned centrally, compared with deep-seated rotational slope failure when the zone is positioned toward the dome flank . Finally (3) dome-cutting tensile fractures form in the presence of a small weak zone (60 m diameter, ~14% of dome width), whereas large weak zones (120 m diameter, ~27% of dome width) promote formation of longer and deeper fractures that jeopardize larger dome volumes. Our results corroborate previous field observations at lava domes and indicate large fracture formation, which greatly influence dome stability and outgassing, can be explained by the presence of concealed alteration zones. This improved understanding of the mechanisms responsible for dome instability enables better hazard assessment at volcanoes worldwide.

211

Material parameter controls on caldera slope morphology: comparing numerical models and natural observations

Dr Claire Harnett[1], Dr Eoghan Holohan[1], Mr Robert Watson[1], Dr Martin Schöpfer[2]
[1]University College Dublin, Dublin, Ireland, [2]University of Vienna, Vienna, Austria

Volcanic calderas are delimited by a 'caldera wall' which can be several hundred meters in height. This represents the degraded scarp of a fault that accommodates roof subsidence. Here, we assess the roles of friction and cohesion on caldera wall morphology by: (i) analysing the slope properties of several young natural calderas in the ALOS-3D global digital surface model (DSM), and (ii) comparing those observations to the results of a text-book analytical solution and of new Distinct Element Method (DEM) modelling.

Our analysis of the DSM suggest that caldera wall heights are not as closely linked to slope angle as previously suggested. Slope angles range from 20 – 65° and slope heights range from 99 m - 1085 m. We find that the smaller slope heights are not robustly tied to greater slope angle. When compared to analytical predictions, these slope-height data yield expected rock mass cohesion values of less than 0.25 MPa for all calderas, which is 2-3 orders of magnitude less than typical laboratory-scale values.

The DEM models explicitly simulated the process of progressive caldera collapse, wall formation and destabilisation, enabling exploration of the emergence of slope morphology as a function of increasing subsidence and of mechanical properties. Results confirm that low bulk cohesion values < 3 MPa are required to reproduce the observed ranges of slope angles and slope heights, and they indicate that friction is the dominant control on slope evolution. Different failure mechanisms resulted as a function of cohesion and friction during early collapse: (1) granular flow with low friction and cohesion, and (2) block toppling at high friction and cohesion. During later collapse, shear failure dominates regardless of cohesion. At higher cohesion and/or friction values, the models resulted in non-linear concave-upward slope profiles that are seen at many natural calderas.

887

Gravitational Loading Controls for Dike Propagation Directions at Stratovolcanoes

Dr Andrew Harp[1], Meredith Townsend[2]
[1]*California State University, Chico, Chico, United States,* [2]*University of Oregon, Eugene, United States*

Historical observations and geologic evidence indicate that flank eruptions are common occurrences at stratovolcanoes with eruptions ranging in character from effusive to explosive. The opening of new eruptive vents low on the slopes of stratovolcanoes pose a significant risk to the populations and infrastructure that often reside there. Interpretations of analogue and numerical modeling, as well as evidence collected from ancient plumbing systems within eroded stratovolcanoes, suggest that stress barriers generated by the gravitational loading of a growing edifice may deflect the propagation direction of ascending radial dikes toward the flanks of the volcano. However, a relationship between edifice geometry and the propagation direction of radial dikes remains poorly understood and difficult to resolve using numerical modeling or geophysical techniques at active volcanic systems.

Analogue gelatin models are well suited for investigating dike propagation beneath stratovolcanoes because their parameters can be carefully scaled to simulate volcanoes in nature. Furthermore, the transparency of gelatin allows continuous monitoring of radial dike propagation directions and geometries. We present the results of gelatin experiments where a magma analogue was injected into a 50 x 50 x 30 cm3 acrylic tank of gelatin (crustal analogue) and beneath a simulated volcanic edifice (also gelatin). A mold was used to systematically vary the size of the simulated edifice and therefore the resulting stress conditions in the crust below it. Following injection of the magma analogue at the base of the tank, cameras monitor the simulated radial dike as it ascends toward the edifice base to record variations in the 3-dimensional geometry, position, and propagation direction of the dike.

395

Preliminary Holocene tephrostratigraphy of peat sequences from southern Peruvian bofedales

Christopher Harpel[1], Kevin Cueva[2], Marco Rivera[3], Charles Lewis[1,4], Thomas Bianchette[5], Marquinho Cabrera[3], Nelida Manrique[2], Saida Japura[2], Hilda Alavi[3]

[1]U.S. Geological Survey Volcano Disaster Assistance Program, Vancouver, United States, [2]Instituto Geológico, Minero y Metalúrgico del Perú, Observatorio Vulcanológico del INGEMMET, Yanahuara, Peru, [3]Instituto Geofísico del Perú, Observatorio Vulcanologico del Sur, Cayma, Peru, [4]College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, Corvallis, United States, [5]Department of Chemistry, Oakland University, Rochester, United States

Volcanic ash was recovered from a sequence of nine peat cores sampled from wetlands (known locally as bofedales) at four locations in southern Peru: Sallalli, Lago Macurca, an unnamed wetland southeast of Ampato volcano, and Laguna Salinas. Preliminary 14C dating from the cores' bases yielded maximum ages of 2,020 ± 30 14C yr BP, 4,960 ± 30 14C yr BP, 6,690 ± 30 14C yr BP, 11,440 ± 45 14C yr BP for cores from the wetland southeast of Ampato, Laguna Salinas, Sallalli, and Lago Macurca, respectively. Additional 14C ages from one of the Sallalli cores are stratigraphically consistent. At least ten discrete ash layers are identified within the cores with several correlated between different locations. The Sallalli, southeast of Ampato, and Lago Macurca bofedales are proximal to Sabancaya volcano and ash from the volcano's eruptions from 1986–1998 commonly crops out in the cores as an approximately 1-cm thick gray layer. Sabancaya's eruptions between 2016 and the present have similarly emplaced ash forming about a 1-cm thick gray layer at the modern surface. In addition, the cores contain ash from multiple distal eruptions including from the 1600 CE Huaynaputina eruption, which forms a prominent regional marker bed. The ash layers contain shards with blocky, bubble wall, and micropumice morphologies which are applied in conjunction with the phenocrysts present to help identify individual ash layers. Degree of weathering for individual ash layers is highly variable with periods of reworking following eruptions being evident in several cases. Glass compositions for the ash range from 54.5–79 wt.% SiO2 but are dominated by rhyolites and trachytes. Such peat cores have yielded a rich record of volcanism in southern Peru that provides insights into ash distributions and hazards, regional eruption rates, ages for previously undated eruptions, and perhaps document previously unknown eruptions.

1071

Granular Interactions in Volcanic Mass Flows: Non-locality and thin layer stability in granular flows

Christopher Harper[1], Dr. Josef Dufek, Dr. Eric Breard
[1]*University Of Oregon, Eugene, United States*

The past twenty years has seen great improvement in describing granular material through a combination of continuum mechanics and discrete element methods yielding insights into diverse phenomena from volcanic edifice stability to basal forces in PDC. However, both approaches have clear limitations; continuum mechanics approximates the constituent particles with smooth averages, and discrete element models only explicitly describe particle particle interactions. This results in a poor understanding of how the individual granular interactions manifest in larger more complicated networks of contact. This meso-scale, where we transition from viewing grains as a conglomeration of individual interactions to behaving like a fabric of contacts, is key to understanding non-local behavior and ultimately describing transitions in granular dynamics such as flow initiation and jamming. Here we examine through analytical expressions and discrete element simulations how non-local affects and mesoscale phenomenon can emerge solely from base assumptions about individual particles. Even using a system as simple as a chain of mono-disperse inelastic particles, we show that the work done by particle-particle interactions is a function of chain length, demonstrating that non-locality is present at the smallest scales in the simplest of systems. Furthermore, we show how this non-locality creates a limiting behavior for the effective inelasticity of the colliding particle, which we show can give rise to an energetically favorable states of motion. Finally, we frame the emergence of this dynamic state as a potential generating mechanism for thin layer stability, a perplexing granular phenomenon where stability asymptotically decreases with non-dimensionalized height. Understanding thin layer stability could help explain criterion for retrogressive collapse and the stability/creation of levees created in the wake of a pyroclastic flows. More generally, we hope to show that there are still significant insights to be gained from more rudimentary analysis of systems of grains.

349

On the Origin of Embayments

Megan Harris[1], Madison Myers[1], Nathan Lenhard[2]
[1]Montana State University, Bozeman, United States, [2]Missouri State University, Springfield, United States

Although embayments are increasingly being used to understand processes occurring within magmatic systems, it is highly debated whether these are growth or dissolution features. Exploring the origin of embayments may allow for increased understanding of the pre-erupted variability in magmatic intensive parameters (e.g. pressure and temperature fluctuations) prior to the onset of eruption. Currently, two mechanisms have been proposed to explain the formation of embayments: 1) rapid growth due to undercooling1, or 2) dissolution due to superheating, potentially aided by bubble drilling2. To discriminate between these two mechanisms, we first analyzed the relationship between the embayment boundary and zoning bands using cathodoluminescence (CL) images of quartz crystals from five silicic eruptions. Of the 303 crystals imaged, we find that the majority (79%) preserve zoning relationships indicative of growth (zoning wraps around embayment or oscillatory/sector zoning), where only 5% of images show clear dissolution relationships (embayment cross cuts zoning), highlighting that growth dynamics (aka undercooling) are likely dominating their formation. We next sought to form embayments experimentally using a cold-seal pressure vessel, where crystals are subjected to undercooled and superheated conditions. Experiments were conducted at temperatures 55-80C above/below the liquidus to promote dissolution/growth, respectively, and ranged in duration from 24-672 hours. In contrast to CL results, we find that embayments are more readily formed in superheated conditions, while undercooled conditions resulted in crystal faceting and moderate embayment growth. 3D tomography results show that embayments in quartz can be formed by dissolution, but that their formation in natural conditions is likely strongly influenced crystal growth. This work highlights the importance of embayments for recording disequilibrium conditions and highlights the importance of future experiments to aid understanding of the magmatic conditions that lead to their formation.

1Anderson (1991) Am. Min., 76, 530-547
2Busby and Barker (1966) Journal Am. Ceramic Soc., 49, 441-446

449

Insights from Diverse Geochronologic Methods Applied to Hydrothermal Explosions in the Yellowstone Plateau Volcanic Field

Dr Lauren Harrison[1], Dr Shaul Hurwitz, Dr Joseph Licciardi, Dr Cathy Whitlock, Dr Nathan Brown, Ms Karissa Cordova, Dr Mark Stelten, Dr Jefferson Hungerford
[1]*U.S. Geological Survey, Menlo Park, United States*

Hydrothermal explosions can be triggered by the sudden release of pressure during mass wasting events, seismic activity, or the mechanical failure of a sealed, low-permeability cap. An excellent place to investigate the interplay of these triggers is the Yellowstone volcanic field's hydrothermal system, which has been active through recent glacial epochs (Bull Lake ~150-140 ka and Pinedale ~22-13 ka) and exhibits small (<2 meter) and 18 large (>300 meter) explosion craters. It is currently unknown whether the very large hydrothermal explosion craters were clustered in time or formed randomly due to a lack of reliable geochronology on most of the craters. We focus on Pocket Basin and Twin Buttes, two large craters in the Lower Geyser Basin, one of Yellowstone's largest and most active thermal areas. The Pocket Basin explosion crater is a 365- by 800-meter depression with shallowly dipping inner slopes and an asymmetric hydrothermal breccia deposit ringing the crater. The Twin Buttes explosion crater is roughly circular with a circumference of ~645 meters and contains multiple smaller nested craters. We used cosmogenic exposure dating and luminescence bleaching profiles of boulders excavated by the explosions, luminescence cooling ages of sediment excavated by the explosions, chronology of tephra in lake sediment cores, and 40Ar-39Ar dating of related deposits to determine the age of these two large explosions. We find the explosions were primed by the hydrothermal sealing of permeable glacial gravels and triggered by a landslide of glacially-buttressed features upon deglaciation. Modelling LiDAR data constrains the triggering mechanism, volume, and energy of these explosions. The link between glaciation, hydrothermal systems, and surface morphology furthers our understanding of the hazards posed by hydrothermal explosions in one of the largest hydrothermal systems in the world.

959

Extraordinary coastal morphological changes due to lahar events following the 2017-2018 volcanic eruption on Ambae (Vanuatu)

Miss Christy Haruel[1], Dr Philipson Bani[1], Mr Dan Tari[2]
[1]LMV - IRD Nouméa, New Caledonia, Nouméa, New Caledonia, [2]Vanuatu Meteorology and Geohazards Department, Port Vila, Vanuatu

The Ambae basaltic shield volcano in Vanuatu, with its summit of 1499m and a volume of 2500 km3, went through an increasing eruptive activity over the last three decades. It commenced with a phreatic event in 1995, followed by a Surtseyan manifestation in 2005 and most recently a sub-plinian eruption in 2017-2018. Consequently, the summit crater lake Vui has evolved to became one of the most voluminous acidic crater lake worldwide. During the 2005 event a new cone was formed in the lake but then progressively eroded away after the eruption. The 2017-2018 eruption, in contrast to the two previous events, was extremely intense and has induced significant coastal morphological changes as consequence of successive lahar events. Indeed, the thick ash deposits on the very steep slopes at the central part of the island were easily re-mobilised during heavy rainfalls and cyclones to form lahars. In this work we combine the satellite imagery, field observations, meteorological and historical records to assess these lahar events, their subsequent deposits and the related hazards. We highlight the remarkable and prominent morphological transformation induced by lahar deposits along the coastlines and creek mouths in northern and southern part of Ambae. We estimate a total area exceeding 234 km2 of lahar deposits. Such a change of this magnitude has never been seen vividly or recorded in this detail before on Ambae. New black sand beaches were formed, and in some cases exposing fresh water springs previously submerged under water. Such morphological changes enhance positive impacts on the local community, such as in providing new water sources and potential for tourism.

1308

Did CAMP magmatism extend to the proto–Cameroon Volcanic Line in the Gulf of Guinea?

Dr. Festus Aka[1], Dr Takeshi Hasegawa[1], Mr. Shota Watanabe[1], Dr. Asobo Asaah[2], Dr. Linus Nche[1,3], Dr. Hikaru Iwamori[4], Dr. Hirochika Sumino[4], Dr. Tetsuya Yokoyama[5], Dr. Mie Ichihara[4], Takeshi Ohba[6]

[1]Ibaraki University, , Japan, [2]Industry and Technological Development, , Cameroon, [3]Institute for Geological and Mining Research, , Cameroon, [4]University of Tokyo, , Japan, [5]Tokyo Institute of Technology, , Japan, [6]Tokai University, , Japan

Pre-Gondwana breakup configurations suggest that the Boreborema Province of NE Brazil and the areas of present-day Gulf of Guinea in west/central Africa formed a tight conjugate fit in the west Gondwana supercontinent. Gondwana breakup was associated with extensive magmatism, e.g., the Central Atlantic Magmatic Province (CAMP). CAMP intruded as dyke swarms in areas of present-day West Africa, South America, NE/SW United States, Eastern Canada, and Western Europe. While the Boreborema Province of NE Brazil was widely affected by pre-, syn- and post- Gondwana breakup magmatism (including CAMP) from ca300Ma to the Present, it is not clear why whole-time equivalents of pre- and syn- breakup magmatism have not yet been reported in areas of present-day Jos Plateau, Benue Trough and the Cameroon Volcanic Line (CVL) in the Gulf of Guinea. In our on-going investigation of whether CAMP magmatism extended to the CVL, we gave compiled 846 geochemical and 340 age data for the CVL system, and 416 geochemical and 111 age data for global CAMP. Less than 100 mafic dykes have been reported on the CVL. Even though only 10 of the reported CVL dykes have been dated, with (six Ar-Ar and four K-Ar) ages ranging from 421Ma–15Ma, we identify a tholeiitic dyke on the CVL with Ar-Ar date of 192±7Ma, which is within error of the Ar-Ar age window (200-197Ma) for CAMP tholeiites in NE Brazil, and our 199±3Ma estimate for CAMP world-wide. This CVL tholeiite is similar in its ΔNb=0.056, $(La/Sm)_n$= 1.80 and $(La/Yb)_n$=4.96 to CAMP from NE Brazil Maranhão and Mosquito basins. It's Nb/La ratio (0.73) is well within the unfractionated (MgO>4wt%) tight CAMP range of 0.74±0.21 (n=270). Our hunt for CAMP on the Gulf of Guinea continues with more fieldwork and precise dating of oceanic and continental CVL mafic dykes.

758

Upper Triassic mafic dykes of Lake Nyos II (comparisons with other dykes): Geochemical evidence for paleosubduction-modified mantle beneath Cameroon Line

Dr Takeshi Hasegawa[1], Festus Aka[1], Shota Watanabe[1], Linus Nche[1,2], Asobo Asaah[3], Hikaru Iwamori[4], Tetsuya Yokoyama[5], Hirochika Sumino[4], Mie Ichihara[4], Takeshi Ohba[6]

[1]*Ibaraki University, Mito, Japan,* [2]*Institute for Geological and Mining Research, , Cameroon,* [3]*Industry and Technological Development, , Cameroon,* [4]*University of Tokyo, , Japan,* [5]*Tokyo Institute of Technology, , Japan,* [6]*Tokai University, , Japan*

The explosion that formed Lake Nyos maar on the Cameroon Volcanic Line (CVL) exposed mafic dykes intruding Cambrian monzonites on the lake walls. In previous work (Aka et al., 2018), we reported Upper Triassic K-Ar ages for Nyos dykes and compared them to 347 radioisotopic age data collected over the last ca. 50 years for the CVL system. Here, we present major/trace element and Sr-Nd-Pb isotope data for the Nyos dykes and compare them to similar published data for other Mesozoic, and yet undated mafic dykes, and Cenozoic eruptives (850 data) on the CVL, to infer the petrogenesis, melting dynamics, and nature and evolution of mantle source(s) beneath the CVL. Sixty-five major element data for unfractionated (MgO > 4 wt%) Nyos and other CVL dykes suggest that they are both alkaline and tholeiitic in composition, and that their chemistry has not been compromised by shallow level and post-intrusion processes. LREE/MREE, LREE/HREE, Nb/La and ΔNb ratios for Mesozoic dykes from Nyos, and some dykes from Manjo, Bafoussam and Tikar are indistinguishable from those of Cenozoic CVL eruptives: $(La/Sm)_n=3.57\pm0.84$, $(La/Yb)_n=19.98\pm8.05$, Nb/La=1.33±0.23, ΔNb= 0.21±0.15, suggesting spatio-temporal homogeneity in the asthenospheric plume (HIMU OIB-like) mantle source of these basalts. Bangoua, Dschang, Maham, Bangangte, Kemkem and Figuil dykes differ from Nyos dykes and from CVL eruptives in that the former are characteristically depleted in HFSE with Nb*=0.58±0.15 (n=44) and Ta* = 0.64±0.23 (n=22). Nb* and Ta* are 0.98±0.11 and 1.24±0.05 for Nyos dykes and 1.68±0.34 (n=438) and 1.14±0.15 (n=392) for CVL eruptives. These Nb and Ta depletions in CVL dykes mimic HFSE behavior in 30 global primitive arc volcanics with Nb*=0.29±0.17, Ta*=0.59±0.17 (Schmidt and Jagoutz, 2017). This first report of systematic HFSE depletion on the CVL not caused by crustal contamination is interpreted to result from paleosubduction metasomatism of the CVL mantle.

279

Repeated aeromagnetic survey aiming for monitoring the volcanomagnetic effects and 3D imaging of the magnetization changes

Professor TAKESHI HASHIMOTO[1], Mr. Keiichi Shibuya[1]
[1]*Institute of Seismology and Volcanology, Hokkaido Universisy, Sapporo, Japan*

Aeromagnetic surveying has been conventionally used to investigate the subsurface heterogeneity of rock magnetization through an inversion of static magnetic field anomalies. We have applied the same procedure to the time-varying field and succeeded in three-dimensional imaging of the time variation of magnetization. The achievement was made possible by two technological innovations. Firstly, autonomous drones or uncrewed helicopters have made repetitive surveys practical. The ability to repeat the same route with high precision made detecting temporal changes easier than human-crewed aircraft. Secondly, a 3D inversion code allowing localized sources with sharp boundaries became available by introducing L1-L2 norm regularization.

We extracted time-varying components of magnetic field anomalies from two aeromagnetic datasets acquired in 2013 and 2020 from Mount Tarumae in Hokkaido, Japan. We modeled the distribution of magnetization changes with a 3D inversion code by Utsugi (2019). As a result, a sub-vertical remagnetized column was imaged just below the summit lava dome. The remagnetized region almost overlapped with the micro-earthquake hypocenters. It also overlapped with the most conductive region estimated by Yamaya et al. (2009) based on magnetotellurics. In addition, the Japan Meteorological Agency reported that the maximum fumarolic temperature decreased approximately from 600 to 500°C during the period. Considering these facts, it is likely that the remagnetized area corresponds to a gas conduit in a two-phase state. It may have been cooled due to a reduced supply of high-temperature gas, resulting in the remagnetization. Thermal deformation of the rocks may have caused microseismicity.

Although aeromagnetic surveying applies to any volcano, the high sensitivity of magnetics to short-range sources makes it suitable to detect shallow processes preceding wet eruptions, such as temperature changes in a hydrothermal system to several hundred meters deep.

417

Magma Supply System beneath Aso Caldera, in the Southwest Japan Arc, based on 3-D Electrical Resistivity Models by Network-MT Data

Dr Maki Hata[1], Makoto Uyeshima[1], Mitsuru Utsugi[2], Nobuo Matsushima[3]
[1]Earthquake Research Institute, The University Of Tokyo, Tokyo, Japan, [2]Aso Volcanological Laboratory, Institute for Geothermal Sciences, Graduate School of Science, Kyoto University, Kumamoto, Japan, [3]National Institute of Advanced Industrial Science and Technology, Ibaraki, Japan

Aso caldera, with dimensions of 18×25 km, lies on Kyushu Island in the Southwest Japan subduction zone. The caldera was formed during 270–90 ka by a series of huge eruptions that produced hundreds of cubic kilometers of pyroclastic deposits with VEI-7. A post-caldera cone of Naka-dake in Aso caldera is a quite active volcano, at which magmatic and phreatomagmatic eruptions occurred during 2014–2016, ash emissions continued from July 2019 to June 2020, and a phreatic eruption occurred in October 2021. In and around Aso caldera, network-magnetotelluric (network-MT) surveys, in which the electric potential differences of the ground are measured by using long metallic wires/dipoles (~10 km) of the commercial telephone company's networks, were carried out during 1993–1998 [e.g., Hata et al., 2015]. In addition, we newly performed network-MT surveys around Aso caldera during 2019–2022 in order to obtain data of electric potential differences at a high sampling rate compared to previous data. Then, we found network-MT response functions between the potential differences at respective dipoles and the magnetic field at a geomagnetic observatory in Kyushu. For clarifying magma supply system beneath Aso caldera in a crustal depth scale, we determined three-dimensional (3-D) electrical resistivity models through inversion analysis of the network-MT response functions in two period ranges of 480–20,480 s and 30–20,480 s. In the inversion analysis, we used a data-space inversion code, which can be considered the length and direction of respective dipoles [e.g., Siripunvaraporn et al., 2004]. Moreover, the dipoles are distributed at the uppermost surface of the 3-D models as to cover the area of Aso caldera into reticular formation. In this presentation, we discuss the magma supply system beneath Aso caldera which are inferred from the 3-D resistivity models based on the respective data sets.

804

Progressive shearing during magma mixing in the Streitishvarf composite dyke, Iceland

Miss Tegan Havard[1], Dr Janine Kavanagh[1], Dr Stefano Urbani[1], Dr Elisabetta Mariani[1], Dr Thomas Jones[1], Dr Steffi Burchardt[2]
[1]University Of Liverpool, Liverpool, United Kingdom, [2]Uppsala University, Uppsala, Sweden

The Eastfjords of Iceland are the exhumed remains of Neogene age rift zones, characterised by gently dipping flood basalts, and volcanic centres with associated dyke swarms and silicic intrusions. Here, we focus on the 26m wide Streitishvarf composite dyke which is composed of ~4-5m thick mafic margins and an ~8m thick felsic core separated by a ~3m thick hybrid transition zone. The 10.7 (± 0.2) Ma old dyke is exposed at multiple locations along the >15 km length and displays macro-scale indicators of flow through visually distinct 2-25cm long ellipsoidal mafic enclaves carried in the felsic core. We collected samples for microscale analyses at approximately 1 m intervals along a cross section located in the north of the Streitishvarf peninsula, and complemented this suite with samples from three further exposures. We use a combination of detailed field image analyses and scanning electron microscope (SEM) techniques (energy dispersive spectroscopy [EDS] and electron backscatter diffraction [EBSD]) to investigate how distinct magmas interact within a dyke geometry, and the capture of flow dynamics from macro- to micro-scale.

We find evidence for the progressive mixing of the two end-member mafic and felsic magmas across the dyke, facilitated by shear. The interaction between the two magmas changes spatially along the length of the dyke, likely linked to change in relative height in the crust and distance from the source. Microscopy shows that flow is not only captured in the macro-scale by enclave alignment but also by alignment of plagioclase crystals in the microstructure. Flow indicators are evident in the felsic core and hybrid zones, but are not clearly seen in the mafic margins. We compare our findings of magma flow to previous magnetic fabric analysis work, and relate our findings of the subsurface dynamics to potential implications for magma replenishment and eruption in fissure systems.

805

Investigating mixing of magmas in dykes using analogue experiments

Miss Tegan Havard[1], Dr Thomas Jones[1], Dr Janine Kavanagh[1]
[1]*University Of Liverpool, Liverpool, United Kingdom*

Basaltic fissure systems can display a wide range of behaviour during their eruptive episodes which poses danger to nearby people and infrastructure. Magmas stored within the subsurface plumbing systems that feed basaltic fissure eruptions physically and chemically interact, with strong evidence that physically distinct magmas can mix during ascent. The success and extent of this interaction can determine the nature of eruptive products and eruption longevity. Previously, most analogue experimental studies investigating the interaction of magma in plumbing systems have used chamber-like or pipe-like geometries (i.e. cuboid or cylindrical respectively) and immiscible fluids representing magma mingling. It is difficult to extrapolate these findings to high aspect ratio, dyke geometries that characterise fissure systems and to situations where magmas have mixed. Therefore, to better explore magma mixing in a high aspect ratio geometry, we have designed a new analogue experimental setup and use miscible fluids to capture these dynamics.

We present results from nine scaled analogue experiments where a variety of miscible fluid pairs, representing two magmas of differing composition, interact in a dyke-like geometry. The higher density fluid is layered below the lower density fluid in a stable configuration before the apparatus is inverted to initiate exchange and possible interaction between the fluids. Images were captured over the course of an experiment and processed to quantify mixing and change in Reynolds number over time. Fluid samples were taken to complement the images and track the evolution of the fluid physical properties (density, viscosity) during mixing. We relate our experimental results to (1) evolving magma chemistry and viscosity during subsurface magma replenishment and eruption, and (2) to a natural fissure system in Iceland that displays physical and chemical interaction of multiple magmas.

1182

Identifying and ranking hotspots for potential volcanic ash-induced disruption to electricity infrastructure

Dr Josh Hayes[1,2], Associate Professor Susanna Jenkins[2], Mr Mathis Joffrain[3], Dr Eisuke Fujita[4], Dr John Wardman[5]

[1]GNS Science, Lower Hutt, New Zealand, [2]Earth Observatory of Singapore, Singapore, Singapore, [3]Axa, Paris, France, [4]National Research Institute for Earth Science and Disaster Resilience, Tsukuba, Japan, [5]Maximum Information, London, United Kingdom

Volcanic ash can disrupt electric power supply infrastructure through a variety of mechanisms. At a national or regional scale, there may be many different volcanoes that could affect electricity assets, and different parts of the network may have differing exposure to ashfall hazards and/or vulnerability to disruption. To prioritise emergency response and recovery planning activities, it is necessary to identify volcanoes that are particularly likely to impact electricity systems, and the components of these networks that have a high susceptibility to ash-induced disruption. In this work we present a screening process for identifying hotspot areas particularly prone to ashfall, and volcanoes with the greatest potential to cause interruption to power supply. We apply the approach to Japan, a country with a high density of volcanoes and electricity infrastructure assets. Using a grid-based amalgamated weighted scoring method, we score and weight each grid cell based upon the level of importance of the electrical components contained within that cell. This is then coupled with probabilistic volcanic ash hazard and vulnerability models to assign a potential 'disruption score' for each grid cell. Our approach identifies Fujisan as a volcano that can produce particularly disruptive ash footprints, due to its proximity and positioning relative to the Tokyo Bay Area. However, when factoring in eruption probabilities, Fujisan drops several places in the rankings. Major urban centres, including the Tokyo Bay Area, are predictably key disruption hotspots, but we also identify hotspots where major power generation sites are located. The methodology we have developed is intended as an initial screening process to identify areas of particular concern as part of national or regional infrastructure investigations that may warrant further and in-depth risk and resilience analyses.

1170

Towards a national volcanic hazard and risk model for Aotearoa New Zealand: Scoping the needs, gaps, and opportunities

Dr Josh Hayes[1], Dr Graham Leonard[1], Professor Thomas Wilson[2], Dr Rebecca Fitzgerald[1,3], Dr James Williams[2], Dr Christina Magill[1], Professor Mark Bebbington[3], Dr Stuart Mead[3], Professor Jan Lindsay[4], Dr Alana Weir[2], Mr Rodrigo Calderon[2]

[1]GNS Science, Lower Hutt, New Zealand, [2]University of Canterbury, Christchurch, New Zealand, [3]Massey University, Palmerston North, New Zealand, [4]University of Auckland, Auckland, New Zealand

Volcanic hazards have been identified as a key strategic risk for Aotearoa New Zealand. There is a strong desire from central and local government agencies for better characterisation of volcanic hazard and risk, which has catalysed several major volcano hazard/risk/resilience research programmes in Aotearoa New Zealand. Thus, there is currently a unique strategic opportunity to use this enhanced volcanic risk science to develop a framework that enables transferability of volcanic hazard and risk models across the many different volcanoes of country. To achieve such an outcome requires substantial scoping to identify needs, gaps, and opportunities to maximise the benefit for nation. Here, we introduce a project scoping the potential for a national volcanic hazard and risk model framework in Aotearoa New Zealand. A gap analysis is being undertaken across the four test cases (Taranaki, Tongariro National Park, central Taupo Volcanic Zone calderas and Auckland Volcanic Field) to identify where data is missing and/or framework limitations exist. Methods are being developed to deal with these gaps within the framework, allowing for consistent application of the framework across all volcanoes. Loss and impact assessments will be conducted using the framework for Taranaki, Ruapehu and a caldera volcano to test consistency at different types of volcanoes with different hazards and in different geographic settings. This project is anticipated to accelerate, strengthen, and coordinate the development of nationally applicable volcanic risk information.

251

A new HPHT rheometer for measuring the viscosity of volatile-bearing magmas.

Professor Heidy Mader[1], Dr Richard Brooker[1], Mr Laurence Breeze[1], Mr Charles Clapham[1], Miss Francesca Haywood[1], Dr Amanda Lindoo[1], Mr Gerald Mwale[1]
[1]*University of Bristol, Bristol, United Kingdom*

Magma rheology provides the primary control on magma flow and eruptive dynamics. Consequently, reliable measurements of the viscosity of volatile-bearing magmatic melts at the high pressures and high temperatures (HPHT) experienced in magma chambers and conduits are needed to constrain models. To-date measurements of the viscosity of high temperature melts have been largely limited to anhydrous melts (ambient P, HT) due to the technical challenges posed in making rheological measurements inside a pressurized device. In this talk, we will present a new HPHT rheometer that is capable of achieving pressures and temperatures up to 250 MPa and 1200C and measuring viscosities in the range 100Pas-30,000Pas. This is a concentric cylinder HPHT instrument that connects an external rheometer head to an internal spindle using a magnetic coupling. We will discuss the technical features and challenges that result in an uncertainty on the viscosity measurements of ±5%. We will also present preliminary data obtained for pantellerite melts.

194

Are caldera faults sintered volcanic conduits without evidence for catastrophic rapid slip events?

Miss Francesca Haywood[1], Dr Fabian Wadsworth, Dr Dave McGarvie, Dr Richard Brown, Miss Annabelle Foster

[1]University Of Bristol, Bristol, United Kingdom, [2]Durham University, Durham, United Kingdom

Caldera subsidence is accommodated by the removal and eruption of large volumes of (mostly) fragmental magma through the crust, often along caldera ring faults or between foundering crustal blocks. Very large caldera-forming eruptions have never been witnessed, and so the fragmental magma flux and associated caldera subsidence rates are poorly constrained. The presence of aphanitic fault-filling rocks in some calderas has been used to argue for a 'superfault' model, in which caldera fault slip rates are high enough to cause frictional melting. We revisit this model using textural analyses at the classic Glencoe Caldera locality, and find that the caldera fault fill is the sintered remnant of the fragmented eruptive products, and that frictional melting is not required. We support this with geochemical mass balance calculations that lead us to conclude that: (1) the fault fill is a volcanic remnant associated with the eruption; (2) partially resorbed quartz grains in the glassy groundmass originate from the country rock quartzite and resorb when incorporated into the quartz-undersaturated sintered mass; and (3) that the late-stage fault intrusions represent the mush from which the eruptive melts are derived. In the context of large caldera-forming eruptions, our model implies that the caldera faults associated with large caldera-forming eruptions are active throughout much of a sustained eruption, rather than moving only rapidly and briefly.

459

Evaluating magma reservoir stability at the actively deforming Soufrière Hills Volcano, Montserrat

Dr Matthew Head[1], Prof Patricia Gregg[1], Dr James Hickey[2], Dr Yan Zhan[3], Dr Karen Pascal[4,5]
[1]University of Illinois at Urbana-Champaign, , United States, [2]University of Exeter, , United Kingdom, [3]The Chinese University of Hong Kong, , Hong Kong SAR, [4]Montserrat Volcano Observatory, Flemmings, Montserrat, [5]University of the West Indies, , Trinidad and Tobago

Soufrière Hills Volcano (SHV) is an andesitic, composite volcano on the island of Montserrat, located within the Eastern Caribbean island arc. The current eruptive episode of SHV began in 1995 and is characterised by phases of magma extrusion, dome-building and destruction, punctuated by periods of intra-eruptive repose. These periods of quiescence are accompanied by inflation of the ground surface until the next phase of activity, as revealed by geodetic monitoring across Montserrat. There have been 5 distinct eruptive phases to date; the most recent of which ended in 2010, making the present repose period the longest since the 1995 eruptive episode began. SHV has been actively deforming throughout its current period of repose, attaining up to ~150 mm of vertical displacement, and raising questions about when the eruptive phase may resume. In this study, we investigate the sustained inflation recorded by continuous GPS (cGPS) stations since February 2010. We aim to determine the magmatic overpressures required to drive the observed deformation, and identify the thresholds at which mechanical failure may be expected to occur. We employ the Ensemble Kalman Filter (EnKF), adapted for analyses of volcanic deformation, to sequentially assimilate and invert the cGPS observations. We couple the EnKF routine with Finite Element Method (FEM) thermomechanical models to estimate the best-fit parameters of the deformation source at each time step. The FEM approach offers the ability to incorporate island topography and surrounding ocean bathymetry, as well as heterogeneous crustal properties obtained from seismic tomography. We apply a gravitational load to the model domain and evaluate brittle failure criteria to assess any changes in the mechanical stability of the deforming magmatic system. With the extended period of quiescence and continuous deformation presently observed at SHV, an understanding of potential eruption triggers is critical for assessing future eruptive hazard.

462

Using statistical data assimilation to constrain volcanic deformation at Seguam Island, Alaska

Dr Matthew Head[1], Prof Patricia Gregg[1], Mr Jiahui Wang[2], Prof Zhong Lu[2]
[1]University of Illinois at Urbana-Champaign, , United States, [2]Southern Methodist University, , United States

Seguam Island is a volcanic centre located within the central Aleutian arc, Alaska, comprising two remnant Quaternary calderas and several post-caldera cones. Pyre Peak, an active stratovolcano that rises above the rim of Seguam's western caldera, is the primary site of modern volcanic activity and most recently erupted in 1993. There is no geodetic or seismic instrumentation on Seguam Island, so recognising phenomena associated with volcanic unrest is reliant on remote sensing methods such as Interferometric Synthetic Aperture Radar (InSAR). Previous studies have identified episodic inflation and deflation of the eastern caldera and sustained post-eruptive subsidence in the vicinity of Pyre Peak. Here, we present newly processed InSAR data acquired by Sentinel-1 from June 2016 to October 2021, totalling 101 observations. This data reveals similar deformation patterns to those previously observed at Seguam Island; continuous subsidence near Pyre Peak, at a rate of ~1 cm/yr, and ~4 cm of uplift within the eastern caldera. To constrain the causative sources of the observed deformation, we employ the Ensemble Kalman Filter (EnKF), adapted for analyses of volcanic deformation, to sequentially assimilate and invert the InSAR observations. We use the Finite Element Method (FEM) to construct full 3D models of Seguam Island, and combine them with the EnKF routine to determine the best-fit parameters of the deforming magmatic system. This approach provides the necessary flexibility to explore the observed uplift and subsidence signals. Initial results indicate two distinct sources, and that the deformation patterns are controlled by the island topography. With the magmatic system composed of two contrasting components (i.e., inflationary and deflationary), we investigate how the coupling of the deformation sources affect the induced crustal stress field. We evaluate stress-based failure criteria within the crustal domain, and consider the implications for the evolution of the magmatic system underlying Seguam Island.

302

Mesh Design for inversion model resolution of the magmatic system beneath Mount Tongariro, New Zealand

Dr Wiebke Heise[1], Dr Charles Williams[1], Dr Peter McGavin[1], Mr Grant Caldwell[1], Dr Ted Bertrand[1], Dr Stephen Bannister[1], Dr Yoshiya Usui[2], Dr Geoff Kilgour[3]

[1]GNS Science, Lower Hutt, New Zealand, [2]Earthquake Research Institute, University of Tokyo, Tokyo, Japan, [3]GNS Science, Wairakei, New Zealand

Tongariro Volcanic Centre is a large andesite-dacite stratovolcano complex located at the southern end of the Taupo Volcanic Zone which is located above the subduction of the Pacific plate below the Australian plate in the central North Island of New Zealand. Data from 128 magnetotelluric (MT) measurements have been modelled with a 3-D inversion code which uses an unstructured tetrahedral mesh and can model the pronounced topography of the Tongariro Volcanic Centre.

We test different mesh sizes to investigate the resolution of the MT model at different depths. Main focus was the depth were magma storage is predicted at ~ 5-10km depth. We show the influence of mesh design and smoothing parameter alpha on the 3D-inversion result.

The resulting 3-D resistivity model shows the near surface hydrothermal system and its connection to a deeper magmatic source. Comparison with the seismic tomography shows a good correlation of low Qp and low electrical resistivity values suggesting that the magmatic source at depth extends to the east of the volcanic complex. Together seismicity, electrical resistivity, seismic tomography and petrological data give a coherent picture of the magmatic system of the Tongariro volcanic centre that agrees well with the conceptual geological model.

1051

THE TEMPO OF VOLCANISM AT ULTRAHIGH PRECISION

Tyler Cantrell[1], Dr Matthew Heizler[1], Dr Jake Ross[1], Dr Matthew Zimmerer[1], Dr Peter Lipman[2], Dr William McIntosh[1]
[1]New Mexico Tech, Socorro, United States, [2]U.S. Geological Survey, Menlo Park, United States

A grand opportunity and challenge for geochronology is to determine the temporal evolution of large-volume silicic volcanism at the maximum precision provided by 40Ar/39Ar sanidine data. Because single crystal sanidine dates of mid-Cenozoic volcanic rocks are ubiquitously dispersed when measurement precision approaches ~±0.3 per mil, ambiguity of the calculated eruption age inhibits accurate estimation of volcanic and magmatic processes that occur during short (ca. 0-20 ky) intervals. We attempt to understand and mitigate the causes of dispersion via detailed experiments and also evaluate the accuracy of calculated eruption ages for stratigraphically constrained units from the Southern Rocky Mountain volcanic field, USA.

Possible mechanisms that may lead to single-crystal age dispersion include 1) over estimation of analytical precision, 2) excess argon in melt inclusions, and 3) crystal-to-crystal variation in neutron dose during irradiation. For (1), homogeneous aliquots of well-mixed sanidine yield normal distributions, indicating that analytical precision is accurately estimated. For (2), comparison of single crystals with and without melt inclusions generally show no measurable age difference indicating that inclusions in mid-Cenozoic sanidine are likely only minor sources of dispersion. For (3), well-constrained geometric control on crystal placement during irradiation shows that grain-to-grain variation in neutron flux contributes significantly to dispersion, but that flux variation itself cannot account for the total observed dispersion.

Two aerially and near-temporally equivalent mid-Cenozoic eruptive sequences yield stratigraphically consistent sanidine ages. Pre- and postcaldera lavas associated with the ~5,000 km3 28.2 Ma Fish Canyon Tuff erupted within 20 ± 11 ky. Four compositionally distinct ~27 Ma ignimbrites and associated caldera-filling lavas, totaling >2,000 km3, erupted from within the Fish Canyon caldera during a span of 28 ± 13 ky. Rapid durations of spatially focused silicic volcanism must be accommodated within any interpretation of large-volume magmatic processes and integrated into hazard assessment at active calderas.

363

EXCITE: free-of-charge transnational access to electron and X-ray microscopes

Dr Eric Hellebrand[1], Dr Sylvia Walter[1], Dr Veerle Cnudde[2], Dr Oliver Pluemper[1], Dr Geertje ter Maat[1]
[1]*Utrecht University, Utrecht, Netherlands,* [2]*Ghent University, Ghent, Belgium*

The characterization of volcanic materials by X-ray and electron microscopic techniques is an established component of all modern volcanological studies that involve field-based sampling, or lab-based experiments. Particularly the 2D- and 3D imaging of volcanologically relevant variables, such as porosity, are essential for our understanding of conduit dynamics and hazard assessment. Access to length scales ranging from macroscopic pores down to nano-scale cannot be obtained by one single technique, but requires characterization by several specialized research instruments. An efficient analytical workflow that captures the physical and chemical properties across eight orders of magnitude is commonly not available at most academic institutions. There is an urgent need to make multi-scale, multi-dimensional characterizations of all Earth and planetary materials available to a broad spectrum of Earth-science disciplines.

To overcome this challenge, 24 imaging facilities joined forces to establish EXCITE, a large-scale infrastructure project supported by the European Union's Horizon-2020 program. EXCITE enables free-of-charge access to high-end microscopy facilities in 9 European countries. Analytical techniques and scientific expertise offered through the EXCITE network include X-ray tomography, EPMA, FIB-SEM, TEM, as well as SEM-based imaging, element mapping, EBSD, cathodoluminescence and other specialized imaging tools. Transnational access calls are announced twice per year on the website: excite-network.eu. Awarded projects are required to sharing results through open-access data publications.

EXCITE is also developing imaging advancements that will extend current leading-edge. In particular, the EXCITE strategy is to integrate joint research programs with networking, training, and trans-national access activities, to enable both academia and industry to answer critical questions in Earth-materials science and technology. As such, EXCITE builds a community of highly qualified Earth scientists, develops correlative imaging technologies providing access to world-class facilities to new and non-expert users that are often hindered from engaging in problem-solving microscopy of Earth-materials.

800

From magma to tuff: using sanidine to interrogate the physical distribution plumbing systems and the Lava Creek Tuff, Yellowstone

Stacy Henderson[1], Dr. Madison Myers[1], Dr. Colin Wilson[2], Dr. Darin Schwartz[3]
[1]Montana State University, Bozeman, United States, [2]Victoria University of Wellington, Wellington, New Zealand, [3]Boise State University, Boise, United States

Recent results from the 2.08 Ma Huckleberry Ridge Tuff (Swallow et al., 2019, J Petrol 60, 1371, for overview) have demonstrated great complexity in its eruptive style and magmatic plumbing systems. In contrast, the 1000 km3 0.63 Ma Lava Creek Tuff (LCT) has not been investigated in enough detail to determine whether it, too, shows comparable eruptive and compositional complexities. Currently, the LCT is divided (Christiansen, 2001, USGS Prof Pap 729-G) into two members, A and B, defined from reversals in welding profiles and the presence of phenocrystic amphibole in LCT-A. However, this picture is known to be too simple from the discovery of two new LCT-age ignimbrite units in the Sour Creek Dome area (Wilson et al., 2018, Bull Volcanol 80, 53). Here we present single-grain sanidine cathodoluminescence (CL) imaging and crystal chemical data that are being used to reconstruct emplacement packages in the LCT and relate these to vent sources and parental magmatic bodies.

Bulk ignimbrite samples have been collected at eight locations around the caldera rim, with preliminary data from five samples, representing three locations, presented here. CL imaging demonstrates that samples of both LCT-A and -B contain four to seven visually distinct populations, which vary in proportion by site locality. Remarkably, electron microprobe and bulk sanidine ID-TIMs analyses show that Or%, Ba chemistry, and Pb-isotope compositions are strongly sample dependent, including stratigraphically at the same location, rather than related to visual populations or existing members. These preliminary data suggest that although the LCT may have been sourced from discrete magma sources similar to the HRT, the unzipping of the caldera and tapping of these discrete magma bodies appears to be more systematic, potentially indicating multiple vent sources. Samples from additional localities, coupled with melt chemistry will help constrain more confidently how many magma sources were involved.

1207

Can signatures of lava flow dynamics yield unique rheological model parameters?

Mr James Hewett[1], Mathieu Sellier[1], Miguel Moyers-Gonzalez[2], Dale Cusack[3], Ben Kennedy[3]
[1]Department of Mechanical Engineering, University of Canterbury, , New Zealand, [2]School of Mathematics and Statistics, University of Canterbury, , New Zealand, [3]School of Earth and Environment, University of Canterbury, , New Zealand

Understanding the fluid dynamic behaviour of lava flows allows for more accurate models and enhances the suite of tools available for mitigating the adverse effects of volcanic eruptions. A critical component of modelling lava flows is resolving its rheology, that is describing its deformation response due to forces, for example, when flowing over terrain (bounding surfaces) and down a slope (gravity). In this work, we explore modelling the lava rheology as a Herschel–Bulkley fluid, which contains some consistency, a yield stress (a threshold of stress required before fluid motion), and a power law index (representing either shear-thinning, Newtonian, or shear-thickening). The challenge for determining these three parameters based on just field measurements of the free surface of lava flows is that the mathematical problem may not be well-posed. We report on our parameter estimation studies which used optimisation methods to minimise the discrepancy between modelled and observed free surface dynamics.

574

Can we help optimise volcano GPS networks using stress-based numerical modelling?

Dr James Hickey[1], Karen Pascal[2,3], Racquel Syers[2]
[1]University of Exeter, , United Kingdom, [2]Montserrat Volcano Observatory, , Montserrat, [3]Seismic Research Centre, University of the West Indies, , Trinidad & Tobago

Volcano deformation is a key observable during volcanic unrest and can ultimately help track and forecast the subsurface migration of magma and its possible eruption at the surface. Continuous GPS (cGPS) networks excel at constraining the temporal patterns of volcano deformation and providing the 3 main components of surface displacement, but can be hindered by their discrete point locations and possibly miss key spatial information. We use the cGPS network at Soufrière Hills Volcano (SHV), Montserrat, to demonstrate how sites within a GPS network may or may not be ideally situated to profit from an optimal signal:noise ratio. Using a range in complexity of models, from 3D Finite Element models incorporating topography and tomography-derived subsurface heterogeneity through to homogenous half-space analytical models, we explore cumulative surface deformation patterns expected from a subsurface distribution of literature-derived deformation source configurations. For SHV, peak horizontal (east-west, and north-south) deformation is located off-shore, highlighting the difficulties with optimising GPS design on small ocean-island volcanoes. However, onshore areas are also identified where signal:noise ratio is expected to be high. Peak vertical deformation is shifted east of the surface expression of the deformation source centroid due to the impact of edifice topography. In general, topography/bathymetry plays a greater role in altering the relative distribution of surface displacement patterns than subsurface heterogeneity. Our work identifies areas of Montserrat that have high expected signal:noise ratio that could be good candidates for future GPS sites or are already hosting established GPS sites, and our methods can be easily adapted to test for similar patterns and GPS site efficiencies at other deforming volcanoes worldwide.

572

Social sensing a volcanic eruption and its impacts: application to Kīlauea 2018

Dr James Hickey[1], James Young[1], Michelle Spruce[1], Ravi Pandit[1,2], Hywel Williams[1], Rudy Arthur[1], Wendy Stovall[3], Matthew Head[4]
[1]University of Exeter, , United Kingdom, [2]Cranfield University, , United Kingdom, [3]USGS, , USA, [4]University of Illinois at Urbana-Champaign, , USA

Protecting lives and livelihoods during volcanic eruptions is a key challenge for volcano monitoring and emergency management organizations. It is complicated by scarce knowledge of how communities respond in times of crisis and the lack of widely accepted best practise in communicating hazard and risk mitigation information. Social sensing is the systematic analysis of unsolicited social media data to observe real-world events. We use social sensing to investigate the impacts of a volcanic eruption and analyse the spread of information across social media. We focus our analyses on data sourced from Twitter for the 2018 eruption of Kīlauea, Hawaii, USA. Our initial dataset contains over 160,000 tweets identified using a 'Kilauea' keyword search preceding, during, and following the eruption. We train and apply a machine learning algorithm to classify and extract relevant tweets related to the eruption, reducing our dataset to ~140,000 tweets. The volume of relevant tweets explodes in early May, coincident with the onset of unrest and beginning of the eruption, then slowly tails off with a return to background levels in late August. Ongoing manual topic analysis will identify key themes of discussion throughout the eruption and recovery. Automated sentiment analysis shows a minor shift towards more negative emotions at the start of the eruption. There is no correlation between sentiment score and distance from the eruption. A large proportion of relevant tweets include links to external URLs, with YouTube, USGS Volcanoes, and a local news agency being the top shared web domains. Our work shows how hazard and risk information is disseminated, discussed, and reacted to on Twitter, which informs our understanding of community response actions and how misinformation can spread. Social sensing shows great promise for further development and application in volcanology and other hazard sciences.

1387

Creative methods from the 'Landscapes of the Mind' project for advancing science with stakeholders

Dr Anna Hicks[1], Dr Nicole Manley[1], Dr Carol Cotterill[2]
[1]British Geological Survey, Edinburgh, United Kingdom, [2]Lamont-Doherty Earth Observatory, Columbia University, P.O. Box 1000, 61 Route 9W, USA

Landscapes of the Mind is a network-based research project working towards elevating creative practice to broaden the dialogue, and influence decisions, about how landscapes are remembered, preserved or changed. The network comprises artists and researchers from a variety of disciplinary backgrounds from musicians to archaeologists, all bringing their various personal experiences, emotions and disciplinary norms to the project.

Here we present the approaches and findings from three participatory activities, relevant to studies about hazard and risk in volcanic environments. The first is a visual matrix – an innovative arts-based method where participants bring associations to image-based material, rather than analysing the images as might happen in a focus group. Inspired by ‘creative expressions’ that each participant presented, themed around ‘Landscape’, ‘Water’ and ‘Time’, we explored ideas around our struggle to make sense of time, cultural/societal differences in landscapes to revere or to fear, and our imaginations of future landscapes. Both matrices were a novel and interesting way to explore our thoughts, memories and emotions about landscape.

Our second activity, ‘Transformational Moments’, was designed to build on storytelling ideas that emerged from the STREVA project. The aim was to share our own personal 'landscape transformational moments', not only to impart ‘back stories’, but also to explore what commonalities there might be between a disparate group.

The final event was a creative retreat at a sculpture park, where each participant created an artwork inspired by ways to work with stakeholders/decision makers. Does trying to change the mind of the decision maker themselves matter (if possible?), or is addressing the delivery/process of uncovering and sharing ‘evidence’, more important? Much of our decision making is based on experience and emotive response, and more knowledge is required to understand how we can bridge creative and traditional evidence-based decision-making around volcanic hazard and risk.

497

Precursory deformations related to the 2017 eruption of Shinmoe-dake volcano (Japan) detected by PALSAR-2 InSAR

Dr Yuji Himematsu[1], Dr Taku Ozawa[1]
[1]*National Research Institute For Earth Science and Disaster Resilience, Tsukuba, Japan*

Volcanic inflation prior to eruptions is one of the indicators of pressurization within a magma source or a subsurface hydrothermal system associated with the supply of materials or heating from deeper depths. Satellite SAR data have been helpful as regards detecting precursory deformations on or around active craters with high spatial resolution and improving the accuracy when modeling pressure source geometry. Here, we investigate the precursory ground deformation associated with the October 2017 eruption of Shinmoe-dake volcano using satellite SAR data and discuss the physical mechanism based on modeling results.

We applied ALOS-2/PALSAR-2 data observed in 2016–2017 to a multi-temporal InSAR analysis for investigating the spatiotemporal variation in ground deformation on Shinmoe-dake volcano. The results of the SAR time-series analysis showed both an asymmetric pattern of line-of-sight (LOS) shortening that dominated the near-range side of the volcanic flank and an LOS extension on the crater. The signal amplitude of the LOS shortening on the volcanic flank became more significant from May–June 2017 until the October 2017 eruption.

Preliminary modeling results using analytical solutions of surface deformations imply that a spatial pattern similar to the observed deformation can be reproduced by an outward displacement in the radial direction of an open pipe located 300–500 m beneath the surface. The model geometry does not contradict the results of previous geophysical studies related to the 2011 eruption, which suggested that a volcanic conduit at shallower depths has developed on Shinmoe-dake volcano. The spatial pattern of deformations caused by the overpressure of a closed pipe provide a worse fit than those of an open pipe, implying that the lava dome in the crater plays a minor role as a plug that increases pressure within a volcanic conduit.

512

Analysis of seismic records related to the eruptive activity at Ioto, Japan, in July and August 2022

Dr Takashi Hirose[1], Dr Hideki Ueda[1], Dr Tomofumi Kozono[1], Dr Masashi Nagai[1]
[1]*National Research Institute for Earth Science and Disaster Resilience, Tsukuba, Japan*

Ioto is an active caldera volcano located 1,200 km south of Tokyo, Japan. Active seismic, tectonic, and geothermal activities are ongoing at this volcano. The analysis of seismic records on the island is important for monitoring the activity at Ioto. Detailed analysis of seismic waveforms is also useful for studying the mechanism of eruptions. In this presentation, we report the results of our analysis of seismic records associated with the eruptive activity off the eastern coast of Ioto that began on July 11, 2022.

We analyzed continuous seismograms from July 11 to August 20, 2022, for five seismic stations at Ioto maintained by the National Research Institute for Earth Science and Disaster Prevention and the Japan Meteorological Agency. Totally 9396 events were detected during the entire study period. From the spectral analysis results, it was inferred that the detected events were monochromatic tremors with a peak in the range of 0.5–1.2 Hz.

During the study period, the number of monochromatic tremors increased and decreased repeatedly. We found four active periods; monochromatic tremors occurred at almost equal intervals during these periods. In contrast, the intervals of monochromatic tremors during quiet periods were more scattered than those during active periods. Temporal changes in tremor waveforms were examined by calculating waveform correlations for all combinations of tremors, and it was found that the waveforms of tremors that occurred within the same active period were similar. On the other hand, during the quiet period, the waveforms of tremors did not show high similarity even though they occurred in close temporal proximity to each other. Further detailed investigations may provide new insights into the mechanism of eruptions at Ioto.

Acknowledgments: We would like to thank the Japan Meteorological Agency for providing continuous seismograms.

1165

Volcanic Disaster Waste Clean-up in Rural and Urban Environments

Miss Esther Hiscock[1], Professor Thomas Wilson[1], Doctor Alana Weir[1], Doctor Joshua Hayes[2]
[1]University of Canterbury, , , [2]GNS Science, ,

Volcanic disaster waste clean-up is challenging due to the volume of waste produced, the variety of waste types, the spatiotemporal extent of the waste, and generally limited availability of potential disposal sites. Effective clean-up planning is important for areas affected by volcanic disaster waste to help shorten recovery time and build resilience. This study aims to develop a multi-criteria selection process that can be used in clean-up decision making for the management of volcanic waste products in urban and rural environments, and identifies potential waste disposal locations. Long-duration, multi-phase, multi-hazard Taranaki Mounga eruption scenarios are used to calculate disaster waste volume estimations to demonstrate how the clean-up model and disposal site selection workflow can be applied. For example, a high-impact Taranaki eruption scenario can amount to ~4,200,000 m3 of tephra deposits in New Plymouth (population ~69,000), Inglewood (population ~3,600), Stratford (population ~9,900), Hāwera (population ~9,800) urban areas, and the State Highways. For comparison, this is approximately double the total soil liquefaction clean-up from the 2010-2011 Christchurch Earthquake Sequence (to date Aotearoa New Zealand's most costly disaster), highlighting that tephra clean-up and waste disposal site planning will be important to deal with the large quantities of volcanic waste following an eruption in Taranaki. The approach developed in this work will aid in creating more efficient plans for disaster waste clean-up, assessing the suitability of current debris disposal sites for volcanic waste and identify new disposal sites. This work aims to contribute to volcanic resilience research in the Taranaki region, Aotearoa and improve global understanding of clean-up requirements for urban and rural environments in a volcanic context.

1033

The relationship between pre-existing strike-slip faults and eruptive vent openings during the 2021 Fagradalsfjall eruption, Iceland

Dr Ásta Rut Hjartardóttir[1], Dr. Tobias Dürig[1], Dr. Michelle Parks[2], Dr. Vincent Drouin[2], Mr. Vigfús Eyjólfsson[1], Dr. Hannah Reynolds[1], M.Sc Esther Hlíðar Jenssen[2], Dr. Birgir Vilhelm Óskarsson[3], Dr. Joaquín M. C. Belart[1,4], Dr Páll Einarsson[1], Dr. Joel Ruch[5], M.Sc. Nils Gies[3], Dr. Gro B. M. Pedersen[1]

[1]Institute Of Earth Sciences, University Of Iceland, Reykjavík, Iceland, [2]Icelandic Meteorological Office, Reykjavík, Iceland, [3]Icelandic Institute of Natural History, Reykjavík, Iceland, [4]The National Land Survey of Iceland, Akranes, Iceland, [5]University of Geneva, Geneva, Switzerland

An eruption started on a ~180 m long fissure on the 19th of March 2021 at the Reykjanes peninsula, Iceland, after a NNE-oriented dike intrusion had been ongoing for ~3 weeks. The eruption occurred in the Fagradalsfjall volcanic system, which has been less active during the Holocene than other volcanic systems on the Reykjanes peninsula. A zone of strike-slip faults, which are mostly oriented to the N-S, extends from west to east along the Reykjanes peninsula. This zone crosses the area where the 2021 eruption occurred. A high spatial and temporal resolution ICEYE InSAR interferogram spans ~17 hours before the eruption and ~7 hours after it started. This interferogram shows movements on several N-S strike-slip faults, mostly north of the eruption. The dike crossed some of these strike-slip faults. After the initial eruption had been ongoing for two weeks, several new eruptive fissure openings occurred over a time-span of eight days. Interestingly, these eruptive fissure openings occurred where the dike crossed the strike-slip faults, both the ones which had been detected on the ICEYE interferogram, and also a strike-slip fault previously identified on an aerial photograph and Digital Elevation Model. This suggests that high-resolution InSAR images along with information on dike openings can be used to estimate risk and possible locations of new vent openings. The eruption was monitored by both video cameras and time-lapse cameras, where some of the new fissure openings were detected. The time lapse from first visible steam until glowing lava was detected ranged between 15 s and 23 minutes.

1031

The characteristics of volcanic systems at the periphery of rift zones, examples from the Tungnafellsjökull and Hofsjökull volcanic systems, Iceland

Dr Ásta Rut Hjartardóttir[1], Dr. Páll Einarsson[1], Dr. Michelle Parks[2]
[1]*Institute Of Earth Sciences, University Of Iceland, Reykjavík, Iceland,* [2]*Icelandic Meteorological Office, Reykjavík, Iceland*

Iceland is located at the Mid-Atlantic plate boundary. There, the Eurasian and the North American plates are diverging at a rate of about 2 cm/yr. In central Iceland, most of the spreading occurs along the Northern and the Eastern Volcanic Zones. On the other hand, geodetic measurements indicate that the northern part of the Western Volcanic Zone and the Central Iceland Volcanic Zone have very little or no deformation. In this study we focus on the Hofsjökull and Tungnafellsjökull volcanic systems in the Central Iceland Volcanic Zone. These volcanic systems have clear calderas and fissure swarms, with dense network of faults and a few eruptive fissures from the Holocene. Most of the fissure swarms at the active plate boundary are NNE oriented, i.e. close to being perpendicular to the plate spreading vector. However, the northern part of the Hofsjökull fissure swarm is not on the main plate boundary and is NNW oriented. Therefore, alternate processes, other than plate spreading, must be considered to explain the orientation of the fissure swarm. The Tungnafellsjökull fissure swarm shows evidence of recent movements, as clear sink holes are located along some of its faults. In addition, seismicity in the volcanic system correlates with seismic unrest in the neighbouring Bárðarbunga volcanic system. During the 1996 and 2014 unrest, eruptions, and dyke intrusions in the Bárðarbunga system, seismicity also increased in the Tungnafellsjökull fissure swarm, and InSAR interferograms showed deformation along the faults with the fresh sink holes in 1996. Thus, some deformation can occur in the Tungnafellsjökull fissure swarm, apparently as a response to unrest in the Bárðarbunga volcanic system.

1465

DEEPEN, COMPASS and IDDP-3 – locating, drilling into and producing from super-hot geothermal systems

Dr Vala Hjorleifsdottir[1], Dr Gunnar Gunnarsson[1], Kolbrún Ragna Ragnarsdóttir[2]
[1]OR - Reykjavík Energy, Reykjavík, Iceland, [2]ON Power, Reykjavík, Iceland

It is a common practice to drill make-up wells to maintain the production capacity of geothermal fields as they decline during production. As time passes, make-up drilling becomes less economically feasible as all promising targets, within the reach of conventional drilling techniques, have been drilled into. At that point, the field can only be extended downwards, towards the heat source into possibly super-hot formations containing high enthalpy fluids.

Several wells have been drilled into super-hot or supercritical formations globally. However, to our knowledge, no one has yet succeeded in producing electricity using fluids from these formations. There are several challenges to achieving this goal, both in defining, finding and understanding the optimal targets, and in designing wells and surface installations that can withstand high temperatures and corrosive fluid chemistry. OR-Reykjavík Energy together with its subsidiary, ON Power, is currently leading three projects aimed at producing from the deeper part of the geothermal systems to support their Hellisheiði and Nesjavellir geothermal power plants. In this presentation we will briefly discuss their current status and expected results.

DEEPEN, a Geothermica ERA-NET project, aims at derisking the exploration for superhot fluids, by developing methods co-interpreting different datasets to find super-hot fluids, as well as acquiring new data at both Hengill (Iceland) and Newberry (USA) volcanoes.

COMPASS, a Horizon Europe project, is focused on constructing a stable deep well, by advancing methods for cementing and cladding.

IDDP-3 is the third well of the Iceland Deep Drilling Program. The goal is to drill into super-hot formations and successfully produce from them. This project is getting started and currently the aim is to drill in 2026. The timeline is critically dependent on developing well technology that can withstand the harsh environment.

1374

Photographs of eruptions in Iceland - use in research and sharing via EPOS

Mrs Thórdís Högnadóttir, Prof Magnús T. Gudmundsson[1], Emerita Gudrún Larsen[1], Anna Margrét Sigurbergsdóttir[1], Kristín Thorsteinsdóttir Sonnentag[1]
[1]*Nordvulk, Institute of Earth Sciences, University of Iceland, Reykjavík, Iceland*

The photos taken of the large Katla eruption in 1918, its eruption plume, the jokulhlaup path with stranded icebergs, and from the eruption site in the Mýrdalsjökull ice cap in 1919, set this event apart from previous eruptions in Iceland. They have allowed analysis and understanding of Katla 1918 that is not possible for earlier eruptions. This includes establishing the location of the vents and observing changes in eruption intensity and style. Large number of photographs exist of later eruptions, including the important eruptions of Hekla 1947-48 and Surtsey 1963-67. However, no reasonably comprehensive, accessible photo collections have been in place for volcanic eruptions in Iceland. At the Institute of Earth Sciences, University of Iceland, monitoring of volcanic eruptions, mostly from aircraft, has been done in a systematic way since 1996, a period with nine eruptions. The photos from the eruptions of Gjálp in 1996 and Grímvötn in 1998 were taken on film and exist mostly as slides. From 2000 onwards, photos are mostly digital. EPOS (European Plate Observing System) is a multidisciplinary, distributed research infrastructure that facilitates the integrated use of data, data products, and facilities from the solid Earth science community in Europe. Under EPOS, an Icelandic infrastructure project, EPOS-Iceland, has as one of its aims to create a data base of photos from eruptions in Iceland. The eruptions to be included in the base are from the period 1996-2022. The images will include detailed metadata, including the relevant data on event, location, time, type of event, phenomena observed. The EPOS data bases are set up using the FARE principle and the images should therefore be available for future research by those interested in exploiting the data.

1179

Investigating the Morphology of a Lunar Sinuous Rille using Remote Sensing and Terrestrial Analogs

Mr Orion Hon[1]
[1]*LPL/ U. of Arizona, Tucson, United States*

Lunar sinuous rilles are thought to have been transport systems for lava on the moon, much like a terrestrial lava channel or tube. The exact formation mechanisms for these systems are not well constrained and there are major questions as to whether the rilles are constructional or erosional. Most sinuous rilles lack the obvious levees associated with terrestrial constructional channels, but there is also little concrete evidence for pure erosional formation. Establishing the origins of these sinuous rilles is made more difficult due to obfuscation by impacts, pyroclastic volcanism, and alteration experienced since their formation.

A variety of volcanic features, including multiple sinuous rilles are found on the Aristarchus Plateau within the mare of Oceanus Procellarum. A particularly unusual sinuous rille system in the Northern Aristarchus region is composed of two branches, which join towards the rille's northern end. Remote sensing measurements show that the rille is surrounded by smooth, dark materials that have been previously interpreted as part of the Aristarchus pyroclastic deposit, and the rille in some places appears to be constrained by pre-existing topography on the plateau.

Changes in morphology along the length of the sinuous rille have similarities with terrestrial lava channels. Downslope decreases in the cross-sectional area of the rille may reflect volume changes due to volatile loss during transport, while disappearance of the rille into the mare shares similarities with a transition from channelized flow to inflated sheet emplacement on flatter ground. Terrestrial analogs were selected for specific features/characteristics they share with the studied lunar rille system. An important analog is the Fissure 8 lava channel from the 2018 Kīlauea eruption. This channel shares several important morphological properties with the studied rilles, including similarly changing channel dimensions and gradual disappearance of the channel at its north distal end.

905

Fracture Structures in and around Hakone Volcano Revealed by Dense Seismic Observations

Dr Ryou Honda[1], Dr Yuki Abe[1], Dr Yohei Yukutake[2], Prof. Shin'ichi Sakai[3]
[1]Hot Springs Research Institute Of Kanagawa Prefecture, Iriuda 586, Odawara, Japan, [2]Earthquake Research Institute, The University of Tokyo, Yayoi 1-1-1, Bunkyo-ku, Japan, [3]Interfaculty Initiative in Information Studies, The University of Tokyo, Hongo 7-3-1 , Bunkyo-ku, Japan

In Hakone volcano that locates at northern tip of Izu-Bonin arc, most of direction of old fissures and dikes are Northwest-Southeast, which correspond to compressional axis of regional stress filed due to collision of Philippine Sea plate. Preexisting fracture systems, including old fissures, dikes, and microfractures in the caldera, are possibly used as channels for magma and hydrothermal fluid intrusions during an eruption. Indeed, in phreatic eruption occurred in 2015 possibly used an old fissure. To reveal such a fracture system in the Hakone volcano is important to understand phreatic eruption in the future. To do so, we investigated on fracture structures based on S-wave splitting analysis and adopted the fuzzy c-means method to perform clustering on S-wave splitting analysis results.

The results show that the fracture system in the Hakone caldera can be divided into four clusters (A1, A2, B1 and B2). In the central cone vicinity, craters or dikes corresponding to the compressive axis of the regional stress field are dominant, whereas the fault systems with the best orientation to the regional stress field develop around the central cone. Cluster B1 can be explained by the northwest–southeast alignment of micro cracks or dikes corresponding to the direction of maximum horizontal pressure of the regional stress field. The others are likely explained by fault fracture zones, which have an optimal orientation for regional stress fields, or by the alignment of micro cracks affected by the local stress field. Cluster B2 suggests the existence of fracture zones of the Tanna and Hirayama fault systems, which cross the Hakone volcano from north to south. Clusters A1 and A2 are possibly explained by the conjugate system of B2. However, the alignment of micro cracks generated by the local stress field or old volcanic structures can also be a cause of the clusters.

744

Three-dimensional Resistivity structure around the Kagamiike-kita crater of Mt. Motoshirane, Kusatsu-Shirane Volcano (Central Japan), using the audio-frequency magnetotellurics

Ms Asami Honda[1], Dr Wataru Kanda[1], Dr Takao Koyama[2], Dr Shinichi Takakura[3], Dr Yasuo Matsunaga[1], Dr Tatsuji Nishizawa[4], Mr Satoshi Ikezawa[2]

[1]Tokyo Institute of Technology, Meguro-ku, Japan, [2]Earthquake Research Institute, The University of Tokyo, Bunkyo-ku, Japan, [3]Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Japan, [4]Mount Fuji Research Institute, Yamanashi Prefectural Government, Fujiyoshida, Japan

In 2018, a phreatic eruption occurred at the Kagamiike-kita crater of Mt. Motoshirane, one of the pyroclastic cones of the Kusatsu-Shirane Volcano (KSV), for the first time in historic times. The eruption was abrupt and the volcanic activity of Mt. Motoshirane had not been monitored, which resulted in casualties. Most previous studies on KSV have focused on the Yugama crater, which repeated phreatic eruptions in recent years and resides on another pyroclastic cone ~2 km north of Mt. Motoshirane. In very few geophysical studies prior to the 2018 eruption, a broadband magnetotelluric study identified a low resistivity zone at a depth of ~2 km beneath Mt. Motoshirane, but shallower structures were not well defined due to poor resolution. According to an X-ray diffraction analysis of the erupted ash, the explosion depth was inferred to reach the basement rocks. The analysis of tilt records before and after the eruption suggested that the fluid ascended through pre-existing cracks. However, since these studies were based on uncertain shallow structures, the source region of the eruption has not yet been sufficiently constrained. Hence, this study carried out an AMT survey around the 2018 craters to clarify the shallow structure. A three-dimensional resistivity structure model revealed a rough two-layer feature, with high resistivities at shallow depths overlain by low resistivities beneath. The boundary between these two layers corresponds to the top boundary of the Neogene basement rocks. The most remarkable feature was that these low resistivities interpreted as the basement rocks are not found beneath the 2018 craters. In addition, a relatively high resistivity region was found beneath the top of the conductive basement layer and interpreted as a fluid reservoir. Based on these characteristics, we present how fluids were transported to the shallow levels through the pre-existing cracks and discuss how the eruption occurred.

1348

Recent unrest at Askja Volcano after >40 years of subsidence

Professor Andy Hooper[1], Michelle Parks[2], Vincent Drouin1[2], Benedikt Ófeigsson[2], Freysteinn Sigmundsson[3], Erik Sturkell[4], Ásta Hjartadóttir[3], Ronni Grapenthin[5], Halldór Geirsson[3], Sigrún Hreinsdóttir[6], Hildur Friðriksdóttir[2], Josefa Sepulveda Araya[1], Rikke Pedersen[3], Sara Barsotti[2], Bergrún Óladóttir[2]
[1]COMET, School of Earth and Environment, University Of Leeds, Leeds, United Kingdom, [2]Icelandic Meteorological Office, Reykjavik, Iceland, [3]Nordic Volcanological Center, Institute of Earth Sciences, Reykjavik, Iceland, [4]Department of Earth Sciences, University of Gothenburg, Gothenburg, Sweden, [5]Geophysical Institute, University of Alaska Fairbanks, Fairbanks, USA, [6]GNS Science, Lower Hutt, New Zealand

After subsiding since at least 1983, inflation was detected at Askja Volcano at the start of August 2021, at a continuous GNSS station located west of Öskjuvatn (OLAC) and in interferograms from Sentinel-1. The inflation continues and, as of September 2022, ~40 cm of uplift has been measured at OLAC.

Askja is situated in the Northern Volcanic Zone in Iceland, and comprises both a central volcano and a fissure swarm covering approximately 190 x 20 km. The central volcano includes a series of nested calderas formed during previous plinian eruptions. Historic eruptions have comprised both basaltic effusive eruptions and silicic explosive eruptions, although the former are more common. Eruptions occur on average three times per century. The last eruption at Askja occurred in 1961. This was predominantly effusive and produced a lava field of approx. 0.1 km3. The last plinian eruption to occur was in 1875 and formed the most recent caldera, which is now filled by lake Öskjuvatn (~200 m deep). Deformation measurements commenced in 1966 with levelling observations, and since then additional monitoring techniques have been employed, including GNSS and InSAR. Levelling measurements between 1966-1972 revealed alternating periods of deflation and inflation. Measurements from 1983-2021 detailed persistent subsidence of the Askja caldera, decaying in an exponential manner.

The recent uplift can be explained by magma inflow into shallow depths (~2 km) at a rate of 0.6-0.8 m3/s. According to a recent study by Galetto et al (2022), this rate falls within the transition zone between rates that lead to a propagating fracture and potentially eruption, and those that do not. We will present an overview of the GNSS and InSAR observations to date together with our latest geodetic modeling results, and discuss future eruptive scenarios, based on the location of the intruded magma and historic activity.

1217

A non-destructive and efficient approach to cryptotephra identification in marine sediment cores

Dr Jenni L Hopkins[1], Ms Madison Clarke[1], Dr Shaun R Eaves[1], Ms Janine E Bidmead[1,2], Ms Charlotte O Pizer[1], Dr Jamie D Howarth[1], Dr Alan R Orpin[3], Ms Grace E Frontin-Rollet[3], Dr Richard J Wysoczanski[3]
[1]Victoria University Of Wellington, Wellington, New Zealand, [2]GNS Science, Lower Hutt, New Zealand, [3]National Institute of Water and Atmospheric Research, Wellington, New Zealand

Volcanic eruptions have punctuated New Zealand's geologic history for millions of years. Evidence of many eruptions occurs as distal macroscopic tephra deposits preserved in deep marine sediment cores, often many hundreds of kilometres from source. As such, these macroscopic tephras likely record only the largest eruptions, potentially introducing a preservation bias in the record. The recent development of cryptotephra identification, laboratory concentration of material, and quantification methods are allowing an increasingly detailed picture of more frequent volcanic activity to be uncovered.
Here we present a new method for identifying cryptotephra using non-destructive core scanning techniques (e.g., XRF, magnetic susceptibility, density analyses) coupled with statistical, machine-learning techniques to aid analysis. Data collected from down-core scans are modelled to quantitatively discriminate and characterise the macroscopic tephra then, unsupervised machine learning and statistical techniques (e.g., Principle Component Analysis) are used to identify potential cryptotephra within the dataset. New results generated during our method development phase have been applied to both targeted sections of core and complete cores. Previously unidentified (crypto)tephra deposits have been isolated, characterised and used to further refine the data interrogation code (developed in R statistical language) and unsupervised machine learning approach. With the addition of detailed core chronologies through radiocarbon dating, we reveal new insights on eruption frequency and longevity, and how they modulate tephra inputs to the marine sedimentary environment.

472

Melt-rich nodules capture the isotopic heterogeneity of a magma mush reservoir

Ms Emma Horn[1], Dr Rex Taylor[1], Dr Thomas Gernon[1], Dr Michael Stock[2]
[1]*University Of Southampton, Southampton, United Kingdom,* [2]*Trinity College Dublin, Dublin, Ireland*

The structure and connectivity of magma reservoirs beneath both mafic and felsic volcanic systems is not well understood. Here we investigate the development of a magma plumbing system by examining the isotopic diversity present in the juvenile material ejected in a single eruptive phase: the 312 ka Fasnia Member event on Tenerife. Specifically, this material includes a suite of rapidly cooled, melt-rich nodules which sample a mafic mush magma reservoir that was explosively fragmented during this eruption. Alongside this mush, the Fasnia deposits include phonolitic pumice, which represents the bulk eruptive magma of this event. We measured high-precision Pb isotopes on melt and crystals separated from the mush, along with the phonolitic pumices, and studied these compositions in the context of the isotopic evolution of Tenerife magmatism. This captures the scale of isotopic heterogeneity present during fragmentation of a crystal mush magma reservoir. Interstitial melts in the cumulate mush are isotopically heterogeneous, reflecting the episodic influx of basaltic magma, each containing different proportions of components from the mantle. These components remained in discrete domains or layers with the mafic mush during its development over timescales of ~10 kyrs. In contrast, the overlying phonolitic reservoir is isotopically homogeneous, reflecting a well-mixed melt-rich body that integrated mantle components through a period >30 kyrs. Coordinated changes in the isotope composition of the basaltic and phonolite systems indicate the phonolites developed principally by fractionation of basaltic magma batches. Based on comparable isotopic and petrological data, a similar structure of magma reservoirs appears to have persisted through the last ~2 Myrs of development of Tenerife. This persistence may be a common feature beneath volcanoes with either bimodal or a continuum of compositions from mafic to felsic.

1345

Uncertainties and the need to model them – an aviation volcanic ash forecast requirement

Dr Matthew Hort[1], Dr Frances Beckett, Dr Susan Leadbetter, Dr Andrew Jones, Mr Benjamin Evans, Dr Claire Witham
[1]*Met Office, Exeter, United Kingdom*

The aviation industry has laid out to the International Civil Aviation Organization (ICAO) requirements for quantitative volcanic ash forecasts to enable them to conduct flight safety-risk assessments. Within this there is also the requirement that these forecasts include probabilistic information on the likelihood that forecast concentrations will exceed certain concentration thresholds. The use of probabilities in meteorological forecasting is common and well established. However, this is not the case for volcanic ash forecasting where a considerable number of additional inputs are required, all with associated uncertainties e.g., eruption parameters, ash properties, in plume processes, ash-meteorology interactions. The understanding and quantification of the range of uncertainties needed to perform and evaluate a full probabilistic forecast in real-time does not currently exist. Incomplete probabilistic descriptions can still provide useful additional guidance over traditional deterministic approaches and the VAACs will start to deliver such products in 2024.Indeed, some VAACs already use probabilistic products as part of their internal processes. This talk will lay out the direction of probabilistic volcanic ash forecasting for aviation and highlight both the challenges and opportunities that this presents for modelling, observations, the VAACs, their aviation customers and the diverse research communities that can contribute to understanding and quantifying the uncertainty.

272

Reconciling petrologic and monitoring perspectives on magma ascent for the 1980 Plinian eruption of Mount St. Helens

Miss Behnaz Hosseini[1], Dr. Madison Myers[1]
[1]*Montana State University, Bozeman, United States*

Integrating petrologic records with real-time observations of magma ascent remains a great ambition of volcano science. We thus demonstrate the ability of a newly developed continuous two-stage decompression-diffusion model to reconcile embayment- and monitoring-based magma ascent rates, applied to the 1980 eruption of Mount St. Helens (USA). We remodel H_2O concentration gradients in plagioclase-hosted embayments (n = 3)[1] from the Plinian phase of the eruption using our model that optimizes initial (deeper) and final (shallower) decompression rates, and the pressure at which this transition occurs. The model recovers best fit profiles defined by an initial slow decompression (0.008-0.01 MPa/s) followed by a final stage up to two orders of magnitude faster (0.2-0.8 MPa/s), similar to results for the 1991 eruption of Mount Pinatubo (Philippines)[2] and in agreement with numerical conduit model predictions[3]. Combined with recovered transition pressures (60-100 MPa, 2.2-3.8 km), initial ascent rates and times range from 0.3-0.4 m/s and 4.5-6.5 hours, respectively, with final ascent rates of 10-30 m/s translating to <1-5 minutes in the shallow conduit. Our results bring petrologic estimates of magma ascent into closer agreement with the monitoring record, where the onset of the second phase of Plinian activity manifested as strong ground motion accompanied by an eruptive column ~3.5 hours after the lateral blast[4], indicating magma ascent on the order of 0.6-0.7 m/s from 7-9 km depth[5]. Our work highlights that embayments can preserve complete records of magma ascent and should be leveraged in actively-monitored settings for an integrated understanding of magma movement from the deep conduit to the surface.

[1] Humphreys et al. (2008) Earth Planet. Sci. Lett. 270.
[2] Saalfeld et al. (2021) AGU Fall Meeting.
[3] Mastin (2005) J. Volcanol. Geotherm. 143.
[4] Scandone & Malone (1985) J. Volcanol. Geotherm. 23.
[5] Eichelberger (1995) Annu. Rev. Earth Planet. Sci. 23.

861

Using tree molds to capture the complex, staged emplacement of the July 1974 basaltic lava flow at Kīlauea

Professor Bruce Houghton[1], Sebastien Biass[2], Kristine Curran[1], Thorvaldur Thordarson[3], Tim Orr[4], Carolyn Parcheta[4], Edward Llewellin[5], Peter Mouginis-Mark[1]

[1]University of Hawaii, Honolulu, United States, [2]University of Geneva, Geneva, Switzerland, [3]University of Iceland, Reyjkavik, Iceland, [4]U.S. Geological Survey, Hilo, USA, [5]Durham University, Durham, United Kingdom

Basaltic lava flows have complex geometries that reflects both their intrinsic properties (e.g., viscosity, eruption flux) and external influences (e.g., pre-eruptive topography). The surface of lava flows is generally easy to constrain, but only reflects the final emplacement stage. As a result, the dynamics and evolution of their morphology during emplacement is often wholly unknown. In addition, unavoidable uncertainty in flow thickness and pre-flow topography may lead to a poor constraint on lava volume, and, in turn, in a simplistic and generally static picture of flow transport and emplacement. 'Tree molds', formed when advancing lava encloses trees up to the maximum height reached by the lava, record such parameters as inundation height, the depth by which the lava then drained, and the final preserved thickness of lava. Comprehensive interpretation of tree mold data offers temporal snapshots that shed light on the dynamics of flow emplacement. Here we use an unusually complete data set from 282 tree molds to reconstruct the spatiotemporal evolution of the ~2.1 km-long July 1974 flow at Kīlauea. The tree mold data yield a previously unrecognized picture of dynamic, staged emplacement, separated by intervals of ponding such that, in places, flow depth during emplacement was as much as twice the thickness of the preserved deposit. Drainage of the ponds would have led to episodic surges in advance of the flow, decoupled from fluctuations in vent discharge rate, with a final surge occurring after the cessation of eruption. Such complex emplacement histories must be accounted for in predictive models of flow emplacement at Kīlauea and elsewhere.

783

2021 Icelandic eruption tests the bounds of sustained lava-fountaining explosive eruptions

Professor Bruce Houghton[1], Caroline Tisdale[1], Thorvadur Thordarson[2], Jona Pálmadóttir[2], Jacqueline Licari[2], Ed Llewellin[3], Eva Eibl[5], Iðunn Valdimarsdóttir[2], Lilja Pétursdóttir[2], Ármann Höskuldsson[2], William Moreland[2], Gylfi Hersir,[4], Egill Guðnasson[4], Thorbjörg Águstsdóttir[4]
[1]University of Hawaii, Honolulu, United States, [2]University of Iceland, Reykjavik, Iceland, [3]Durham University, Durham, United Kingdom, [4]Iceland GeoSurvey, Reykjavik, Iceland, [5]Potsdam Universitat, Potsdam, Germany

Lava fountaining represents the prolonged sustained end of weak basaltic explosive eruptions yet paradoxically many well observed lava fountaining eruptions are episodic in character. Eruptions with widely spaced fountaining episodes can convincingly be modelled in terms of the semi-regular ascent of new small batches of magma from shallow storage.

The 117-day eruption on the Reykjanes peninsula, Iceland in 2021 was captured in exceptional detail, and live-streamed globally. Fagradalsfjall 2021 extends the footprint of lava fountaining to include phases of extremely 'rapid' fountaining, a class somewhat analogous to the 'rapid' class of Strombolian explosions. The 41-day climax of the eruption had 7058 fountaining episodes (Eibl et al., 2022) with a frequency of lava fountaining episodes never previously seen anywhere— approximately 4000 times the frequency seen during the high fountaining eruptions at Puʻu ʻŌʻō, Kīlauea in 1983–1986 or 400 times the frequency of at Etna in 2021. This pattern of behavior with episodes, lasting only 3-4 minutes, separated by similar repose intervals, is much harder to explain in terms of variations in supply of discrete batches of new fresh magma from depth. We propose that while, in the longer term, slow and irreversible changes in the eruption, on timescales of weeks, were driven by variations in eruption rate and by shifts in conduit geometry and stability, episodes, and pulsating of the eruption, on hour- to-second scales, were determined by variations in the complex concurrent flow of buoyantly rising, decoupled large gas bubbles and the coupled mix of a melt phase and smaller gas bubbles.

Eibl, E.P.S, Thordarson, T., Höskuldsson, A., Gudnason, E.A., Dietrich, T. Hersir, G.P., & Ágústsdóttir, T. 2022. Evolving Shallow Conduit Revealed by Tremor and Vent Activity Observations during Episodic Lava Fountaining during the 2021 Fagradalsfjall Eruption, Iceland. Bulletin of Volcanology Special Volume on the Fagradalsfjall eruption.

982

Conduit erosion processes highlighted by physical properties of lithics from the AD 1655 Burrell eruption of Taranaki Mounga, New Zealand.

Mr Henry Hoult[1], Professor Ben Kennedy[1], Dr Alex Nichols[1], Dr Leighton Watson[1], Professor Shane Cronin[2]
[1]University Of Canterbury, Christchurch, New Zealand, [2]University of Auckland, Auckland, New Zealand

Volcanic conduits are transport pathways connecting magma storage regions in the crust to the vent at the surface. The physical properties of conduit wall rock directly influence conduit stability and the extent of outgassing of the ascending magma. Unstable conduits destabilize eruption plumes, increasing the likelihood of pyroclastic flow generation. Permeable conduit walls facilitate magma outgassing during ascent, dampening degassing-driven pressure build up within the conduit and hence decreasing eruption explosivity. Lithic clasts, non-juvenile pyroclasts generated by conduit wall erosion, allow the physical properties of conduit walls to be quantitatively investigated. Here we present the physical properties of different lithic types collected from the last fall deposits of Taranaki Mounga's AD 1655 Burrell eruption. 2D image analysis of thin sections and uni-axial rock mechanics experiments were performed to identify the porosity, permeability and tensile and compressional strengths. These characteristics were shown to vary depending on the crystallinity, density and extent of fracturing or alteration of the sample. Interconnected vesicles and microfracture networks identified lithic clasts with greater permeability, potentially facilitating magma outgassing and conduit failure. Movements in the fragmentation depth from a region of higher wall strength to lower may induce significant wall collapse and unsteady eruption dynamics. Identifying the physical properties of lithic clasts from explosive eruptions can therefore be used to identify variations in conduit wall strength and hence estimate a volcano's susceptibility to abrupt changes in eruption style. This has significant implications for hazard scenarios and risk mitigation at volcanoes worldwide.

1161

Recent unrest episodes at Taupō Volcano revealed by GNSS measurements

Dr Sigrun Hreinsdottir[1], Ian Hamling[1], Finnigan Illsley-Kemp[2], Cyril Journeau[3], Jessie Schuler[2], Neville Palmer[1], Eleanor Mestel[2], Nico Fournier[4], Rory Hart[1], Susan Ellis[1], Peter Otway
[1]GNS Science, Lower Hutt, New Zealand, [2]School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand, [3]Institut des Sciences de la Terre, Université Grenoble Alpes, Grenoble, France, [4]Wairakei Research Centre, GNS Science, Taupo, New Zealand

Taupō Volcano, located in the North Island of New Zealand, is one of the most productive rhyolitic centres in the world. It lies within the Taupō Volcanic Zone (TVZ), an active continental rift resulting from the oblique subduction of the Pacific Plate beneath the Australian plate along the Hikurangi Trench. Taupō volcano last erupted around 232 ± 10 CE ejecting 35 km³ DRE in a caldera forming event. In the last 150 years 19 episodes of minor to moderate unrest episodes have been documented, the most recent of which began in May 2022 with increased seismicity and ground inflation.

GNSS and InSAR measurements at Taupō volcano are limited by the presence of Lake Taupō, that fills the caldera formed during the Oruanui supereruption 25.5 kyr ago, and later modified by the 232 CE Taupō eruption. GNSS campaign measurements have been conducted every few years around the lake since 1990. In 2002 the first continuous GNSS station was installed at Taupō Airport and for the last 10 years the volcano has been monitored with 10 GNSS stations operated by the national monitoring network GeoNet. The GNSS measurements, along with InSAR and lake leveling measurements, reveal a complex pattern of deformation which can be explained by different inflation sources at different times, inferred as potentially geothermal and/or magmatic superimposed onto an active, faulted tectonic environment. In addition, GNSS measurements recorded triggered deformation for about two weeks following the 2016 Kaikōura earthquake but no significant local seismic events (M>3) were recorded associated with this deformation. This deformation can be interpreted as dyke or creep on a fault parallel with the Taupō rift. The inflation sources for the last two unrest periods captured by GNSS measurements, 2019 and 2022, are inferred to be located within the lake-filled caldera at intermediate depth (4-8 km).

657

Using crystal alignment in a basaltic dyke to investigate magma flow in volcanic plumbing systems.

Miss Jade Hrintchuk[1], Dr Janine Kavanagh[1], Dr Elisabetta Mariani[1]
[1]University Of Liverpool, Liverpool, United Kingdom

Crystal alignment, shape and size within volcanic rocks can be used to interpret magmatic fluid flow and deformation during their ascent through the crust. Examples include crystals acting as deformation markers during magma ascent in silicic lava domes, and using mantle xenoliths and xenocrysts to interpret mafic magma chamber processes. We investigate how plagioclase feldspar crystals record information related to magma flow and magma overpressure by studying a basaltic dyke from the Budj Bim Volcanic Complex (BBVC), Newer Volcanics Province (NVP), South East Australia. The BBVC is the only known fissure-fed eruption in the NVP. The sampled dyke was the main pathway for magma ascent in the Little Mount scoria cone, and comprises of olivine phenocrysts (<2 mm), rare quartz xenocrysts (<1 mm) and a fine-grained plagioclase feldspar-rich groundmass. Scoria pyroclasts from the cone deposits show evidence of physical mingling with country rock fragments, which is inferred to have occurred during ascent. Preliminary optical and scanning electron microscopy show xenocryst incorporation is also evident at the microscale within the solidified dyke, and olivine phenocrysts show simple zoning. Electron backscattered diffraction (EBSD) observations show the plagioclase microcrysts share a crystallographic preferred orientation (CPO). The presence of plagioclase CPO can be used as an indicator of magma flow, as elongate crystals are expected to align parallel to the flow direction. In addition, intracrystalline distortion can be used to investigate the pressures and strains a magma has experienced during the final stages of the eruption, when rapid crystallisation causes the magma to lock-up. Understanding the dynamics of historic fissure eruptions such as the BBVC can help to interpret and constrain the physical and chemical processes occurring within basaltic feeder dykes, their impact on future fissure eruption dynamics and the hazards they pose.

967

Variability and trends in oxidation state of La Reunion Island basalts 2007 eruption: observations from sulfur X-ray absorption micro-spectroscopy

Dr Ying-Jui Hsu[1], Prof Fidel Costa[1,2,3], Dr Marine Cotte[4,5], Prof Andrea Di Muro[6], Prof Simon A. T. Redfern[1]
[1]Asian School of the Environment, Nanyang Technological University, , Singapore, [2]Earth Observatory of Singapore, Nanyang Technological University, , Singapore, [3]Institute De Physique Du Globe De Paris, Universite Paris-Cite, UMR 7154 CNRS, Paris, France, [4]The European Synchrotron Radiation Facility, Grenoble, France, [5]Laboratoire d'Archéologie Moléculaire et Structurale (LAMS), Sorbonne Université, CNRS, UMR8220, Paris, France, [6]Laboratoire de Géologie de Lyon, Terre, Planètes, Environnement, CNRS, UMR 5276, Ecole Normale Supérieure de Lyon, Université de Lyon, Université Claude Bernard Lyon 1, Villeurbanne, France

The magma redox state of large mafic ocean island volcanoes is influenced by a range of processes, from the mantle source through the transport and degassing. We focus on a well-studied suite of samples erupted prior and after the 2007 caldera collapse in Piton de la Fournaise to gain insights into the oxidation state of basaltic magmas. We investigated olivine-hosted melt inclusions with sulfur X-ray absorption near-edge spectroscopy at the micrometric length scale (µXANES). The µXANES signals allow estimating fO2 from integrated abundance of S6+/∑S. We find that the melt inclusions in pre-caldera samples show more variable S oxidation states, with reduced S coexisting with pyrrhotite as well as mixed of sulfide and sulfate species coexisting in the melt, than in the post-caldera samples. Measurements across and within inclusions reveal small micron-sized areas with significant variations in oxidation state. We estimated fO2 values and most values are close to the FMQ (fayalite-magnetite-quartz oxygen buffer assembly). In addition, we observe the highest "abnormally" oxidized individual inclusions with an fO2 as high as FMQ +0.9. Such high oxidation values are commonly close to sulfur-poor areas near a bubble within an inclusion, at the 10s µm length scale. The post-caldera samples appear more homogenous with much less variability in oxidation state within melt inclusions. Our results illustrate the complexity of oxidation/reduction processes at the microscopic length. This may explain the diversity of previously reported results on oxidation state of similar volcanic samples from Piton de la Fournaise.

438

Numerical investigation of crystal/bubble settling in magmas

Professor Christian Huber[1], Professor Marc Parmentier[1], Pedro Jose De Santana Neto[2], Professor Jonas Latt[2], Professor Olivier Bachmann[3]
[1]Brown University, Providence, United States, [2]Universite de Geneve, Geneva, Switzerland, [3]ETH, Zurich, Switzerland

Gravitational settling of crystals or bubbles in magmas plays a major role on their chemical differentiation. The overall reduction in segregation velocity between the crystals or bubbles and the melt with increasing particle volume fraction is generally referred to as hindered settling. Hindered settling is generally parameterized empirically through separation velocities that are power-law functions of the particle volume fraction (Richardson and Zaki, 1954; Russell et al, 1989; Faroughi and Huber 2015). These empirical laws implicitly assume a prescribed and homogeneous particle (here crystal/bubble) volume fraction at the continuum scale, which limits their applicability when considering systems with heterogeneous distribution of particles. This is especially true because particle settling in general is known to develop wave instabilities, leading to heterogeneous distributions of fluid and particle volume fractions. We use a combination of numerical models across different spatial scales to study the process of hindered settling and develop a continuum-scale model that expand the theory beyond the limitation of homogeneous particle volume fraction. First, we present a suite of fully resolved hybrid lattice Boltzmann-discrete elements particle settling simulations in 3D (>104 particles). These simulations are used to test the validity of new continuum-scale model based on two-phase flow theory. This continuum model introduces a correction in the description of the stress tensor acting on particles whereby dissipation is accounted for when heterogeneities in particle volume fraction induce a divergence in the particle velocity field. We show that accounting for this stress naturally introduces a diffusion-like behavior in the suspension that is needed to explain the development of particle waves observed in these suspensions.

706

Using risk comparisons to communicate natural hazard risks: lessons for volcanology

Manomita Das[1], Dr Emma Hudson-doyle[1], Associate Professor Julia Becker[1], Dr Sally Potter[2], Dr Danielle Charlton[3], Dr Lauren Vinnell[1], Dr Graham Leonard[4]

[1]Joint Centre for Disaster Research, Massey University, , Aotearoa New Zealand, [2]GNS Science, Tauranga, Aotearoa New Zealand, [3]GNS Science, , Aotearoa New Zealand, [4]GNS Science, Avalon, Aotearoa New Zealand

Communicating risks of unfamiliar and newly emerging hazards such as those associated with volcanic unrest is difficult. Communicators often use risk comparisons to put unfamiliar risks into perspective by presenting risk numbers of unfamiliar hazards against risk numbers of familiar hazards. For example, the chance of a person getting affected by a volcano in their lifetime might be compared with their chance of getting affected in a car accident in their lifetime. This helps in making the risk information meaningful by providing the audience a familiar reference point. However, using risk comparisons like this to communicate risks is fraught with challenges. Comparing two risks with different properties can make risk comparisons less reliable. Risk comparisons also neglect the subjective perceptions of risk which might lead to over or underestimation of the individual risks being compared. Past studies have identified that risk comparisons can bias judgements, influence decisions, and in certain cases it has led to public outrage. Thus, despite risk comparisons being a simple and easy way to educate and inform audiences about unfamiliar hazard risks, their use remains limited. This paper reviews studies published in the past twenty years and summarizes the latest findings on risk comparison. Mainly it explores whether risk comparisons can be useful to present unfamiliar volcanic and other natural hazard risk, how they can be framed effectively, and what pitfalls should be avoided in their use.

263

Mental models and the understanding of hazard and risk: lessons for communicating uncertainty in volcanology.

Dr Emma Hudson-doyle[1], Jessica Thompson[1], Associate Professor Stephen Hill[2], Dr Matt Williams[3], Prof Douglas Paton[4], Dr Sara Harrison[5], Professor Ann Bostrom[6], Associate Professor Julia Becker[1]
[1]Joint Centre for Disaster Research, Massey University, Wellington, New Zealand, [2]School of Psychology, Massey University, Palmerston North, New Zealand, [3]School of Psychology, Massey University, Auckland, New Zealand, [4]College of Health and Human Sciences, Charles Darwin University, Darwin, Australia, [5]GNS Science, Avalon, New Zealand, [6]Evans School, University of Washington, Seattle, USA

The science associated with assessing volcanic hazards and informing decision-makers contains many layers of complex and interacting uncertainties. This is compounded by the evolving nature of response needs, and the changing network of communication pathways. Further, varied understanding about what scientific uncertainty is, and where it comes from, affects people's trust in and use of science advice. It is thus crucial to understand these diverse perspectives. This enables scientists and science advisors to use the shared concepts underlying associated mental models to develop effective communication strategies that engender and maintain trust.

To understand perceptions of uncertainty associated with natural hazards science and advice, we conducted twenty-five mental model interviews in Aotearoa NZ with a diverse range of participants involved in risk, from physical scientists, through to policy writers, emergency managers, and the public. These three-phase interviews included initial elicitation of free thoughts about uncertainty, a mental model mapping activity, and a closing semi-structured interview protocol to explore further questions around scientific processes and an individual's philosophy of science. Qualitative analysis led to the construction of key themes, including: (a) the importance of recognizing the role of human behaviours, (b) understanding the 'actors' involved as sources of uncertainty alongside data sources, (c) acknowledging influences such as governance and funding decisions, and (c) the difficulty that most participants had in defining what uncertainty actually is.

Participants highlighted the positive role of uncertainty for promoting debate and as a catalyst for further inquiry. They also demonstrated a level of comfort with uncertainty and advocated for 'sitting with uncertainty' for transparent reporting in advice. We present these findings to enhance hazard and risk communication, alongside the design of our interview methodology, which could be adapted for participatory and co-development research to build shared understanding of the science and uncertainties involved in volcanic risk assessment.

1185

Physical controls of fragmentation efficiency at Mt. Pelée, Martinique

Mila Huebsch[1,2], Dr. Ulrich Kueppers[2], Dr. Guillaume Carazzo[3], Prof. Corrado Cimarelli[2], Dr. Kai-Uwe Hess[2], Dr. Adrian Hornby[4], Dr. Audrey Michaud-Dubuy[3], Prof. Michael Heap[6], Dr. Anne-Marie Lejeune[3,7], Dr. Diego Perugini[5], Daniel Weller[2], Prof. Donald Dingwell[2]

[1]University Of Auckland, Auckland, New Zealand, [2] Ludwig-Maximilians-Universität, Munich, Germany, [3]Institut de physique du globe de Paris, Paris, France, [4]Cornell University, Ithaca, USA, [5]University of Perugia, Perugia, Italy, [6]University of Strasbourg, Strasbourg, France, [7]Sorbonne University, Sorbonne, France

Montagne Pelée, Martinique, exhibits a wide range of eruptive styles from dome formation to violent Plinian activity. Dome collapse events in 1902 triggered devastating pyroclastic density currents (PDC), including the buoyant PDC which destroyed the coastal town of St. Pierre. The most recent eruption took place in 1929-1932 in a similar style termed “Pelean.” With the flanks of the volcano long repopulated, understanding possible eruptive behaviours and related impacts is paramount to preparation and mitigation efforts.

Field-based evaluation of eruption behaviour based on grain size distribution (GSD) is impeded by incomplete deposit preservation as substantial fractions were deposited into the ocean. To investigate the influence of magma textures and overpressures on fragmentation efficiency and eruption dynamics, we collected and characterized samples from PDC deposits of the 1929-1932 and 1902-1905 Pelean eruptions, as well as the P1 (1300 CE), P2 (280 CE), and P3 (79 CE) Plinian eruptions. All samples are andesitic in composition and contain rhyolitic glass. Consistent with the slower cooling and more extensive outgassing anticipated for Pelean activity, these materials contain greater crystal contents and are less porous (~25-30% crystallinity, ~30-50% open porosity) than the Plinian materials (~10-20% crystallinity, ~55-70% open porosity). Using a range of applied overpressure (5-20 MPa), rapid decompression experiments were performed on representative cylindrical cores drilled from blocks from each eruption. The fragmental products were sieved to determine GSDs, from which fragmentation efficiency was quantified as the fractal dimension Df for cross-experiment comparison. Our results show fragmentation efficiency to increase with applied potential energy up to a porosity threshold. As observed for the Plinian samples in our study, porosity continues to enhance fragmentation efficiency above this threshold while applied pressure does not. With primary fragmentation being isolated in rapid decompression experiments, we highlight the reflection of secondary processes in field total GSDs.

953

Dynamics of magma-water interaction at different confinement and pressure conditions at Hunga volcano

Mila Huebsch[1], Dr. Joa Paredes-Mariño[1], Dr. Ingrid Ukstins[1], Dr. Jie Wu[1], Dr. David Adams[1], Prof. Shane Cronin[1], Dr. Mathieu Colombier[2], Dr. Anton Maksimenko[3], Dr. Matthew Cameron[3], Dr. Ian Schipper[4], Dr. Annaleise Klein[3], Dr. Mark Tobin[3], Dr. Jitraporn Vongsvivut[3], Taaniela Kula[5], Dr. Marco Brenna[6], Prof. James White[6], Rachael Baxter[6], Dr. Marshall Palmer[6]

[1]University Of Auckland, Auckland, New Zealand, [2] Ludwig-Maximilians-Universität, Munich, Germany, [3]Australia's Nuclear Science and Technology Organisation, Melbourne, Australia, [4]Victoria University of Wellington, Wellington, New Zealand, [5]Tonga Geological Services, Nuku'alofa, Tonga, [6]University of Otago, Dunedin, New Zealand

On January 15th, 2022, the submarine caldera volcano Hunga, in the Kingdom of Tonga, created an extremely high eruption plume (55-57 km) dominated by ash-sized material and a high water/aerosol content. The fall distribution, extending at least 260 km from the volcano, and fine grainsize, with 36 wt.% (± 5 wt.%) of analyzed ash finer than 63 µm, contrast with typical Plinian eruptions. The measured observations of this eruption do not fit current models of eruption column generation and energy release, possibly due to poorly understood magma-water interaction processes. External water may amplify magma fragmentation and bolster explosivity, in a feedback loop between micro-fragmentation and ongoing direct contact between magma and water. During such a large-scale event, variable rates and styles of magma-water interaction can occur over time and space, in different water depths and sub-sea floor confinement conditions. Pyroclastic products and syn-eruption observations across subaerial, shallow subaqueous, and deep subaqueous stages of the 2022 Hunga eruption provide a unique opportunity to explore the diverse modes of magma-water interaction. We present textural analysis of internal crystal and vesicle distributions, and particle surface morphology, using 3D X-ray tomography data (~15 µm resolution) obtained at the Australian Synchrotron, supplemented by 2D SEM imagery (~100 nm resolution). These analyses are used in combination with in situ geochemical analysis by electron probe microanalysis to identify syn-eruptive magma crystallization, gas exsolution, and fragmentation processes. Additionally, volatile concentrations including H_2O and CO_2 in groundmass glass are used to estimate changes in viscosity and ultimately assess explosive potential. By comparing pyroclastic products of each style of activity at Hunga, we explore the varying consequences of rapid quenching on eruption dynamics and the significance of primary and secondary fragmentation in submarine explosive eruptions.

1461

Hyperspectral Mapping of Ancient Volcanic Terrains to Support Geologic Mapping for Resource Assessments

Alexandra E Huff[1], Lisa Thompson[2]
[1]*Arizona State University, Tempe, United States,* [2]*Arizona Geological Survey, Tucson, United States*

Geologic maps and related investigations of volcanic terrains are foundational to natural resource assessments of ore mineralization and deposits. Leveraging this, the Arizona Geological Survey (AZGS) is conducting geologic mapping of the Kaiser Spring volcanic field and Burro Creek area, Arizona, to establish the existence, mineralization, and extent of lithium-bearing deposits. Geochemical analyses conducted will support mapping efforts, however, they are constrained to samples that are collected by hand. Significant factors affecting sample collection and mapping efforts include traversability, weather, and proprietary land access permissions. Therefore, we propose to integrate infrared spectral data of rock units with field observations to circumvent these limitations and support accurate spatial identification and classification of geology units in the study area.

We collected infrared spectral data from remotely-sensed imaging of the study site and lab-based analysis of hand samples. The airborne Hyperspectral Thermal Emission Spectrometer (HyTES) instrument from NASA Jet Propulsion Laboratory (JPL) collects thermal infrared (TIR) emission spectra between 7.5-12 μm over 256 spectral bands. HyTES was flown March 17th, 2022, and collected 22 segments of data across a 20 x 25 km area encompassing the study site. During field mapping, 19 representative hand samples of identified rock units were collected for geochemical analyses related to mineral resources. To bridge this data with HyTES data, we collected laboratory TIR emission spectra of each sample. We will present 1) spatial distribution maps of dominant units derived from HyTES data, 2) geochemical results correlative with TIR emission signatures of hand samples, and 3) integrated map results tracing lithium-bearing rock units between field and HyTES observations. Results will aid in first-order identification of geologic units in remote or inaccessible regions and aims to demonstrate the value of remotely sensed and lab-based TIR data to field-based geologic mapping investigations of ancient volcanic terrains and resource assessments.

1082

Volatile Budget of the 2018 Mount Veniaminof Eruption, Alaska

Ms Ellyn Huggins[1], Dr. Philipp Ruprecht[1], Dr. Matthew Loewen[2], Dr. Robert Bodnar[3], Dr. Matthieu Harlaux[1], Dr. Kristi Wallace[2]

[1]University Of Nevada, Reno, Reno, United States, [2]U.S. Geological Survey, Alaska Volcano Observatory, Anchorage, United States, [3]Virginia Tech, Blacksburg, United States

Syn-eruptive variations in volatile budget can be a factor in transient changes in effusive-explosive transitions within a single eruptive period. Mount Veniaminof is a frequently active, open-vent, tholeiitic arc volcano on the western Alaska Peninsula that erupted in September–December 2018. The eruption started with small lava flows and culminated in a larger explosive event in November that produced a 450 km-long continuous ash plume—one of the most significant ash-producing events in recently observed eruptions at Veniaminof. A temporally constrained tephra record was sampled post-eruption by exposing tephra layers preserved in a snow pit and correlating them with deposits imaged by satellite during the eruption. Bulk compositions are basaltic andesites (58 wt% SiO_2) with olivine ranging from Fo_{64-79}; previous work derived ascent rates using microlite number density consistent with low magmatic H_2O concentrations of <0.75 wt%.

We present volatile element concentrations (H, C, S, Cl, F) from a total of 87 olivine-hosted melt inclusions (MI) from 6 separate tephra layers to assess potential syn-eruptive changes to the volatile budget. H_2O concentrations within MI suggest moderately-hydrous magmas, ranging from 0.3-2.4 wt% H_2O, higher than expected from regional geochemical trends. H_2O contents can be reconciled with previous estimates using a polybaric storage history consistent with the large range in CO_2 concentrations in the MI (8-1025 ppm, without shrinkage bubble; a subset of analyzed shrinkage bubbles by Raman spectroscopy increases the maximum concentrations to 2180 ppm). The presence of mineral precipitates along the circumference of some shrinkage bubbles suggest that reported concentrations are minimum CO_2 measurements. H_2O and CO_2 measurements correspond to minimum entrapment pressures <400 MPa and entrapment depths <15 km. Our estimates of magma storage depths are supported by relatively deep precursory long period earthquakes (16-20 km) with little variation in volatile concentration through time during the eruption.

1106

SO2 emissions from explosive basaltic eruptions

Dr Ery Hughes[1], Dr Geoff Kilgour[1], Prof Jon Blundy[2]
[1]Te Pū Ao | GNS Science, Avalon, New Zealand, [2]University of Oxford, Oxford, UK

Volcanic SO2 can lead to global impacts on climate and health, depending on the magnitude and injection height into the atmosphere. Global impacts are caused by the conversion of SO_2 into aerosols, which leads to solar screening for weeks to months after an eruption. Large SO_2 emissions are associated with explosive eruptions of evolved magma compositions (e.g., Pinatubo 1991, El Chichon 1982, etc.). Additionally, long-lived basaltic fissure eruptions release large quantities of SO_2 due to their long duration resulting in large magma volume and associated sulfur being erupted (e.g., Kīlauea 2018, Laki 1783–1784, flood basalts). However, short-lived, highly explosive basaltic volcanism can also inject significant SO_2 into the upper atmosphere due to the high plumes and sulfur-rich nature of basalts (e.g., Ambae 2018–2019, Sunset Crater 1085 CE, Masaya ~6ka).

We quantify the SO2 released from Okatiana (Aotearoa New Zealand) basalts (Okareka 23.5 ka, Rotokawau 3.4 ka, Kaharoa 0.6 ka, and Tarawera 1886 CE) using the petrologic method. Tarawera (Plinian eruption) released up to ~4 Tg SO_2 over ~5 hours into the stratosphere (~28 km column heights); whereas Rotokawau (phreatomagmatic to Strombolian) may have released up to ~10 Tg SO_2 but over a much longer time period and only into the lower atmosphere (5–7 km column heights). Okareka and Kaharoa have very small volumes and hence released an order of magnitude less SO_2. Krakatau 1883 released 5.6 Tg SO_2 and it can be difficult to detangle the effects from the Tarawera 1886 eruption. However, recent shows southern hemisphere cooling 1–2 years after Tarawera, supported by our calculated SO_2 emissions. We compare these emissions to other magma compositions and styles of eruption. We explore the conditions that result in high sulfur contents of basaltic melts that would lead to high SO_2 emissions form basaltic eruptions.

933

Speciation and isotopic variations of sulfur during degassing

Dr Ery Hughes[1], Dr Lee Saper[4], Dr Philippa Liggins[3], Prof Edward Stolper[2]
[1]Te Pū Ao | GNS Science, Avalon, New Zealand, [2]Caltech, Pasadena, USA, [3]University of Cambridge, Cambridge, UK, [4]University of Edinburgh, Edinburgh, UK

Sulfur is the third most abundant volatile element in silicate magmas after hydrogen and carbon. It is present in several phases (e.g., silicate melt, vapor, FeS-rich melt, solid and liquid sulfates) and multiple species and oxidation states in silicate melt (e.g., S^{2-} and SO_4^{2-}) and vapor (e.g., S_2, SO_2, H_2S, and OCS). Despite the resulting complex behavior of sulfur in magmatic systems with changing intensive variables (e.g., temperature, pressure, and oxygen fugacity), there has been considerable progress recently in the development of thermodynamic models of these systems that provide a framework for understanding these complexities.

We present a multi-volatile (COHS) thermodynamic model of silicate melt ± vapor ± sulfide melt ± anhydrite to understand how sulfur behaves in basaltic magmas in the crust. We find that the sulfur solubility minimum and maximum that have been experimentally observed influence the behavior of sulfur during degassing. Melts that start more reduced than the sulfur solubility minimum reduce as they ascend to the surface, whereas melts that begin more oxidized than the solubility minimum oxidize during degassing. High water contents promote degassing of sulfur at greater depths than low water contents, and the effect is more pronounced for reduced systems. Under reducing conditions, sulfur in the melt becomes isotopically heavier during degassing, whilst under oxidizing conditions sulfur becomes lighter, highlighting the different speciation of the melt and vapor under oxidized and reduced conditions. We apply our model to melt inclusion data from the literature to highlight its utility for understanding natural systems.

676

New Zealand's Tsunami Warning System: Applications to Volcanic Hazard Communication

Miss Rachel Hunt[1], Dr Carina Fearnley[2], Dr Simon Day[3], Professor Mark Maslin[1]
[1]Department of Geography, University College London (UCL), London, United Kingdom, [2]UCL Warning Research Centre, Department of Science and Technology Studies (STS), University College London (UCL), London, United Kingdom, [3]Institute for Risk and Disaster Reduction (IRDR), University College London (UCL), London, United Kingdom

Research was conducted on New Zealand's tsunami warning system to enhance communication and responses between agencies and the public. The findings of this research can be applied to the enhancement of volcanic risk communication, particularly in a multi-hazard context where volcanic activity may result in tsunami hazards.

Using social research methods to investigate warnings and responses in New Zealand, 107 documents and archives were collected and 57 semi-structured interviews were conducted with hazard researchers, warning specialists, and emergency managers. The majority of the interviewees were from New Zealand, with some participants also being recruited from Australia, the Pacific Islands, the UK, and the USA. This allowed for national, regional, and local responses in New Zealand to be compared to those in different countries to explore how warning systems operate in practice.

Three key findings are established. First, the division of responsibilities between the various research institutes, national agencies, regional groups, and local councils involved in monitoring, disseminating, and responding to warnings can lead to the potential for error and delay in issuing these warnings, highlighting the need for consistent messages and coordinated responses. Second, the integration of local knowledge into education campaigns, emergency drills, and citizen science projects can result in the public being more likely to self-evacuate after observing natural warning signs, emphasising that resilience can be developed at the community level. Third, the use of technological and non-technological methods for warning communication through a multi-channel approach can improve the effectiveness of warning systems, stressing that technology should not be solely relied upon within these systems.

These findings raise important questions around the interactions of warning and response agencies for multi-hazard warnings, how local knowledge can be used to build resilience, and the role of numerous technologies in communicating warnings for multiple hazards to the public in New Zealand.

270

Decadal to centennial eruptive history of Steamboat Geyser in Yellowstone National Park, USA: inferences from radiocarbon dating of silicified trees

Dr Shaul Hurwitz[1], John King, Gregory Pederson, Lauren Harrison, Mara Reed, Jefferson Hungerford, Michael Manga
[1]*USGS, Menlo Park, United States*

The first documented eruption of Steamboat Geyser, the tallest active geyser in the world located in Yellowstone's Norris Geyser Basin, was in August 1878. Since then, Steamboat's eruption intervals ranged from 3 days to 50 years based on available records. Most eruptions occurred in three phases (Reed et al., PNAS 2021): 1) September 1961 to early 1969, 2) January 1982 to September 1984, and 3) since March 2018. The geyser's powerful eruptions can reach heights >120 m and since 2018 have prevented tree growth up to 30 m from the vent. Eruptions in the 1960s resulted in similar tree dieback. To examine the pre-documented decadal to centennial patterns of Steamboat Geyser eruptions, we collected 20 specimens of silicified wood from trees that grew at distances of <10 m from the vent. Because trees cannot grow in the geyser's vicinity when it is active, we infer that the trees grew when it was not erupting. No specimens had more than 20 annual rings, suggesting only short periods of growth. Calibrated radiocarbon dates of the specimens suggest that tree growth was mainly clustered in three periods: the late 15th Century, mid-17th Century, and late 18th Century. These periods mostly correlate with drought in the Yellowstone Region, although not as severe as the drought correlated with quiescence of Old Faithful Geyser between 1233–1362 CE, towards the end of the Medieval Climate Anomaly (Hurwitz et al., GRL 2020). At Steamboat Geyser, trees either did not grow during the Medieval Climate Anomaly drought (as at Old Faithful Geyser), or the tree remnants were covered by sinter deposits. The link between drought, geyser hibernation, and tree growth at both Old Faithful and Steamboat Geysers suggest that the Yellowstone hydrothermal system systematically responds to changes in regional climate.

848

Re-evaluating the source, style and impacts of the 1800–1835 eruption cluster with new ice core isotope and cryptotephra analyses

Dr William Hutchison[1], Dr Andrea Burke, Dr Patrick Sugden, Prof. Siwan Davies, Dr Michael Sigl
[1]*University Of St Andrews, St Andrews, United Kingdom*

1800–1850 CE is the coldest period in the last 500 years and marks the final phase of the Little Ice Age. A cluster of major volcanic events took place at this time and include the 1815 eruption of Tambora, in Indonesia, the 1835 eruption of Cosegüina, in Nicaragua, and two unidentified eruptions in 1809 and 1831. Although these events are linked to global climate impacts, major uncertainties remain about the source of the unidentified eruptions, and whether all events were indeed represented by stratospheric sulfur emissions.

Polar ice cores provide exceptional archives of past volcanism. A key development is the analysis of sulfur isotopes in ice core sulfate which encodes detailed information about the eruption source and plume height which can be used to determine climate impact. Cryptotephra deposited alongside the sulfur peaks can also be extracted and analysed in conjunction and used to pinpoint the volcanic source of these emissions and their precise timing.

Here, we undertake a high-time resolution isotopic and cryptotephra analysis of the 1800–1835 period in Antarctic and Greenlandic ice cores. Our initial results show clear sulfur isotope ($\Delta^{33}S$) anomalies for all volcanic events which indicate stratospheric S injections. For 1815, 1831 and 1835, $\Delta^{33}S$ shows a large time-evolving $\Delta^{33}S$ signal, consistent with a single low-latitude eruption and the known source volcanoes (i.e., Cosegüina and Tambora). For 1809, $\Delta^{33}S$ is more muted and shows a more complex time-evolving pattern suggestive of multiple eruptions. Importantly, ice core cryptotephra extracted for 1809 corroborate this hypothesis and suggest distinct geochemical tephra populations around this time. Ultimately, this combination of high-time-resolution S isotopes and cryptotephra offer exciting new insights into the source and style of these major volcanic events, and the role of volcanism at the end of the Little Ice Age.

847

Timing and climate impacts of Iceland's largest basaltic eruptions: new insights into the 939 Eldgjá eruption from ice core archives

Dr William Hutchison[1], Dr Gill Plunkett, Dr Joe McConnel, Ms Imogen Gabriel, Dr Emma Tomlinson, Dr Andrea Burke, Prof. Siwan Davies, Prof. Kirstin Krüger, Dr Michael Sigl
[1]*University Of St Andrews, St Andrews, United Kingdom*

Icelandic fissure eruptions pose severe hazards in terms of air quality and environmental pollution. The 939 Eldgjá eruption was the largest Icelandic lava flood eruption of the Common Era and has been linked to northern hemisphere summer cooling in 940 CE based on tree ring reconstructions. Despite the magnitude and potential impacts of this event key uncertainties remain. For example, it is unclear whether Eldgjá had a stratospheric plume which could explain the long-term cooling. In addition, previous low-time resolution ice core studies have identified a roughly contemporaneous dacitic eruption, complicating the attribution of climate-change to Eldgjá.

We present new high-time resolution Greenland ice records of the 939–940 CE period to unravel the precise timing and climate impacts of volcanism. Multiple sulfur isotopes are used to fingerprint stratospheric SO_2 emissions, while cryptotephra are used to pinpoint the volcanic source of these emissions. We show that the main Eldgjá ice core S peak has a $\Delta^{33}S$ of 0 ± 0.2 ‰, consistent with a tropospheric SO_2 injection. $\Delta^{33}S$ values down to –0.4 ‰ do however follow the main S peak and evidence a stratospheric component and hence a climate impacting phase.

Cryptotephra provide vital insights into the sources of volcanism. We show that basaltic tephra that match Eldgjá compositions are found during the main S peak when $\Delta^{33}S$ displays typical tropospheric values. Tephra associated with the anomalous $\Delta^{33}S$ values that follow the main S peak do not show geochemical affinity to Eldgjá and instead show arc-like signatures. This suggests that an unidentified arc volcano, rather than Eldgjá may be the culprit for the stratospheric S component. Our study shows how the combination of high-time-resolution S isotopes and cryptotephra can be used to gain valuable new insights into the precise timing and potential climate impacts of these major volcanic episodes.

938

Broadband magnetotelluric survey in the Akan-Kutcharo caldera area, northern Japan – understanding of interactions between volcanic and tectonic activities

Dr Hiroshi Ichihara[1], Prof Takeshi Hashimoto[2], Prof Koki Aizawa[3], Mr Tomohiro Inoue[2], Mr Masamitsu Takada[2], Mr Kazumi Okada[2], Mr Atsuo Suzuki[2], Dr Shinichiro Horikawa[1], Mr Haruno Koike[1], Dr Ryo Honda[4]
[1]Nagoya University, Nagoya, Japan, [2]Hokkaido University, Sapporo, Japan, [3]Kyushu University, Fukuoka, Japan, [4]Mount Fuji Research Institute, Fujiyoshida, Japan

The western edge of the Kurile arc, located on the eastern part of Hokkaido Island, Japan, possesses large calderas (Kutcharo and Akan Calderas) that caused destructive caldera-forming eruptions in the past. This region is scientifically attractive in discussing the interaction between volcanic and tectonic activities as follows.

1) Large low electric resistivity anomalies interpreted as high melt-fraction regions are found beneath both the calderas (Honda et al., 2011; Inoue et al., 2022). However, they do not seem connected in the deep extensions.
2) Discontinuity of regional crustal deformation rate is known along the volcanic arc (Tada and Kimura, 1987). However, no obvious tectonic fault zone is not found. It may indicate a ductile tectonic transition zone formed by volcanic activities.
3) On the other hand, local seismicity including magnitude 5 to 6 class earthquakes is seen between the calderas. The 1938 Kutcharo earthquake (M6.0) occurred along a concealed caldera fault (Ichihara et al., 2009; 2013).

A regional 3D resistivity model in and around the Akan-Kutcharo caldera area will help understand the above issues. This study carried out broadband magnetotelluric (BBMT) surveys at 41 sites. Along with existing BBMT data by Ichihara et al. (2013), Honda et al. (2011), and Sato et al. (2001), about 150 BBMT stations covering the study area are available. We use these data to propose a 3D resistivity model to discuss the above research themes.

Acknowledgments: Students from Hokkaido University, Kyushu University, and Chiba University helped us to establish BBMT stations. Earthquake Research Institute, the University of Tokyo, provided BBMT instruments (2020-F2-04, 2021-F2-04, 2022-F2-04).

1489

Understanding the flow-to-fracture transition of volcanic fluids through analogy experiments

Dr Mie Ichihara

How flowing magma breaks like a solid is a fundamental problem that has been investigated for decades. This talk introduces the recent multi-disciplinary project on the flow and fracture of complex fluids, consisting of experimental, theoretical, and numerical approaches. In volcanology, the glass transition is considered to appear at high strain rates and control the brittle fracture of magma. In physics, on the other hand, the glass transition is more frequently associated with the appearance of yield strength at low strain rates. The project aims to bridge this discrepancy and establish the fracture mechanics for complex fluids.

We experimentally show the contrasting flow/fracture behaviors of Maxwell-type viscoelastic fluid, Bingham-type yield-strength fluid, Newtonian viscous fluids, and those with solid particles. The experiments include bubble growth and fracture within and at the surface of the fluids, flow and fracture around a cylinder, and flow and rupture of fluid films under extension. We emphasize that the observation of elasticity at small strain is not sufficient to infer that fluid can generate brittle fractures.

We also develop a numerical method to simulate the flow and fracture of Maxwell-type viscoelastic fluids, combining the finite element methods and phase field algorithm. The simulations reproduce the essential features of some experiments and indicate that inhomogeneity is essential for initiating fracture in fluids.

When complex fluids are concerned, it is not straightforward to scale the laboratory phenomena to the natural volcanic systems. However, we demonstrate that a deep understanding of experimental phenomena can improve our understanding of how volcanic systems work by considering the physical and/or mathematical analogy. We name these approaches analogy experiments.

481

Improved infrasound array processing methods for detecting volcanic events

Dr Alexandra Iezzi[1,2], Dr Robin Matoza[2], Mr Jordan Bishop[3], Dr David Fee[3,4], Dr Weston Thelen[1], Dr Seth Moran[1]

[1]USGS Cascades Volcano Observatory, Vancouver, United States, [2]Department of Earth Science and Earth Research Institute, University of California, Santa Barbara, United States, [3]Wilson Alaska Technical Center, Geophysical Institute, University of Alaska Fairbanks, Fairbanks, United States, [4]Alaska Volcano Observatory, Geophysical Institute, University of Alaska Fairbanks, Fairbanks, United States

Explosions and mass movements at volcanoes can be detected, located, and quantified using infrasound data at distances from local to global. Infrasound complements multidisciplinary data because it records near-surface processes (e.g., mass movements) that may not be well-constrained by seismic data alone. Infrasound sensors have increasingly been used in volcano monitoring and are deployed as single sensors, networks, and arrays. Arrays are advantageous as they offer improved signal detection and noise suppression capabilities. However, infrasound array processing is commonly implemented for a single broad frequency band, which can lead to signals of interest going undetected due to the choice of frequency limits for processing or the occurrence of simultaneous sources.

We present a new narrow-band least-squares algorithm (Iezzi et al., 2022) that processes infrasound array data in multiple sequential narrow frequency bands and present applications of this technique to eruption and mass movement signals at volcanoes in the Cascades and Alaska. We find a mass movement signal at Redoubt volcano that was previously undetected using standard array processing techniques because its frequency content was higher than the normal processing limits. Additionally, we revisit infrasound data from a 2005 explosion at Mount St. Helens and find a more accurate representation of event duration as well as changes in frequency content, which may have implications for source processes. This new narrow-band least-squares algorithm enhances our ability to track changes in frequency content through time, distinguish between multiple simultaneous sources that are distinct in their frequency content, and generally improves the ability to detect and locate volcanic events in near real-time.

Iezzi, A.M., R.S. Matoza, J.W. Bishop, S. Bhetanabhotla, and D. Fee (2022). Narrow-Band Least-Squares Infrasound Array Processing, Seismol. Res. Lett., 1-16, doi:10.1785/0220220042.

483

Investigating eruption and acoustic wavefield directionality using UAV-mounted infrasound sensors

Dr Alexandra Iezzi[1,2], Dr Robin Matoza[2], Dr David Fee[3,4], Mr Richard Buzard[3], Ms Julia Gestrich[3,4], Dr Markus Schmid[5], Dr Valeria Cigala[5], Dr Ulrich Kueppers[5], Dr Giorgio Lacanna[6], Dr Maurizio Ripepe[6]
[1]USGS Cascades Volcano Observatory, Vancouver, United States, [2]Department of Earth Science and Earth Research Institute, University of California,, Santa Barbara, United States, [3]Geophysical Institute, University of Alaska Fairbanks, Fairbanks, United States, [4]Alaska Volcano Observatory, Geophysical Institute, University of Alaska Fairbanks, Fairbanks, United States, [5]Department of Earth and Environmental Sciences, Ludwig-Maximilians-Universität (LMU) München, 8033 Munich, Germany, [6]Department of Earth Science, University of Florence, Florence, Italy

Infrasound technology can be used to monitor and characterize explosive sources including volcanic eruptions. For example, infrasound networks have been used to quantify mass flow rate and eruption mass. However, infrasound sensors are usually placed on Earth's surface, thus providing a limited sampling of the acoustic radiation pattern and directionality of volcanic eruptions. Consequently, studies commonly assume that infrasound from volcanic eruptions either radiates equally in all directions or that there is no vertical directionality. The lack of clarity on the sources of infrasound signals can however create a bias in data interpretation (Iezzi et al., 2022). By placing infrasound sensors on aerial platforms (in addition to ground-based deployments), we can enhance our knowledge of the infrasound wavefield radiated from volcanic eruptions and apply that knowledge to improve source estimates for research and monitoring purposes.

As part of a multidisciplinary study in May 2022, we deployed nine ground-based single infrasound sensors surrounding the summit crater of Stromboli volcano, Italy as well as an infrasound sensor aboard an Uncrewed Aerial Vehicle (UAV). We captured eruption infrasound from at least seven events (both short-duration explosions and jetting) from multiple active vents during times when the UAV-mounted infrasound sensor strategically hovered near the explosion. We account for topographically induced directionality by modeling acoustic propagation over a high-resolution digital elevation model created during the deployment. Analysis of the data shows that observed directionality from some events may be explained primarily due to the influence of topography, while other events may have a directional source component. This proof-of-concept study is aimed at providing unique information on explosion dynamics that successfully extends data collection capabilities to previously unreachable locations near active volcanoes.

Iezzi, A.M., Matoza, R.S., Fee, D. Kim, K., and Jolly, A.D. (2022), Synthetic Evaluation of Infrasonic Multipole Waveform Inversion, Journal of Geophysical Research.

1420

Continuously operable simulator and forecasting the deposition of volcanic ash at Sakurajima volcano, Japan

Professor MASATO IGUCHI[1], Dr. Haruhisa Nakamichi[1], Mr. Kosei Takishita[1], Dr. Alexandros Poulidis[2]
[1]*Kyoto University, Kagoshima, Japan,* [2]*University of Bremen, , German*

At Sakurajima volcano, frequent Vulcanian eruptions have been seen at the summit crater of Minamidake since 1955. In addition to this eruption style, the eruptive activities of Strombolian type and prolonged ash emission also occur frequently. We studied the design of a simulator of advection-diffusion-fallout of volcanic ash emitted continuously. The time function of volcanic ash eruption rate is given by a linear combination of the volcanic tremor amplitude and the volume change of the pressure source obtained from the ground motion. The simulation is repeated using discretized values of the eruption rate time function at an iteration time interval of the simulation. The integrated value of the volcanic ash deposition on the ground obtained from each individual simulation is used to estimate the value of the ash fallout. The plume height is given by an empirical equation proportional to a quarter of the power of the eruption rate. Since the wind velocity field near the volcano is complicated by the influence of the volcanic topography, the predicted values published by meteorological organizations are made in high resolution by Weather Research and Forecasting (WRF) for the simulation. We confirmed that an individual simulation can be completed within a few minutes of iteration interval time, using the PUFF model as the Lagrangian method and FALL3D-8.0 as the Eulerian method on a general-purpose PC. Except during rainfall, the radar reflectivity, the count of particles per particle size, and fall velocity obtained by the disdrometers can be used for the quasi-real time matching of the plume height calculated from the eruption rate and the ash fall deposition rate obtained from the simulation. We will present concept of the continuously operable simulator.

1181

Multi-disciplinary approach to volcanic architecture reconstruction in the porphyry Cu-Au mineralised Macquarie Arc, Cowal, NSW, Australia

Mr Malai Ila'ava[1], Dr Martin Jutzeler[1], Emeritus Prof Raymond Cas[2], Associate Professor Rebecca Carey[1]
[1]*University Of Tasmania (CODES), Hobart, Australia,* [2]*Monash University, Melbourne, Australia*

The Macquarie Arc in NSW, Australia, is an Ordovician intra-oceanic arc presently preserved as fault-bound remnants separated by Silurian-Devonian basins. It is the second most important alkalic porphyry Cu-Au district in the world. The c.a. 40 x 15km Cowal Igneous Complex (CIC) is in the Junee-Narromine Volcanic Belt, the western-most and largest of four structural belts that comprise the arc.

Previous volcanic facies studies at Cowal were completed at deposit scale but late structural complexity and a lack of clear marker beds precludes confident regional scale correlations. Additionally, the earliest volcanic units in the Macquarie Arc (present in the CIC) are yet to be effectively age-dated. We report preliminary outcomes from detailed volcanic facies analysis of c.a. 27 km of diamond drill core logging over a 10 x 20km area.

The CIC is chiefly a depocenter comprised of two domains. The western third is more deformed with thrusts and tight folds with an interpreted distal succession of lowermost pyroxene-basalt, dominantly mafic-intermediate mudstones and sandstones that gradually coarsen up and possibly culminate in the deposition of a pumice-bearing breccia, thickly bedded massive sandstones, breccia-conglomerates, effusive trachyandesite, thickly bedded pumice and glass shard massive breccias, and an andesitic cryptodome. In contrast, the eastern two-thirds show more subdued deformation with open folds and a relatively proximal volcanic succession of lowermost pumice bearing breccias, overlain (or intruded) by various effusive basalts with a combined thickness of at least 600m. Integrating the facies analysis with igneous geochemistry and U-Pb dating on zircons will constrain subduction processes, tectonic setting and age relationships.
This project showcases how facies analysis can be used as the principal technique for volcanic architecture reconstructions in mineralised terranes and how integrating other datasets such as geochemistry and geochronology may have implications for the volcanic and tectonic evolution of metallogenic provinces.

700

Tephra seismites preserved in unconsolidated organic lake sediments in the Hamilton lowlands, New Zealand, indicate paleoearthquake activity since 17.6 ka

Dr Max Kluger[1], Dr Tehnuka Ilanko[1], Prof. David Lowe[1], Dr Vicki Moon[1], Jordanka Chaneva[1], Prof. Richard Johnston[2], Dr Pilar Villamor[3], Dr Kate Clark[3], Prof. Rolando Orense[4], Richard Melchert[1], Remedy Loame[1], Nic Ross[5]

[1]University of Waikato, Kirikiriroa-Hamilton, New Zealand, [2]Swansea University, Swansea, United Kingdom, [3]GNS Science, Lower Hutt, New Zealand, [4]University of Auckland, Auckland, New Zealand, [5]Hamilton Radiology, Kirikiriroa-Hamilton, New Zealand

Until recently, the Hamilton lowlands in New Zealand's North Island were classified as having low to moderate seismic risk on the basis of (limited) historic earthquake records. Paleoliquefaction features recorded locally in ~20-kyr-old volcanogenic sediments were not regarded as seismogenic, and local faults were unknown. This changed in 2016 with the identification of multiple faults in the lowlands, and of Te Puninga Fault on the western margins of the nearby Hauraki Plains, which also host the active Kerepehi Fault. To re-evaluate seismic hazard in light of these findings, we studied soft-sediment deformation structures (SSDS) in distal rhyolitic tephra layers deposited in numerous 20-kyr-old closed-basin lakes throughout the lowlands. We took multiple sediment cores from 16 lakes, and characterised the tephra layers and associated SSDS using sediment description, geotechnical and mineralogical analyses, and X-ray computer tomography (CT) scanning.

We identified SSDS in seven key tephras, deposited from ~17.6—7.6 ka. These tephras were up to 8 cm thick, each comprising two to six internal beds of extremely fine to medium ash. We observed five types of SSDS, including large, complex, downward-directed dikes. Medium ash beds were the most susceptible to liquefaction. Liquefied tephra materials commonly move downwards into lower-density organic lake sediments because of the presence of fine ash overlying the liquefiable beds. CT scanning provided three-dimensional visualisations of SSDS, enabling us to quantify their dimensions and derive relationships between tephra bedding characteristics and SSDS volumes.

Our analysis of spatio-temporal distributions of SSDS across the lowlands indicates a seismic source to the northeast, potentially Te Puninga and/or Kerepehi Faults, both known to have been active since 20 ka. Based on SSDS and fault activity in the Hauraki Plains, we conclude that liquefaction in the Hamilton lowlands may have been triggered by two phases of earthquake activity since 17.6 ka.

1230

The Silent Trigger: Do slow-slip earthquakes trigger volcanic unrest in the Taupō Volcanic Zone?

Dr Finnigan Illsley-Kemp[1], Katie Jacobs[2], Laura Wallace[2,3], Thea Hincks[4], Thomas Gernon[4]
[1]Victoria University Of Wellington, Wellington, New Zealand, [2]GNS Science, Avalon, New Zealand, [3]University of Texas Institute for Geophysics, , USA, [4]School of Ocean and Earth Science, Southampton, United Kingdom

It is often difficult to determine the triggers that cause a volcano to switch from a state of dormancy to unrest. Several studies suggest volcanic unrest can be triggered by static and/or dynamic stress changes imposed by large earthquakes (Magnitude >7.0) on a subduction zone, and occasionally this unrest can cascade towards eruption. Similar to large earthquakes, subduction zone slow slip events also produce stress changes in the Earth's crust. However, there have been no studies into whether volcanic unrest can be triggered by slow-slip events, which are episodic slip events on the subduction plate boundary lasting days to months, and in some cases release a similar amount of energy as a Magnitude 7 earthquake. We suggest that in 2019 a slow-slip event on the Hikurangi subduction zone triggered volcanic unrest at Taupō and Tarawera volcanoes. Similarly, volcanic unrest at both Taupō and Ruapehu in 2022 has coincided with a large deep slow-slip event. When they occur, slow slip events at the central Hikurangi margin produce extensional stress within the Taupō Volcanic Zone. We will use seismological and geodetic analysis, combined with numerical modelling to develop a clear understanding of the influence of slow slip events on volcanic unrest over the last two decades in New Zealand. We will utilise machine-learning statistical analysis to determine whether volcanic unrest can be triggered by slow-slip event activity. Understanding the linkages between slow slip events and volcanic unrest may allow us to forecast periods of volcanic unrest and reveal the potential for future Great (>M8) subduction megathrust earthquakes to trigger volcanic unrest and/or eruptions.

1277

Interpretations of the resistivity distributions derived from 3D MT inversion in the Hatchobaru geothermal field, central kyushu, southwestern Japan

Mr Haruhiro Inagaki[1], Ms Saki Tsutsumi[1], Dr Yoshio Soeda[1], Dr Sofyan Yayan[1], Dr Hiroki Saito[1]
[1]*West Japan Engineering Consultants, Inc, Fukuoka, Japan*

The Hatchobaru geothermal field is located in central Kyushu, southwestern Japan. The Hatchobaru geothermal power plant has been operated since 1977 by Kyushu Electric Power Co., Inc. The current output power generated by the double-flash system is 110 MW and by a binary unit is 2MW. Adequate reservoir management based on geothermal conceptual model is essential to avoid a decreasing power output. MT data in the field were acquired in 1986, 1994 and 2010, respectively and 1D MT inversion and 2D forward modeling were conducted to construct geothermal conceptual model. However, the subsurface resistivity structures at deeper depth indicate an anisotropy in 3D based on the MT data, and the topography effects to the MT data were not considered during the MT data analyses. In this study, we conducted the 3D MT inversion combined with topography to estimate more reliable subsurface resistivity structures. Subsequently, we examined the reliability of the 3D MT results by comparing with the well lithology, hydrothermal alteration, subsurface temperature etc. As a result of examining the reliability of 3D MT results, we have concluded that the 3D MT inversion method is more reliable method for conceptual modeling in Hatchobaru than the existing MT results. Based on the inverted resistivity structures, extent of geothermal reservoir tapped by well drilling are illustrated as relatively resistive zones below the conductive zones at shallower depth. Additionally, the difference of the resistivity values of the conductive zone at shallow depth is confirmed between the high temperature neutral-pH reservoir and the reservoir containing acidic fluid. Based on 3D MT results, we propose geothermal reservoir compartments in the Hatchobaru field; the high temperature neutral-pH reservoir and the reservoir containing acidic fluid. These update of understanding of reservoir structure in the Hatchobaru will contribute to reservoir management and well targeting for sustainable power output.

1363

Changes in soil degassing style as a possible precursor to volcanic activity

Professor Salvatore Inguaggiato[1], Dr. Fabio Vita[1], Dr. Marianna Cangemi[2]
[1]INGV, Palermo, Italy, [2]University, Palermo, Italy

Paroxysmal explosions are some of the most spectacular evidences of volcanism on Earth triggered by the rapid ascent of volatile-rich magma. These explosions often occur in persistently erupting basaltic volcanoes located in subduction zones and represent a major hazar d due to the sudden occurrence and wide impact on the neighbouring populations. However, the recognition of signals that forecast these blasts remains challenging even in the best-monitored volcanoes.

Establish that the deep portions of a volcano plumbing system are refilled by new volatiles-rich magma intruding from the mantle is therefore a key factor for forecasting eruptions and helping in recognizing possible precursors of paroxysmal events.

Stromboli volcano, Aeolian Islands Italy, is characterized by a persistent strombolian activity is a perfect case study to investigate the relationship between degassing activity and paroxysmal events A continuous geochemical network installed on the Stromboli island (summit and peripheral areas) allowed to acquire a lot of soil CO2 flux data to well investigate and modelling the plumbing volcanic system.

The analysis of a large data set of soil CO2 fluxes collected on the summit crater area, from 2000 to 2019, showed significant changes in values and style degassing before and in coincidence with the main volcanic events. In particular, CO2 summit soil degassing processes showed three main and peculiar behaviors:

A. A Long-Lasting modification, characterized by a slow and continuous increase of CO2 flux, which indicates that the volatiles pressure in the shallow plumbing system increased over time;
B. Transient Modifications, characterized by abrupt changes of CO2 degassing rate, indicating many different pulses of new un-degassed magma arriving in the shallow plumbing system;
C. Strong Increasing of Natural Daily Variation, highlighting drastic changes of the degassing style, just few months before the major paroxysmal events, indicating a strong disequilibrium in the delicate input/output degassing balance.

321

Cluster Analysis of a Global Catalogue of Sentinel-1 InSAR Data

Mr Ben Ireland[1], Professor Juliet Biggs[1], Dr Pui Anantrasirichai[1]
[1]*University Of Bristol, Bristol, United Kingdom*

A common approach to forecasting volcanic behaviour is by identifying analogue systems, thus comparing and classifying monitoring signals is critical for volcano observatories. Previous databases have compiled published analyses of satellite data to define the spatial and temporal properties of volcano deformation patterns, but while the temporal span of a signal is often well-reported, the spatial characteristics are more challenging to extract. Here, we create a new database by extracting key parameters from the first 6 years of systematically processed Sentinel-1 InSAR data. Then we use cluster analysis to group together deformation patterns with similar characteristics. We are particularly interested in whether the clusters correspond to specific processes (e.g. eruptive, non-eruptive), magma composition/rheology or the underlying magmatic architecture. Ultimately, these methods will be used to provide a scientific foundation or the identification of analogue systems and volcano forecasting.

1005

VolcanoStories: An open access research project and resource for the 2021 Volcán de Tajogaite eruption, La Palma, Canary Islands

Mr Ben Ireland[1,2], Ms Sharon Backhouse[1], Mr Fernando Borràs Castelló[3], Miss Rosie Rice[1,4], Mr Samu Cáceres Leal[1]

[1]GeoTenerife Ltd, Tenerife, Spain, [2]University of Bristol, Bristol, United Kingdom, [3]Drones for Geology, Barcelona, Spain, [4]University of Cambridge, Cambridge, United Kingdom

During a volcanic crisis, a wealth of data, stories and other resources emerge, that once consolidated and compiled become key in reflecting on the crisis and learning lessons for future events. However, often during and after a volcanic crisis, intense pressure and workloads prevent or delay the capture or archiving of datasets which may be key when reflecting on the eruption response. GeoTenerife were in a unique position during the 2021 Volcán de Tajogaite eruption in La Palma in this respect, being a geoscience institution researching and reporting on the eruption away from the frontline of the official emergency response. Twinned with a network of local citizens and collaborators on La Palma, this meant we were able to create a framework to capture, record, archive and reflect on a variety of datasets in the moment.

The result of this project is VolcanoStories, an ongoing free and open web resource preserving a compilation of fully open primary and secondary data, intimate syn-eruptive witness testimony, day-by-day updates, 3D drone models of the affected area, and educational resources related to the 2021 Volcán de Tajogaite eruption, highlighting the unique dynamics of the ocean island eruption. VolcanoStories is also supplemented by Lava Bombs, a documentary analysing key themes of communication, trust, pressure, preparedness and collaboration related to the eruption, distilled from VolcanoStories research. The aims of these resources are to maximise dissemination of the research and lessons learnt, both to the local population in La Palma and to researchers in other areas where the lessons learnt from the disaster may be applicable. VolcanoStories has also fostered collaboration with international scientific institutions for research and geoscience training camps, the results of which will be shared in an open-access format as part of the ongoing nature of the project.

721

Temporal changes in chemical composition of acidic sulfate-chloride waters discharged at volcanic edifices in Ebinokogen-Ioyama volcano, Kirishima Volcano Group, Japan

Keigo Mori[2,7], Jun-ichiro Ishibashi[1,2], Kei Yamashita[2,8], Takumi Kanda[2,9], Tomoharu Miyamoto[2], Takeshi Matsushima[2], Harue Masuda[3], Toshiro Yamanaka[4], Shogo Oshima[5], Saki Tsutsumi[5], Yasuhisa Tajima[6]
[1]Kobe University, KOBEC, Kobe, Japan, [2]Kyushu University, Faculty of Science, Fukuoka, Japan, [3]Osaka City University, Osaka, Japan, [4]Tokyo Univ. Marine Sci. Tech., Tokyo, Japan, [5]West JEC Co., Ltd., Fukuoka, Japan, [6]Nippon Koei Co., Ltd. R&D Center, Tsukuba, Japan, [7]CTI Engineering Co., Ltd., Osaka, Japan, [8]Kajima Tech. Res. Inst., Chofu, Japan, [9]Univ. Tokyo, School Frontier Sci., Kashiwa, Japan

We have conducted chemical monitoring of acidic sulfate-chloride (ASC) waters discharged at volcanic edifices as well as observations of nearby geothermal activities, since the shallow magmatic hydrothermal eruption in 2018/04 on Ebionokogen-Ioyama volcano. The main target has been two hot springs Y2a (20-40 m in diameter) and Y2b (~10 m in diameter) in Ioyama-south craters located 50 meters south from the Ioyama crater, and one hot spring W4 (a few meters in diameter) in Ioyama-west craters about 500 meters west from the Ioyama crater. Observed sulfur isotope ratios of the ASC waters were basically stable for 4 years duration; $\delta^{34}S(SO_4)$ = +15 - +25 ‰l for dissolved sulfate and $\delta^{34}S(S^0)$ = +0 - +5 ‰ for native sulfur in particles. The sulfur isotopic signature suggests formation of the ASC waters by scrubbing of magmatic volatile/fluid in the edifices. On the other hand, chemical composition of the ASC waters showed stepwise changes, likely in association with rise and decline of geothermal activities. In Ioyama-west craters, W4 hot spring showed drastic change from Cl/SO_4 >1.0 to Cl/SO_4<0.3 at 2019/12, and rebound to $Cl/SO_4 \simeq 1.0$ at 2020/07 when a new fumarole vent appeared in the vicinity. Afterward both the hot spring and fumarole activities ceased at 2021/07. In Ioyama-south craters, Y2a hot spring showed drastic change from Cl/SO_4>1.0 to Cl/SO_4<0.1 at 2019/12 and rebound to Cl/SO_4>2.0 at 2022/05 after stay in the low value for two years. Later Cl/SO_4 ratio backed to the low range in 2022/06. These temporal changes in Cl/SO_4 ratio are accompanied by changes in other chemical species. For example, B/Cl ratio and As/Cl ratio showed reversed changes. Such drastic changes in water chemistry would be attributed to change in condition of the phase separation of the magmatic fluid that entrains into the ASC waters.

1342

Gas geochemistry of geothermal fluids from the Hatchobaru geothermal field in Kyushu, Japan

Jun-ichiro Ishibashi[1], Akira Ijiri[2], Keigo Kitamura[3], Jun Nishijima[3]
[1]Kobe University, KOBEC, Kobe, Japan, [2]Kobe University, Faculty Maritime Sci., Kobe, Japan, [3]Kyushu University, Dept. Earth Resources Engineering, Fukuoka, Japan

The Hatchobaru geothermal field is located on the northwestern flank of the Kuju Volcanoes in the central part of Kyushu Island, Japan. We have conducted geochemical studies of gas species in geothermal fluids which were obtained directly from the well heads of the Hatchobaru geothermal power plant, as well as in fumarolic and hot spring gases collected from the neighboring areas. Helium and carbon isotopic compositions were very similar to the reported values from volcanic fumaroles of the Kuju-Iwoyama Volcano that is located at about 5 km east. The gas chemistry strongly suggested that the geothermal system was substantially affected by the contribution of magmatic volatiles from the subjacent heat source. Difference between $\delta^{13}C(CO_2)$ and $\delta^{13}C(CH_4)$ yielded an apparent equilibrium temperature of 375-430^{o}C, which is distinctly higher than the estimated reservoir temperature of 250-300^{o}C based on silica and alkali geothermometers. This result could be interpreted as reflecting interactions in the deep region beneath the reservoir.

506

Probabilistic model for ground deformation data of Vulcanian explosions at Sakurajima volcano

Dr Kyoka Ishii[1], Dr Masato Iguchi[1]
[1]*Sakurajima Volcano Research Center, Kyoto University, Kagoshima, Japan*

Statistical analysis of a large database of volcanic observation data can contribute to the development of probabilistic models to forecast eruptions. Sakurajima volcano located in southern Kyushu, Japan is one of the most suitable fields for such analysis. Frequent Vulcanian explosions characterize its eruptive activity for the last 70 years, which provides a huge amount of geophysical data related to explosions. Before and during an explosion, distinct ground deformation is typically observed by extensometers and tiltmeters equipped in underground observation tunnels. These records reflect the inflation of the magma chamber several tens of minutes to hours before an explosion and the subsequent deflation of the magma chamber since the onset of the explosion. Therefore, we investigate the duration of inflation, the amount of inflation, and the ratio of deflation to inflation based on the dataset of strain records in 2009–2015. This period corresponds to the period of heightened activity at Showa Crater. It is expected that the observed distributions of the duration of inflation and the amount of deformation relate to the behavior of the plumbing system of Vulcanian explosions. The observed distributions are compared to several statistical models, such as Log-normal, Weibull, inverse-Gaussian, Log-logistic, and Exponential distributions. The model parameters for each considered model are estimated by a maximum likelihood estimation. We discuss the most appropriate model to explain the observed distribution and the underlying physical processes suggested by that model. In the future, short-term forecasting for the timing and size of recurrent Vulcanian explosions can be practical by using the probabilistic model.

510

Temporal depth change in the magma surface at Aso volcano in 2014–2015

Dr Kyoka Ishii[1], Dr Akihiko Yokoo[2], Dr Takahiro Ohkura[2], Dr Takahito Kazama[3]
[1]Sakurajima Volcano Research Center, Kyoto University, Kagoshima, Japan, [2]Aso Volcanological Laboratory, Kyoto University, Aso, Japan, [3]Graduate School of Science, Kyoto University, Kyoto, Japan

Temporal change in the depth of magma surface at open vent volcanoes reflects the magma supply from the magma chamber. We estimate the temporal depth change in the magma surface at Aso volcano, Japan using seismo-acoustic signals. The magmatic eruption of Aso volcano began in November 2014 and lasted until May 2015. During this five-month episode, Strombolian explosions and continuous ash emissions occurred. Distinct peak frequencies of infrasound signals were observed throughout the eruptive episode, which is derived from acoustic resonance inside the vent. We constrain the depth of the magma surface for five months using the infrasound peak frequency and the arrival time difference of the seismo-acoustic signals. The shape of the resonant pipe (conduit) above the magma surface is also determined by the frequency ratio of the fundamental and higher resonant modes. As a result, the magma surface rose from January 2015. The conduit shape changed from cylinder to conical frustum flaring inside at the same period. Before these changes, the ground deformation data recorded in the underground tunnel show an inflation source at 1–2 km depth. This suggests that increasing magma supply provides the rise of the magma surface. The heat of the injected magma into the shallow conduit weakened the conduit wall near the magma surface, which might cause the shape of the conduit to change. At the end of the eruptive episode, the magma surface dropped ~70 m. Consequently, the crater floor collapsed, which led to the cessation of the magmatic eruption. The drop of the magma surface and the instability of the conduit shape may induce the crater collapse.

1415

The El Botón Arc: Early Nazca Subduction-Related Magmatism in Colombia

Felix Ishimwe[1], Dr Christy Till[1], Dr Agustin Cardona[2], Juan Sébastian Jaramillo[2]
[1]Arizona State University, Tempe, United States, [2]Universidad Nacional de Colombia, Medellín , Medellín, Colombia

Magmatism in subduction zones is complex and its locus and composition are controlled by many variables, which may change through space and time. The Colombian arc, located at the Nazca-South America plate boundary, provides an excellent opportunity to study the spatial-temporal variations in arc magmatism and their primary causes. Magmatism in northernmost Colombia known as the El Botón arc occurred between 13-9 Ma, then migrated southeast to form the Combia center ca. 11-6 Ma, and finally further southeast to the present-day Modern arc. To investigate the tectonic causes of the spatial-temporal change in the geochemical composition of northern Colombia arc, we conducted a comprehensive field campaign and collected samples for geochemical and geochronological analysis. In this study, we focus on the earliest phase of magmatism in the El Botón arc. Lavas in this arc have compositions that range from tholeiitic basalt to trachyte, and contrary to the Modern arc, the major element compositions of El Botón arc magmas predominantly indicate they originated via dry melting. Results from mantle thermobarometry show primary melt-mantle equilibration occurred at sub-crustal pressure at 1300C. These lavas show enrichment of LILE, and depletion of Nb, Ta and Ti, typical signatures of arc magmas. Yet high FeO/MgO, low Mg# at relatively low SiO2 content, and high primary melt temperature argues against a flux mantle melting hypothesis. We interpret that the El Botón primary magmas likely formed by decompression melting of the mantle and incorporated previously metasomatized lithospheric mantle materials during ascent to provide the subduction signatures. Overall, we conclude that the El Botón arc is related to the re-organization of Nazca-South America subduction in Colombia. Subsequent studies of the Combia and the Modern arcs will constrain the entire Colombia arc tectono-magmatic evolution over the past 13 Ma.

190

Quaternary gigantic eruptions and resurgent pluton emplacements in the Northern Japan Alps

Dr Hisatoshi Ito[1]
[1]*Central Research Institute of Electric Power Industry, Abiko, Japan*

Northern Japan Alps, or Hida Mountain Range (HMR) is known to be a site of the world's youngest exposed granite. It also hosts relevant volcanic products, therefore an ideal site to study volcano-plutonic systems. Two plutons of ~1.4 Ma Takidani Granodiorite (~20 km²) and ~1.2–0.8 Ma Kurobegawa Granite (~100 km²) (Ito et al., 2021) are well exposed in the south and north of the HMR, respectively. Zircon U-Pb dating revealed that these are resurgent plutons emplaced after ~1.8 Ma and ~1.6 Ma caldera-forming eruptions, respectively. Al-in-hornblende geobarometry indicates that both plutons were formed at a shallow crustal level of ~6 km in depth. Both plutons are also typified by mingling of microgranular mafic enclaves. The ~1.8 Ma pre-Takidani eruptions are composed of two >300 km³ eruptions with only a ~10,000-year quiescence as revealed by tephrochronology. Interestingly, these two eruptions are petrologically distinct: a preceding dacite eruption followed by a rhyolite eruption with a ~10,000-year repose (Kimura and Nagahashi, 2007). The ~1.6 Ma pre-Kurobegawa eruptions are less studied than the ~1.8 Ma pre-Takidani eruptions, although they seem to constitute at least two subsequent large rhyolite-andesite eruptions. Overall, the HMR experienced a regional tumescence in the Quaternary which caused caldera eruptions and subsequent plutonism at 1.8–0.8 Ma, indicating a regional and sustained magmatic input underneath. It might be noteworthy that both resurgent pluton formation culminated ~0.5 million years after gigantic eruptions.

References:

Ito et al., 2021. The Quaternary Kurobegawa Granite: an example of a deeply dissected resurgent pluton. Sci. Rep., 11, 22059.
Kimura and Nagahashi, 2007. Origin of a voluminous iron-enriched high-K rhyolite magma erupted in the North Japan Alps at 1.75 Ma: Evidence for upper crustal melting, J. Volcanol. Geotherm. Res., 167, 81–99.

1428

Frozen in Time: Characterizing, Unraveling and Connecting the Englacial Antarctic Tephra Record

Dr Nels Iverson[1,2], Dr Nelia W. Dunbar[1,2], Dr Andrei V. Kurbatov[2,3], Dr William C. McIntosh[1,2], Dr Matthew J. Zimmerer[1,2], Dr Philip R Kyle[2]
[1]New Mexico Bureau of Gology and Mineral Resources, Socorro, United States, [2]New Mexico Tech, Socorro, USA, [3]University of Maine , Orono, USA, [4]Climate Change Institute, Orono, USA

In 1971 Gow and Williamson described tephra layers in the first deep Antarctic ice core drilled at Byrd Station in West Antarctica. They suggested the core may contain over 2,000 tephra layers. Observation of fine dust layers of tephra in the WAIS ice core suggests that some layers may be windblown and not tephra fall deposits. This seminal paper launched 50 years of tephra studies aiming to better characterize and integrate Antarctica's englacial tephra records. Currently, there are over 230 different tephra and cryptotephra identified in Antarctic ice cores. Marie Byrd Land (MBL) volcanoes, Mt. Berlin, and Mt. Takahe dominate West Antarctic ice core tephra record, while the East Antarctic record is largely from Northern Victoria Land (NVL) volcanoes (Mt. Melbourne, Mt. Rittman, and The Pleiades) and volcanoes in the Southern Ocean and South Sandwich Islands. Correlation of a tephra layers to their continental source volcano is possible, albeit difficult given the lack of proximal records on ice covered volcanoes or in nearby blue ice areas. Correlation to volcanoes off-continent is mostly unsuccessful, except when tephra is from a globally significant eruption (i.e. New Zealand, Indonesia, South America or Pacific islands). An integrated tephra framework was built using geochemical correlations, ice core chronology and 40Ar/39Ar dating. This integrated record of continental volcanism shows spatial and temporal changes in volcanic activity across Antarctica with time. The Holocene volcanic record is dominated by tephra sourced from NVL volcanoes (75%), whereas the latest glacial period was mainly MBL eruptions (66%). Volcanic activity shifts back to NVL during the Eemian where 65% of the tephra record originates from NVL volcanoes. The Antarctic tephra framework is constantly being improved and further inclusion of tephra from blue ice areas is vital to understanding the abundance, magnitude, and timing of volcanism in Antarctica and the southern Hemisphere.

1162

Condition of mushy magma reservoir that affects on the eruption styles: Case studies of Unzen historical eruptions

Ms Kurumi Iwahashi[1], Dr Atsushi Yasuda[2]
[1]Geological Survey Of Japan, AIST, Ibaraki, Japan, [2]Earthquake Research Institute, the University of Tokyo, Tokyo, Japan

It has recently become clear that mushy magma reservoir with high crystalline contents (>50 vol.%) exists beneath island arc volcanoes. One of the main triggers of volcanic eruptions is the penetration of high-temperature magma into mushy magma reservoirs. It has been pointed out that the temperature and water content of the mushy magma reservoir can cause differences in the eruption style after magma mixing (e.g., Popa et al., 2021). In this study, we investigate condition of magma reservoir and how the eruption triggering mechanism changes at three historical eruptions (1663, 1792, 1991-95) of the Unzen Volcano.
In our study, chemical composition analysis of minerals and melts constituting crystal clots and phenocrysts in the product of each eruption were conducted. EPMA was mainly used for the analysis. The chemical composition of the melts and phenocrysts involved in the magma mixing during the pre-eruptive process of the historical eruptions of Unzen volcano were clarified. Then applying geothermometers, we estimated the temperatures of the magmas involved in the process. Temperature of the magma reservoir of the 1792 eruption was also constrained from analysis of diffusion profiles of Sr in plagioclase phenocrysts.
We also estimated the rate of magma ascent during the 1663 and 1792 eruptions based on the speed of hornblende breakdown. In addition, diffusion profiles of Mg in plagioclase phenocrysts were analyzed to constrain the ascent rate. From these results, we constructed a model of the pre-eruptive process of each eruption, and discuss the pre-eruptive processes that caused the differences in style and eruptive temperature at the time of eruption.

612

Lunar volcanism volumes from GRAIL gravity data

Dr Kris Izquierdo[1], Dr. Michael M. Sori[1], Dr. Brandon C. Johnson[1,2], Dr. Jason M. Soderblom[3]
[1]*Department of Earth, Atmospheric, and Planetary Sciences, Purdue University, West Lafayette, United States,* [2]*Department of Physics and Astronomy, Purdue University, West Lafayette, United States,* [3]*Massachusetts Institute of Technology, Cambridge, United States*

The Moon is a unique laboratory to study volcanic processes of rocky bodies. The lack of plate tectonics, atmosphere, and water allows the preservation of volcanic features while the availability of high-resolution remote sensing data allows the study of these features at a global scale. The global distribution and total volume of basalts on the Moon is of special importance for constraining its thermal evolution. Keeping all other conditions the same, a higher volume of volcanic material would be consistent with a hotter Moon.

In this work, we estimate the global distribution and total volume of basalts that is consistent with the lunar gravity data sampled by the Gravity Recovery and Interior Laboratory (GRAIL) mission. Gravity data allows us to infer not only the volume of the visible basalts but also the volume of basalts that might be hidden by a thin layer of higher-albedo material. These "hidden" basalts have been proposed to represent a significant part of the total volume but are frequently neglected. At each node in a global grid, we compute the spectral components of the localized gravity data, and we find the parameters of the 1-D density model that best fits the data using a Monte Carlo algorithm.

After our preliminary study, we obtain a total basalt volume between 1.3×10^7 and 2.2×10^7 km^3 with a most likely value of 1.7×10^7 km^3, assuming the basalts have a density of 3460 kg/m^3. This volume is in the upper range of previously reported values because we find new regions of hidden basalts that have not been reported before. Future work will consist on mapping craters that excavate underlying basalts to provide geologic evidence of the existence of these new regions of volcanism.

1408

Tres Cumbres Volcano: Polygenetic volcanism in the Sierra Chichinautzin Monogenetic Volcanic Field, Central Mexico.

Dr Carmen Jaimes Viera[1], Dr. Amiel Nieto Torres[2], Dr. Ana Lillian Martin Del Pozzo[3], Dr. Zachary Atlas[1], Dr. Aurelie Germa[1], Dr. Chuck Connor[1], Dr. Paul Layer[4]

[1]School of Geosciences, University of South Florida, Tampa, United States, [2]Escuela Nacional de Ciencias de la Tierra, UNAM, Coyoacán, México, [3]Instituto de Geofísica, UNAM, Coyoacán, México, [4]University of Alaska, Fairbanks, USA

The Sierra Chichinautzin Monogenetic Volcanic Field (SCMVF) is situated ~280 km from the Mesoamerican Trench, in central Mexico, and is part of the Trans Mexican Volcanic Belt (TMVB), The TMVB is the result of the subduction of the Cocos and Rivera plates beneath the North American plate at the Middle American Trench since the Miocene and it is made up of many monogenetic fields separated by large polygenetic volcanoes such as Popocatépetl. The SCMVF has at least 227 volcanic vents that were formed between 1.2 Ma to 2 ka. Although all the volcanoes in the SCMVF are considered as monogenetic vents, we considered the Tres Cumbres volcano as a small polygenetic cone inside of a monogenetic field. This is an andesitic cone that is in the western part of the SCMVF. Stratigraphy, geochronology, geochemistry, and mineral assemblages suggest that this volcano was building in different periods, and the eruptive dynamics shifted between strombolian to violent strombolian to effusive. The first episode was characterized by a large lava flow and a debris flow deposit that were emplacement to the south. The second episode consist of a cinder cone that was destroyed by a lava flow emplaced to the N-NW and the last episode was a lava dome located to the SE of the cone. According to the Ar/Ar dates, Tres Cumbres volcano was active approximately 30 ka, starting during the second gap of monogenetic volcanism in the Sierra Chichinautzin, between the end of the Older CMVF and the beginning of the Younger CMVF, with a last activity dated in ~22 ka. JVMC thanks to Secretaría de Educación, Ciencia, Tecnología e Innovación (SECTEI) for the postdoctoral fellowship.

1174

Temporal-compositional evolution of basalt to rhyolite volcanism in the Paraná Magmatic Province: markers of continental crust modification by basaltic magmatism

Professor Valdecir Janasi[1], Dr. Liza Polo[1], Ms. Natasha Marteleto[1], Dr. Leticia Guimaraes[1], Professor Adriana Alves[1]
[1]*University Of Sao Paulo, Sao Paulo, Brazil*

Assimilation-crystal fractionation is a major process responsible for the wide diversity of magmas (basalt to rhyolite) that built the low-Ti volcanic succession of the Paraná Large Igneous Province in south Brazil as demonstrated by elemental and isotope (Sr-Nd) geochemical modeling. A detailed field survey in the central portion of the Torres Trough has shown that the silicic volcanism at the upper portion of this structure occurs as two well-defined stratigraphic units: the lower Caxias do Sul dacites (1) occur at the top of the main basalt to andesite succession (Torres and Vale do Sol Formations), and were succeeded by a unit of basalt to dacite that becomes thicker and less silicic eastwards (the Barros Cassal unit) and then by the uppermost Santa Maria rhyolites (2). The older basalt to andesite succession shows differentiation trends with weak Fe enrichment unlike that of the tholeiitic series; fO2 estimates based on plagioclase-melt Eu3+/Eu2+ partition show that magmas became progressively more oxidized towards the Caxias do Sul dacites, which represent the more silicic and last erupted products of this succession, and incorporated greater amounts of crust-derived material. The youngest silicic volcanics (Santa Maria) are abnormally high-temperature (up to 1,000°C) rhyolites with very low H2O contents (<2 wt%) that overlie the Barros Cassal unit, a basalt-andesite-dacite succession with typical tholeiitic (Fe-enrichment) trend. Their origin reflects the strong depletion of the continental crust that was drained from H2O and other fertile components by interaction with the preceding voluminous basalt magmatism.

592

Improved Estimates of Crustal Magmatic Storage Through Seismic Receiver Functions

Dr Helen Janiszewski[1], Dr. Lara Wagner[2], Dr. Diana Roman[2], Dr. Daniel Portner[3], Ms. Madeleine Tan[4]
[1]University Of Hawaii At Manoa, Honolulu, United States, [2]EPL, Carnegie Institute for Science, Washington, USA, [3]Arizona State University, Tempe, USA, [4]University of Michigan, Ann Arbor, USA

Recent research points to complex, multi-layered, transcrustal magmatic systems beneath volcanoes. But constraints on depths of magma storage in the mid-to-deep crust beneath volcanoes remain an enigmatic target. At volcanic arcs, magmatic processes at these depths are a critical link between the input from the slab and mantle wedge, the emplacement processes that build and alter arc crust, and the shallow crustal reservoirs that drive eruptions. Magmatic storage depths and pathways may be governed by a variety of properties, including volatile content, crustal stress regime, preexisting structures, and more. To better understand how these variables may impact arc volcano processes, we must employ techniques that allow us to characterize magma storage depths at volcanoes globally. Here, we investigate receiver functions as a technique to provide systematic, first-order constraints on magma storage depths in the mid-to-deep crust using data from the Alaska-Aleutian island arc as a case study. Receiver functions are sensitive to abrupt seismic velocity boundaries, and have detected low velocity zones in the crust interpreted as magmatic-mush systems at Akutan and Cleveland, two Alaska-Aleutian arc volcanoes. They do not rely on the presence of local seismicity, do not require a wide-aperture array to image the whole crust, and can be analyzed at volcanoes with relatively few (< 4) local instruments. We present results of the application of this technique across the Alaska-Aleutian arc, and examine along-arc trends in receiver function properties.

1094

Volcanic lightning reveals plume and umbrella cloud dynamics of the January 2022 Hunga Tonga-Hunga Ha'apai eruption

Dr Paul Jarvis[1], Dr Grant Caldwell[1], Chris Noble[2], Yasuo Ogawa[3], Christopher Johnson[4], Frank Millward[4]
[1]GNS Science, Lower Hutt, New Zealand, [2]MetService, Wellington, New Zealand, [3]Volcanic Fluid Research Centre, Tokyo Institute of Technology, Tokyo, Japan, [4]Department of Mathematics, University of Manchester, Manchester, United Kingdom

The January 2022 eruption of Hunga Tonga-Hunga Ha'apai (HTHH) significantly impacted the Kingdom of Tonga as well as the wider Pacific region. Additionally, much of the physical phenomena associated with the eruption were of a scale unparalleled in the era of human observation. The eruption column attained a maximum height of 58 km whilst the umbrella cloud reached a diameter approaching 600 km within about 3 hours. Also remarkable was the intensity of volcanic lightning generated during the eruption, with the Vaisala Global Lightning Database (GLD360) recording over 3 × 105 strikes near HTHH over a two-hour period.

We have combined Himawari-8 satellite imagery with the spatiotemporal distribution of lightning strikes to constrain the dynamics of umbrella spreading. The first lightning strikes occurred at 04:09 UTC, with lightning intensity peaking at approximately 5000 strikes per minute at 05:03. During this time, lightning was initially concentrated in a circle above HTHH, with an areal extent that grew with the observed eruption cloud. However, by 04:27, radial structure appeared in the lightning spatial distribution, with strikes clustered both directly above HTHH and in an annulus of radius ~ 50 km. Comparison with satellite imagery shows that the radius of this annulus coincided with the umbrella cloud radius, and both grew to about 150 km by 04:47. From this time, the umbrella cloud growth rate decreased whilst the annulus itself contracted to a smaller radius of about 50 km again. Radial structure in the spatial distribution of strikes persisted until about 05:37, after which lightning remained focused at smaller radii.

These observations have important implications for umbrella spreading dynamics, revealing internal flow properties and providing higher temporal resolution data than satellite imagery alone. Consequently, our results provide important data for informing and validating numerical models of umbrella cloud spreading.

1099

A simple calibration tool to correct for the effect of wind on volcanic plume heights calculated from video images

Dr Eveanjelene Snee[1], Dr Paul Jarvis[2,3], Riccardo Simionato[4,2], Simona Scollo[5], Michele Prestifilippo[5], Wim Degruyter[1], Costanza Bonadonna[2]

[1]School of Earth and Environmental Sciences, Cardiff University, Cardiff, United Kingdom, [2]Department of Earth Sciences, University of Geneva, Geneva, Switzerland, [3]GNS Science, Lower Hutt, New Zealand, [4]Dipartimento di Geoscienzem Università degli Studi di Padova, Padova, Italy, [5]Istituto Nazionale di Geofisica e Volcanologia, Osservatorio Etneo, Catania, Italy

Volcanic ash generated by explosive eruptions can be hazardous to lives, livelihoods and infrastructure. Thus, there is a need for observations of volcanic plumes to constrain source parameters for ashfall and ash dispersion modelling. A critical input for such models is the height of the volcanic plume. This information can be obtained from both visible- and infrared-wavelength images of the eruption. However, in order to be useful, such images need to be calibrated to be able to provide accurate values of the height of the plume. Furthermore, the presence of wind complicates this calibration as bent-over plumes have a horizontal component of velocity that is not generally perpendicular to the line of sight of the camera.

We present a novel simple tool to correct for the effect of wind on the position and height of a volcanic plume in windy conditions. This is done through a geometric calibration, projecting the image of the plume onto a vertical plane in the direction of the wind. We show the impact of using this simple calibration on calculated maximum plume heights for two different types of volcanic eruption: a Vulcanian explosion from Sabancaya volcano, Peru, and a sustained plume from Mount Etna, Italy. We conclude that this new simple tool will improve the accuracy of quantitative information, and subsequent analysis, extracted from images of volcano plumes and, therefore, is useful for both research and monitoring purposes.

1394

Submarine terraced deposits linked to periodic column collapse during explosive caldera-forming eruptions

Dr. Johan Gilchrist[1], Professor Mark Jellinek[1], Dr. Emily Hooft[2], Mr. Sean Wanket[1]
[1]University Of British Columbia, Vancouver, Canada, [2]University of Oregon, Eugene, USA

Catastrophic caldera-forming (CCF) eruptions are the most impressive of volcanic phenomena in the geological record. However, relationships between the size of CCF eruptions and the magnitudes as well as types of their associated hazards are equivocal and intensely debated. The character and intensity of hazards predominantly depend on the extent to which mixtures of erupted ash and entrained gases are delivered to the atmosphere and to the ground. Using the results of analog experiments and spectral analyses of well-preserved periodic terracing observed at the Sumisu and Santorini CCF eruption deposits we constrain the the dynamics governing these CCF eruptions. We show that submarine eruptions in a `total collapse' (TC) regime deliver material to the water surface and seabed in periodic annular “sedimentation waves" (SW). Depending on the period between successive SWs, their impact and spread at the sea surface and seabed can excite tsunamis, drive radial PDCs, and deliver material to form concentric backward-facing terraces with a wavelength that decreases with distance, or deposits that thin monotonically. In particular, SWs descending from powerful “deep water” eruption columns with heights comparable to the water depth, involve minimal interactions with the water surface and produce a deposit architecture similar to that observed at Sumisu caldera. SWs from similarly strong “shallow water” eruptions with tall subaerial columns, however, are strongly modified by the dynamics of their impact and spread at the water surface. Where these SWs enter the water as jets and impact the seabed, intensive scouring and deposition produce relatively broad and concave terraces consistent with observations from Santorini and Macauley calderas. Our results enable a novel explicit classification of submarine CCF eruption dynamics and mass eruption rates from the architectures of their deposits and will inform studies of hazards of CCF events and ongoing and future ocean drilling expeditions.

973

Are we underestimating the threat from Fire Following Volcanic Activity?

Dr Susanna Jenkins[1], Mr Jia Yong Quah[1,2], Dr Josh Hayes[1,3], Dr Rebecca Fitzgerald[3], Dr Geoffrey Lerner[1,4], Professor Tom Wilson[5], Dr Peter Baxter[6], Professor Giulio Zuccaro[7]
[1]Earth Observatory of Singapore, Asian School of the Environment,, Singapore, [2]Extreme Event Solutions, Verisk, Singapore, [3]GNS Science, , New Zealand, [4]Instituto de Geofísica, Universidad Nacional Autónoma de México, México, [5]School of Earth and Environment, University of Canterbury, New Zealand, [6]Institute of Public Health, University of Cambridge, UK, [7]PLINIVS Study Centre, University of Napoli Federico II, Italy

Fire following volcanic activity (FFVA) is a highly dangerous and largely understudied volcanic hazard. Eyewitnesses to the 1902 eruption of Mt Pelée, Martinique, describe St Pierre city being immediately engulfed in flames when the first pyroclastic density current struck, leaving no time for its 28,000 inhabitants to escape. In the years since 1902, fires have been triggered by lava flows, ballistic and large clast impacts, as well as pyroclastic density currents. Often, FFVA increases the intensity and area of damage caused by the initial hazard and creates complications for event response and mitigation. Analogous to fire spread from incendiary bombing of cities during WWII, volcanic hazards have the potential to ignite multiple small fires that can, with the right conditions, coalesce to form a mass fire. Mass fires can render fire-fighting ineffective and destroy whole cities, as at St Pierre. In this work, we evaluate the modes and conditions by which volcanic activity can cause fires to ignite and spread. We focus on the problem of FFVA in the context of two case study areas: Vesuvius, Italy, and Auckland Volcanic Field, Aotearoa New Zealand. We developed a generic fault tree, applicable to any volcanic area, to formalise the paths and associated probabilities from volcanic hazard to building ignition. For the Auckland Volcanic Field, we further combined this with a fire spread model to identify the range of damaged area and building loss expected from FFVA caused by volcanic ballistic projectiles. We found that FFVA could increase the initial damaged area and losses more than four-fold. Wind speeds, deposit temperature, and fire load density (the amount of available combustible material) are key when forecasting the potential for FFVA or mass fires, and we recommend that emergency management and preparedness should include proactive policies relevant to the risk of FFVA.

972

Using an event tree approach to understand uncertainty and inform hazard assessment at Changbaishan volcano, China

Dr Qingyuan Yang[1], Dr Geoffrey Lerner[1,2], Dr Susanna Jenkins[1], Mr Jun Rui Chow[1,3], Professor Jiandong Xu[4], Professor Haiquan Wei[4], Dr Bo Pan[4]
[1]Earth Observatory of Singapore, Asian School of the Environment,, Singapore, [2]Instituto de Geofísica, Universidad Nacional Autónoma de México, México, [3]PartnerRe, Partner Reinsurance Asia Pte. Ltd, Singapore, [4]Institute of Geology, China Earthquake Administration,, China

Changbaishan volcano, located on the border of China and North Korea/DPRK, is responsible for one of the largest eruptions in human history (CE 946 Millenium Eruption). A population of >1.6 million live within 100 km of the volcano, and the area is a major tourist attraction and has profound cultural significance. The eruption record of Changbaishan consists of few events, with reports ranging from minor ash emissions through to VEI 6 to 7 caldera-forming events. Unfortunately, there is a lack of consensus or consistent interpretation on the distribution, style and even existence of many of these eruptions, making hazard forecasting difficult. Here, we combine an event tree approach with probabilistic hazard modelling to better understand potential hazards and impacts associated with a future eruption at the volcano and to account for the many inherent uncertainties. We separately model probabilistic hazard and exposure for ballistics, large clasts, tephra fall, pyroclastic density currents and lahars for eruption scenarios ranging from VEI 2 through VEI 7. The footprints of our VEI 6-7 scenario compare favourably with mapped deposits of the Millennium Eruption. We found that small eruptions (VEI ≤3) pose minimal risk to inhabited areas, with the primary threat being to tourists visiting the summit area. Conversely, inhabited areas on both sides of the border are significantly affected by our larger (VEI 6-7) scenario, with probabilities between 50-95% for pyroclastic density current inundation of large cities, airports and critical infrastructure. More study is needed to better understand this enigmatic volcano, particularly with regards its eruptive history and, in the face of recent unrest, the potential hazards and impacts associated with its reawakening. This work marks a first step towards a comprehensive framework for evaluating the future hazard and risk at Changbaishan volcano.

334

Relationship between Large Igneous Provinces, Carbon Release and Global Change

Miss Kerensa Jennings[1], Dr James Muirhead[1], Dr David Dempsey[2]
[1]*University Of Auckland, Auckland, New Zealand,* [2]*University of Canterbury, Christchurch, New Zealand*

Large volumes of greenhouse gases such as CH4 are released from contact metamorphism of organic-rich sediments around large igneous province (LIP) sill intrusions in sedimentary basins, potentially leading to environmental change and mass extinctions. We perform an investigation into the emplacement of LIP sills into sedimentary basins and the subsequent CH4 gas release due to contact metamorphism. A numerical model is used to estimate vitrinite reflectance due to thermal metamorphism of sedimentary rocks during LIP sill emplacement and estimate the volume of methane generation. A suite of LIP sill emplacement scenarios into sedimentary basins are analysed to find the most effective basin set-up for producing the amounts and rates of CH4 release required to drive significant climatic changes and past mass extinctions. Known LIP sill arrangements and emplacement scenarios are analysed, and compared to model results, to identify the differences between LIPs that have resulted in massive climatic perturbations and those that don't.

Conference Theme: Using field data, geophysics, geochemistry, statistics, and modelling to probe volcanic and plutonic systems

1421

Old Crow tephra is Marine Isotope Stage 6 in age

Dr Alberto Reyes[1], Dr Britta Jensen[1], Shaun Woudstra[1], Matthew Bolton[1], Serhiy Buryak[1], Mea Cook[3], Jordan Harvey[1], John Westgate[2]

[1]University Of Alberta, Edmonton, Canada, [2]University of Toronto, Toronto, Canada, [3]Williams College, Williamstown, United States of America

The Old Crow tephra (OCt) resulted from one of the largest known Quaternary volcanic eruptions in the circumpolar north, with an estimated volume of ~200 km³. In eastern Beringia, non-glaciated Yukon and Alaska, OCt is the key stratigraphic marker for the onset of Marine Isotope Stage (MIS) 5e. Directly dating OCt has been challenging because its source is unknown and diverse dating tools have yielded a range of possible ages. However, new zircon U-Pb dates for OCt suggest it was deposited ~207 ka during MIS 7, with wide-ranging implications for chronologies of glaciation, paleoclimate, relict permafrost, and phylogeography. To try and resolve the incompatibility between this date and regional stratigraphy we used a novel approach of examining detrital glass deposition. We analyzed ~1900 glass shards from 28 samples spanning 220 ka to 15 ka at Bering Sea IODP Site U1345. OCt is not a visible tephra in regional marine cores, but because it blanketed eastern Beringia, it would have quickly become part of the sediment load delivered to the Pacific. U1345 was targeted as it has a well-constrained age model from benthic foraminiferal $\delta^{18}O$, receives terrigenous sedimentary input from the Yukon River basin, and is distant enough from the Aleutian arc not to be overwhelmed by visible tephra. OCt shards appear abruptly at ~157 ka, comprising >40% of shards from 157–142 ka, is present at low concentrations in all samples from 134–15 ka, but absent prior to ~160 ka. Collectively this shows OCt was deposited during middle MIS 6 with a likely age of 159±8 ka. As a result, the late Quaternary chronostratigraphic framework for unglaciated northwest North America remains intact, and we show that detrital glass deposition through “time of first appearance” may be a novel method to provide independent age constraints to other large and poorly dated eruptions.

281

Constraints on the 1977-basaltic-andesitic magma evolution at White Island: a combined use of experimental and modelling approaches

Mr Wei-cheng Jiang[1], Prof Simon Turner[1], Dr John Adam[1], Dr Tracy Rushmer[1], Prof John Mavrogenes[2], Prof Shane Cronin Cronin[3]
[1]Macquarie University, Sydney, Australia, [2]Australian National University, Canberra, Australia, [3]University of Auckland, Auckland, New Zealand

White Island (Whakaari in Māori), a submerged andesitic stratovolcano off the coast of the North Island of New Zealand, was believed to be an embryonic porphyry Cu system based on mass balance calculation of Cu budget. However, neither Cu-rich brines nor Cu ore minerals has been found so far. The origin and evolution of White Island magma are also debated. Therefore, more intuitive methods are required. The following aims can be achieved by completed or upcoming experiments: 1) under what conditions did the erupted magmas evolve, deep or shallow; 2) reproduce fluids (brines) at high and low pressures with different ligands (chlorine and sulphur); 3) can either of the models explain potential Cu mineralization at White Island? Preliminary studies were performed on an end-loaded piston-cylinder apparatus at 5-10 kbar and 1000-1200°C with 2, 10, and 50 wt.% water added. The starting materials are natural rock powders from primitive basaltic andesite (TRW34). The path of the liquid line of descent (LLD) of our run products in the CMAS system poorly fits the natural samples. Only low-temperature melts are compatible with the most silica-rich natural glass composition because plagioclase + clinopyroxene + orthopyroxene can only be reproduced in low-temperature runs. It is expected that magma at low pressures with reduced H2O solubility will expand the stable field of plagioclase. In contrast, mineral assemblages of olivine ± spinel are uniquely found in near-liquidus runs, which are also uncommon in natural samples. MELTs modelling under different conditions similarly gave inconsistent LLDs via fractional or equilibrium crystallization mode. Combined with predominantly crystallization of phenocrysts in a pressure range of 0-3 kbar in terms of mineral barometers, White Island magmas are more likely to evolve in the mid-to-shallow crust. Low-pressure magma differentiation and brine formation of White Island samples will be studied in the next stage.

1129

Segmentation and radial anisotropy of the deep crustal magmatic system beneath the Cascades arc

Dr Chengxin Jiang[1], Brandon Schmandt[2], Geoffrey A. Abers[3], Eric Kiser[4], Meghan S. Miller[1]
[1]Research School of Earth Sciences, Australian National University, Acton, Australia, [2]Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, USA, [3]Department of Earth and Atmospheric Sciences, Cornell University, Ithaca, USA, [4]Department of Geosciences, University of Arizona, Tucson, USA

Volcanic arcs consist of many distinct vents that are ultimately fueled by the common process of melting in the subduction zone mantle wedge. Seismic imaging of crustal scale magmatic systems can provide insight into how melt is organized in the deep crust and eventually focused beneath distinct vents as it ascends and evolves. Here we investigate the crustal-scale structure beneath a section of the Cascades arc spanning four major stratovolcanoes: Mt. Hood, Mt. St. Helens, Mt. Adams, and Mt. Rainier. Ambient noise interferometry measurements from 234 temporary and permanent seismographs inform new shear velocity (Vs) tomography. Simultaneous inversion of Rayleigh and Love wave dispersion is used to better constrain the isotropic Vs and identify the unusual occurrence of radially anisotropic structures. Isotropic Vs shows two sub-parallel low-Vs zones at ~15-30 km depth. One anomaly elongated along-strike stretches between Mt. Rainier and Mt. Adams, and another one between Mt. St. Helens and Mt. Hood. We interpret these low-Vs zones as deep crustal magma reservoirs and infer up to ~2.5-6% melt, assuming near-equilibrium melt geometry. The two LVZs are sub-parallel to the arc and nearly meet at the latitude of Mt. St. Helens and Mt. Adams. Negative radial anisotropy, which is uncommon in the western U.S. crust, is prevalent in this part of the Cascadia margin. The prevalence of negative radial anisotropy is interrupted by positive radial anisotropy extending vertically beneath Mt. Adams and Mt. Rainier at ~10-30 km depth, and weaker positive anisotropy beneath Mt. St. Helens dipping to the west. The positive anisotropy regions are adjacent to rather than co-located with the isotropic low-Vs anomalies. Ascending melt that stalled and mostly crystallized in sills with possible compositional difference from the country rock may explain the combination of near-average Vs and positive anisotropy adjacent to the active deep crustal magma reservoirs.

520

Magmatic evolution and migration of the Black Rock Desert volcanic field, central Utah, USA

Dr Brian Jicha[1], Dr Tiffany Rivera[2]
[1]*University of Wisconsin-Madison, Madison, United States,* [2]*Westminster College, Salt Lake City, United States*

Detailed geochemical, geochronologic, and geophysical investigations of volcanic fields can provide insight into lithosphere-asthenosphere interactions, timescales of magmatic processes, or the geomorphic evolution of the field over time. The Black Rock Desert (BRD) volcanic field consists of cinder cones, shield volcanoes, domes, and maars that cover over 700 km^2 in central Utah. Most of these volcanic features crop out along northeast-southwest trending rifts at the confluence of the Basin and Range and Colorado Plateau physiographic provinces. Thirty-five new $^{40}Ar/^{39}Ar$ ages coupled with whole-rock geochemical data indicate that bimodal BRD volcanism (basalt/basaltic andesite and dacite to rhyolite) spans the last ~2.5 million years. The oldest BRD episode produced at least six distinct rhyolites within the South Twin volcanic complex from 2.45 to 2.40 Ma in the southwest sector of the volcanic field. Subsequent eruptions of the Cove Creek (2.08 to 1.67 Ma), Beaver Ridge (1.22 to 0.91 Ma) and Burnt Mountain (0.84-0.68 Ma) units are primarily mafic in composition with minor dacitic eruptions. The youngest eruptive episodes include coeval basalt and rhyolite at ~385 ka and abundant basaltic eruptions, some of which are as young as a few thousand years old. Overall, BRD magmatism has migrated to the northeast at an average long-term rate of ~0.14 km/ka over the last 2.45 Ma. This progression of magmatism is consistent with geophysical models that suggest that rising partial melts help thin the lithosphere at plateau boundaries over time, thereby by promoting continued migration along the margins of, or into the center of, the Colorado Plateau.

243

What can evolving seismic anisotropy tell us about the 2018 Kilauea eruption?

Dr Jessica Johnson[1], Dr Richard Herd[1], Mr Ben McLeod[1], Miss Zuzanna Dylewska[4], Miss Evie Read[2], Miss Ameera Hj Mohammad[5], Dr Jade Eyles[3]

[1]University Of East Anglia, Norwich, United Kingdom, [2]University of Bristol, Bristol, UK, [3]SEIS-UK, University of Leicester, Leicester, UK, [4]CGG, Crawley, UK, [5]Brunei Shell Petroleum, Jalan Utara, Brunei

The 2018 eruption of Kilauea volcano in Hawaii was unique in several ways. One of the interesting aspects was the well recorded incremental collapse of the summit caldera over the course of three months. This collapse was accompanied by over 50,000 earthquakes. These earthquakes tell an interesting story in themselves, but we are using them to measure seismic anisotropy using shear wave splitting (SWS) at a spatial and temporal resolution that has not been achieved at volcanoes before.

Seismic anisotropy is the variation of seismic wave speed with direction and is most frequently observed using SWS. Seismic anisotropy in the crust arises when microcracks in subsurface rocks are aligned, for example when the rock is under differential stress. When this occurs, the rock displays a directional variation in seismic velocity, which can be used as a proxy for maximum compressive stress and is also affected by the type of fluid filling the microcracks. Therefore, SWS analysis can be used to detect changes in stress and pore-fluid movement during volcanic activity.

Preliminary results suggest that cracking of ring faults associated with the caldera collapse can be detected using SWS tomography. Using this tool, the timing and evolution of the deformation can be mapped and modelled to show weakening and failure due to withdrawing magma.

Other interesting aspects of the eruption were the initiation of a dyke intrusion and fissure eruptions despite two existing open vents, the associated M6.9 earthquake on the décollement, and the abrupt end to the activity. Here, we use the unprecedented seismicity, SWS analysis and numerical modelling to investigate the transfer of stress between the propagating intrusion and the M6.9 earthquake, and the start and end of the eruption.

242

The Distributed Strain, Temperature and Acoustic seNsing Suite (DiSTANS): A high temporal and spatial monitoring solution

Dr Jessica Johnson[1], Dr Lidong Bie[1]
[1]*University Of East Anglia, Norwich, United Kingdom*

Traditional methods of subsurface monitoring are restricted in either time or space. Spot measurements record continuously but lack spatial resolution. Campaign measurements capture high spatial resolution data at a single time. Distributed Sensing (DS) is a brand-new technology that utilises optical fibre. The interrogator operates according to a radar-style process: it sends a series of pulses into the fibre at up to 100 kHz and records the return of the naturally occurring scattered signal. It takes advantage of the fluctuations of refractive index due to intrinsic defects within an optical fibre that scatter some of the light back to source. In doing this, the distributed sensor measures at all points along the fibre, with samples as closely spaced as 25 cm.

As the fibre is the sensor, it is also a cost-effective method that can be easily deployed in the harshest and most unusual environments. DS systems are now being tested in a wide variety of applications such as security, integrity monitoring, microseismic monitoring and near-surface geophysical surveys. DS units may even be used (with permission) on existing fibre optic cable installations, increasing the capability and range of monitoring when urban monitoring is required.

The DiSTANS system includes an intelligent distributed acoustic sensor (iDAS) to record high-frequency ground motion associated with sources such as earthquakes and rock falls, intelligent distributed strain sensor (iDSS) to record slower ground deformation, and distributed temperature sensor (DTS) to capture temperature profiles and variations, with 16 km of fibre optic cable.

Initially, DiSTANS will be deployed on the rapidly eroding North Norfolk coast (UK) to characterise rates and trends of erosion, as well as identify areas of weakness. Looking forward, we hope to deploy the system in a volcanic environment to monitor shallow processes associated with hydrothermal recovery following eruption.

491

Spatio-temporal variations in eruption styles, magma compositions, and storage histories: Insights from the Twin Lakes-Wuksi Butte chain, central Oregon, USA

Dr Emily Johnson[1], Dr Cynthia Gardner[1], Dr. Wendy Stovall[1], Dr. Anthony Pivarunas[2]
[1]U.S. Geological Survey, Cascades Volcano Observatory, Vancouver, United States, [2]U.S. Geological Survey, Geology, Minerals, Energy, and Geophysics Science Center, Moffett Field, United States

Distributed volcanoes can exhibit variable eruption styles with complicated magma storage and evolution histories. The north-south trending, 9-km long Twin Lakes-Wuksi Butte chain (central Oregon, USA) likely erupted in the late Pleistocene. The chain contains at least ten edifices; volcanic features range from maars in the south to tuff rings and cinder cones in the north. We combine field mapping, mineral and glass geochemistry, and paleomagnetic data from several vents to evaluate spatial and temporal changes in eruption style, magma compositions, and storage.

Field relationships indicate that volcanism generally progressed from south to north over time. Initial eruptions were dominantly phreatomagmatic, producing maar craters and surge deposits. Younger eruptions in the mid to northern part of the chain change from dominantly magmatic (cinder cones), to phreatomagmatic (<20 m-thick surge deposits), to a final phase of magmatic activity that produced a lava lake, cinder cones, and lava flows. Paleomagnetic directions from the four northernmost vents are used to estimate the longevity of activity and whether these eruptions were coeval with activity at other nearby distributed volcanoes.

Magma compositions are basaltic with low volatile contents (<1 wt% H_2O). Glass and mineral chemistries are slightly more evolved in the older eruptions, which also have lower olivine-glass melt temperatures (~1090°C) than the younger eruptions (~1125°C). Together these data suggest an influx of new, less-evolved magma near the end of activity. Olivine and plagioclase feldspars also have homogeneous cores with thin, abrupt, and more-evolved rims (olivine: Fo_{81} cores, Fo_{75} rims; plagioclase: An_{70}cores, An_{55} rims). Rims are generally broader in later-erupted olivine; diffusion timescales will be calculated to evaluate variations in storage timescales. Altogether, this work provides an in-depth assessment of variations in magma composition, storage, and eruption style over space and time along one distributed volcanic chain.

1211

A Tale of Two Flows: Comparing Seismo-acoustic Signals from Pyroclastic Density Currents and Lahars in Ceniza Drainage of Fuego (Guatemala)

Professor Jeffrey Johnson[1], Amilcar Roca[2], Roberto Merida[2], Armando Pineda[4], Dr. Greg Waite[2], Jerry Mock[1], Ashley Bosa[1], Gustavo Bejar[2], Maggie Holahan[1], Dr. Rudiger Escobar-Wolf[2]
[1]Boise State University, Boise, United States, [2]INSIVUMEH, Guatemala City, Guatemala, [3]Michigan Technological University, Houghton, United States, [4]independent, , Guatemala

Rapid gravity-driven mass movements, including pyroclastic density currents (PDCs) and lahars, can have catastrophic impacts for people and infrastructure on volcanoes. Early warning of such flows is possible through geophysical monitoring, including the analysis of infrasound and seismic signals. This investigation analyzes the infrasound signatures of both PDCs and lahars at Volcan Fuego (Guatemala) occurring in 2022 and descending down the Ceniza drainage. We compare and contrast the signatures of infrasound using three-element arrays located 6 to 11 km from the summit vent. Analysis of the infrasound from these flows is made in conjunction with fortuitous visual observations and seismic data. For the small PDC occurring on 04 July 2022 and larger event on 7 March 2022 we also have time lapse footage (taken at 40 s intervals) of what appears to be a boiling-over event and a column collapse eruption. For the 17 August 2022 lahar we use time lapse footage and also analyze high resolution video of the lahar reaching beyond 12 km. We demonstrate that as the flows descend the infrasound arrays are capable of tracking a moving source of sound that can be used to extract sound source velocity (related to flow speed) as well as acoustic intensity, event duration and surge history, and spectral content. Fundamental differences in the signal character of these two types of volcanic mass movements can then be used to discriminate between lahars and PDCs when viewing conditions are not amenable to direct observation. We also show that infrasound arrays are able to detect the lahars' approach and thus have utility as early warning systems.

1215

Volcano opto-acoustics: conventional cameras used for infrasound wavefield analysis at Yasur Volcano (Vanuatu)

Professor Jeffrey Johnson[1], Dr. Thomas Boyer[2], Dr. Leighton Watson[3], Dr. Jacob Anderson[1]
[1]Boise State University, Boise, United States, [2]independent, , Vanuatu, [3]University of Canterbury, Christchurch, New Zealand

We introduce and explore the capabilities of volcano opto-acoustics, a promising technique for measuring explosion and resonant phenomena at open-vent volcanoes. Joint visual and infrasound study at Yasur Volcano (Vanuatu) demonstrate that cameras are capable of recording infrasound with remarkable fidelity; passage of infrasonic waves pressurizes and depressurizes volcanic plumes and ambient air causing visually detectable vaporization and condensation respectively. In this work we apply image processing to standard video to replicate the spatial distribution of the sound wavefield. Maps of the wavefield show sound radiation patterns for both explosions and tremor and illuminate the propagation of blasts, crater resonance, continuous infrasound tremor, and standing waves. Changes in crater resonance, which have been generally attributed to rising and falling lava lakes, indicate that opto-acoustic monitoring from cameras might have potential to effectively and safely track volcanic unrest from a distance.

278

Improving volcano and earthquake resilience in the Taupō Volcanic Zone (TVZ) using school-based seismometers and connected education programmes

Professor David Johnston[1], Dr Marion Tan[1], Ms Lucy Kaiser[1], Ms El Mestel[2], Dr Finnigan Illsley-kemp[2], Mr Kelvin Tapuke[1], Mr Bubs Smith[3], Dr Graham Leonard[4], Dt Raj Prasanna[1], Dr Julia Becker[1], Dr Lauren Vinnell[1], Mr Josh Stewart[5]

[1]Massey University, Wellington, New Zealand, [2]Victoria University of Wellington, Wellington, New Zealand, [3]Tūwharetoa, Taupō, New Zealand, [4]GNS Science, Lower Hutt, New Zealand, [5]University of Otago, Dunedin, New Zealand

Over the past decade "seismometers in schools" programmes have been developed in Aotearoa New Zealand and overseas, by a range of organisations, for a variety of reasons and aiming to achieve a range of educational outcomes. With the enhancement of digital seismic networks, the decreasing cost of sensors, cheaper and faster internet, and the increasing interest in "citizen science" a range of opportunities exist to further expand participation of school and other institutions in this space. This poster explores the recent development and deployment of a "seismometers in schools" programmes in Taupō Volcanic Zone (TVZ), as part of the ECLIPSE project (Eruption or Catastrophe: Learning to Implement Preparedness for future Supervolcano Eruptions) and discusses the opportunities and challenges for such programmes.

672

An assessment of acoustic source evolution and directivity: Observations from a tiltable liquid-nitrogen charged water cannon

Dr Arthur Jolly[1], Dr Ben Kennedy[2], Dr Robin Matoza[3], Dr Alexandra Iezzi[1], Dr Bruce Christenson[4], Mr Richard Johnson[4], Ms Amilea Sork[2], Dr David Fee[5]

[1]US Geological Survey, , United States, [2]University of Canterbury, Christchurch, New Zealand, [3]University of California Santa Barbara, Santa Barbara, USA, [4]GNS Science, Lower Hutt, Avalon, New Zealand, [5]University of Alaska Fairbanks, Fairbanks , USA

Laterally directed explosive eruptions are an important problem causing multiple fatalities over the past decade. We collected field-scale explosion data from nine acoustic sensors surrounding a tiltable liquid-nitrogen water cannon to assess the importance of eruption directivity from lateral blast events. We varied the blast direction systematically at 0o, 12o, and 24o from vertical, to observe lateral variations in the acoustic wavefield directivity with blast tilt angle. While each event was similar in energy discharge, variations in the acoustic signal were seen event-to-event, producing non-repetitious waveforms and spectra. We document a destructive source process as the primary reason for this evolutionary pattern with implications for the interpretation of evolving source processes in seismic and acoustic applications such as the propagation of fault ruptures or lateral mass flows from avalanche, lahar and other mass flow events. Despite the temporal waveform evolution, we observed systematic features for a subset of vertical and lateral discharges. For vertical discharges, the acoustic energy had a uniform radiation pattern on the surrounding network. For lateral discharges, an asymmetric radiation pattern was seen with higher frequencies in the direction of the blast and depletion of those frequencies behind the cannon. The directivity results suggest that, in natural volcanic systems, near-field blast directionality may be elucidated from acoustic sensors in absence of visual data.

1001

The formation of inflated pyroclasts during explosive mafic eruptions

Dr Thomas Jones[1], Dr Yannick Le Moigne[2], Prof Kelly Russell[3], Prof Glyn Williams-Jones[2], Prof Daniele Giordano[4], Prof Donald B. Dingwell[5]

[1]Lancaster Environment Centre, Lancaster University, Lancaster, United Kingdom, [2]Centre for Natural Hazards Research, Department of Earth Sciences, Simon Fraser University, Burnaby, Canada, [3]Department of Earth, Ocean and Atmospheric Sciences, University of British Columbia, Vancouver , Canada, [4]Universitá degli studi di Torino, Dipartimento di Scienze della Terra, Torino, Italy, [5]Department of Earth and Environmental Science, Ludwig-Maximilians-Universität, Munich, Germany

During explosive eruption of low viscosity magmas, pyroclasts are cooled predominantly by forced convection. Depending on the cooling efficiency relative to other timescales, a spectrum of deposits can be formed. Deposition of hot clasts, above their glass transition temperature, can form spatter mounds, ramparts and clastogenic lava flows. Clasts may also be deposited cold, producing tephra cones and blankets. Thus, the deposit type can provide information about eruption dynamics and magma properties. Here we examine pyroclasts from the ~320-year-old eruption of Tseax volcano, northwest British Columbia, Canada. These newly identified inflated pyroclasts, are fluidal in form, have undergone post-depositional expansion, and are found juxtaposed with scoria. Detailed field, chemical and textural observations, coupled with high temperature rheometry and thermal modelling, reveal that abrupt transitions in eruptive behaviour – from lava fountaining to low-energy bubble bursts – created these pyroclastic deposits. We conclude by outlining the critical conditions required to create inflated pyroclasts during explosive mafic volcanism. These findings should support identification of eruptive style transitions recorded in pyroclastic deposits at other volcanoes.

1003

Shear-thickening and shear-thinning regimes within concentrated pyroclastic density currents

Dr Thomas Jones[1], Dr Abhishek Shetty[2], Dr Caitlin Chalk[3], Prof Josef Dufek[4], Prof Helge Gonnermann[5]
[1]Lancaster Environment Centre, Lancaster University, Lancaster, United Kingdom, [2]Anton Paar USA, Ashland, USA, [3]Department of Earth, Ocean and Ecological Sciences, University of Liverpool, Liverpool, United Kingdom, [4]Department of Earth Sciences, University of Oregon, Eugene, USA, [5]Department of Earth, Environmental and Planetary Sciences, Rice University, Houston, USA

Pyroclastic density currents (PDCs) are the most lethal of all volcanic hazards and are responsible for more than a third of all volcanic related fatalities. An ongoing challenge is to accurately forecast the flow path and run-out distance achieved by these hazardous flows such that effective mitigation strategies can be implemented. Central to this goal is an understanding of the flow mobility – a quantitative rheological model detailing how the high temperature gas-pyroclast mixtures propagate away from the volcanic vent. This is currently a large source of uncertainty, yet critical to accurately forecast the run-out distance achieved by PDCs. Here, we use a novel laboratory apparatus to perform rheological measurements on real gas-pyroclast mixtures at dynamic conditions found in natural PDCs. We find their rheology to be non-Newtonian, featuring a yield stress where the suspension jams and deposition occurs; shear-thinning behaviour promoting channel formation and local velocity increases and shear-thickening behaviour that promotes decoupling and potential co-PDC plume formation. We provide a regime diagram delineating these behaviours and illustrate how a single flow can transition between them during transport.

732

Rift and off-rift axis magmatism in Iceland: Insights on the effects of melt channelling and lithospheric metasomatism

Mrs Maud Jordan[1], Dr. Sebastien Pilet[1], Dr. Marco Brenna[2]
[1]University of Lausanne, 1015 Lausanne, Switzerland, [2]University of Otago, 9016 Dunedin, New Zealand

Magmatism in Iceland is explained by the interaction of the mid-Atlantic ridge with the Iceland plume. Holocene volcanism is not restricted to the rift zone (RZ) but also occurs off-axis, specifically in the western Snæfellsnes Volcanic Belt (SVB) and in the Southern Flank Zone (SFZ). The distribution of volcanic activity between the RZ and the SVB is not continuous as there is a gap of 60-80 km where no Holocene volcanoes are observed. The lavas in the SVB are characterized by transitional to alkaline compositions, with elevated incompatible trace element content. In contrast, the RZ volcanic rocks have tholeiitic compositions with trace element signatures slightly more enriched than MORB. Based on geochemical modelling and numerical simulations for melt extraction at mid-ocean ridge1, we suggest that the SVB alkaline lavas are the result of channelized low-degree melts produced on the periphery of the melting column at distances exceeding 65 km from the ridge axis. These melts accumulate and percolate into the lithosphere producing metasomatic hydrous cumulates. Incongruent melting of these cumulates can reproduce the alkaline compositions observed in the SVB. In contrast, for rift magmas, melt extraction models[1] suggest that low-degree melts produced as far as ~65km from the central ridge axis rise vertically to the base of the lithosphere and are then focussed towards the ridge axis in decompaction channels. We propose that these melts interact with hydrous cumulates previously formed during the development of decompaction channels and acquire specific chemical signature. The mixing of these distal enriched melts with more depleted melts extracted from the central part of the melting regime explains the composition of the RZ lavas. Our results highlight the importance of mantle dynamics below mid-ocean ridges and lithospheric interaction to produce off-axis magmatism with enriched alkaline signatures.

1. Keller et al. (2017) EPSL 464, 55-68

731

Concurrent intraplate/arc-related magmatism in a back-arc setting: Alkaline magma generation in subduction environment (Okete Volcanic Formation, North Island, New Zealand)

Mrs Maud Jordan[1], Dr. Sebastien Pilet[1], Dr. Marco Brenna[2], Dr. Oliver McLeod[3,4], Dr. Adrian Pittari[4]
[1]University of Lausanne, Lausanne, Switzerland, [2]University of Otago, Dunedin, New Zealand, [3]Vicotria University of Wellington, Wellington, New Zealand, [4]University of Waikato, Hamilton, New Zealand

The occurrence of alkaline volcanism can be found in various environments ranging from rift zones to intraplate settings but is generally missing in subduction zones. However, in the North Island of New Zealand, alkaline and arc-related magmas can be found temporally and spatially associated.
Active volcanism in the North Island is represented by the calc-alkaline Taupō Volcanic Zone and the intraplate alkaline Auckland Volcanic Field (AVF) to the northwest. However, during the Plio-Pleistocene, intraplate and arc-related volcanism overlapped within the back-arc, forming both arc-related stratovolcanoes and a dispersed, alkaline monogenetic volcanic field (Okete Volcanic Formation; OVF) that constitute the Alexandra Volcanic Group (AVG). This intercalation suggests a petrogenetic relationship between the formation of intraplate and arc-related magmas, and raises questions about the source of alkaline magmas in the OVF as well as the active AVF to the north.

It is suggested[1] that the AVG lineament, as well as the coevality of intraplate/arc-related eruptions could be the result of a slab-tear allowing asthenospheric flow to rise above the slab providing the source for alkaline magmas. To extend this work and detail the petrogenesis of alkaline magmas in the OVF, we provide additional elemental and isotopic data on basalts and mantle/crustal xenoliths from the OVF and compare their compositions to other alkaline volcanic fields in the North Island.

We aim to evaluate: (1) the mechanisms responsible for the emplacement of alkaline magmas (OVF) within the AVG; and (2) the possible sources of alkaline magmas and the processes leading to time-migration of alkaline magmatism throughout North Island.

1. McLeod et al. (2022) Lithos, 408–409, 106564

326

A myriad of melt inclusions: a 3D view into the types of melt inclusions and what they can tell us

Ms Corin Jorgenson[1], Dr. Michael Stuckelberger[2], Dr. Luca Carichhi[1], Dr. Jordan Lubbers[3], Dr. Giovanni Fevola[2], Dr. Gregor Weber[4], Dr. Guido Giordano[5]
[1]University Of Geneva, Geneva, Switzerland, [2]Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany, [3]U.S. Geological Survey, Anchorage, USA, [4]Oxford University, Oxford, United Kingdom, [5]University Roma Tre, Rome, Italy

Melt inclusions (MI) are small droplets of magma trapped in minerals. MI provide a unique view of pre-eruptive magma, and often capture volatiles prior to degassing. However, volatiles can be trapped in vapour bubbles, thus characterizing vapour bubbles in MI is essential to determine magmatic volatile budget. Formation and trapping of these vapour bubbles give clues to the eruptive sequence of the magma. We present a 3D textural analysis of >2000 MI covering a range of shape, size, bubble distribution, and crystallinity. These inclusions are from high-resolution tomographic scans of clinopyroxene and leucite phenocrysts from Colli Albani (Italy), acquired at the German Electron Synchrotron. Colli Albani has erupted several large volume ignimbrites (up to 79 km^3), unusual for it's mafic-alkaline chemistry, which is usually associated with effusive eruptions (Giordano et al., 2010).

High resolution (0.5 um) tomograms allow us to observe the textural relationship between MI, vapour bubbles, and the crystal and investigate MI which are usually discarded for more analytically manageable inclusions. We suggest 6 types of MIs 1) glassy (single melt phase) and vapour bubble free, 2) glassy with a single bubble, 3) glassy with multiple bubbles, 4) glassy irregular shaped bubbles, 5) tube inclusions, and 6) microcrystalline inclusions. Notably, we find several crystals that host all types of melt inclusions, and often the MI type is size dependent. Single vapour bubble in glassy MI occupies on average 15 % of the MI volume and are usually spheres on the rim of the MI. In contrast, MI with multiple vapour bubbles can have up to 159 bubbles (in a single inclusion), hosted on the rim and occupy on average 8% of the MI volume. We suggest these multiple bubbles are evidence of a rapid syn-eruptive decompression, which could aid in understanding the abnormal mafic-alkaline eruptions of Colli Albani.

325

Extremely rapid accumulation and ascent precedes caldera forming eruption of low viscosity magma

Ms Corin Jorgenson[1], Dr Luca Caricchi[1], Ms Monica Agreda-Lopez[2], Dr. Guido Giordano[3], Dr. Massimo Chiarada[1]
[1]University Of Geneva, Geneve, Switzerland, [2]University of Perugia, Perugia, Italy, [3]University of Roma Tre, Rome, Italy

Basaltic alkaline magma is commonly associated with effusive eruptions, however there are several mafic volcanoes throughout the globe which have had explosive eruptions. Often this behavior is explained by addition of CO_2, contributed by carbonate assimilation in the shallow crust. Here we present Colli Albani, a mafic-alkaline caldera complex, as a case study to investigate this hypothesis. Colli Albani is in central Italy, just 20 km SE of Rome, and has produced no less than seven large volume ignimbrites (up to 79 km^3; Giordano et al., 2010). Through a combination of field observations, mineral chemistry, and Sr and Nd isotopes in clinopyroxene, we show that the high potassic, silica undersaturated and CO_2-rich magmas typical of Colli Albani is produced by partial melting of a metasomatized mantle. These gas rich, low viscosity magmas are transferred rapidly through the crust, which in turn favors the rapid accumulation of 30 km^3 of eruptible magma in the upper crust in tens to hundreds of years. Our results suggest that the caldera forming eruptions at Colli Albani result from the rapid accumulation of magma in the in the shallow crust which is finally destabilized by a CO_2-rich magma sourced directly from the mantle. Our findings have implications for both the future of activity at Colli Albani and monitoring for similar long-quiescent systems, as rapid accumulation in the shallow reservoirs could result in brief period of unrest signals prior to a large eruption.

762

Expanding FAIR access to Earth science data in Iceland

Ríkey Júlíusdóttir[1], Kristín S. Vogfjörd[1], Bryndís Brandsdóttir[2], Gudmundur Valsson[3], Dalia Prizginiene[3], Ásdís Benediktsdóttir[4], Lovísa Ásbjörnsdóttir[5], Thorbjörg Ágústsdóttir[4], Kjartan Akil Jónsson[1], Matthías Pétursson[1], Hanna Blanck[1], Hildur M. Fridriksdóttir[1], Magnús T. Gudmundsson[2], Kristján Jónasson[5]
[1]Icelandic Meteorological Office, Bústadavegur 7-9, 105 Reykjavík, Iceland, [2]Institute of Earth Sciences, Science Institute, University of Iceland, Sturlugata 7, 102 Reykjavík, Iceland, [3]National Land Survey of Iceland, Stillholt 16-18, 300 Akranes, Iceland, [4]Iceland GeoSurvey (ÍSOR), Urdarhvarf 8, 203 Kópavogur, Iceland, [5]Icelandic Institute of Natural History, Urridaholtsstraeti 6-8, 210 Gardabaer, Iceland

EPOS Iceland (epos-iceland.is) is a joint national effort aiming towards FAIR (Findable, Accessible, Interoperable, Re-usable) open access to multi-disciplinary geoscience data with associated metadata from Iceland. The project is a part of Iceland's long-term participation in EPOS-ERIC (European Plate Observing System - European Research Infrastructure Consortium). The collaboration is led by the Icelandic Meteorological Office with participation of the Institute of Earth Sciences of the University of Iceland, the National Land Survey of Iceland, the Icelandic Institute of Natural History, and Iceland GeoSurvey (ÍSOR) and is thus far the largest collaboration between these partners. EPOS Iceland is one of six projects selected for the first Icelandic Roadmap for research infrastructure, funded by the Icelandic Infrastructure fund and the Icelandic Centre for Research (Rannís).

The collaboration strives to provide FAIR access to hitherto inaccessible data and products, e.g. from the national seismic (SIL) and GNSS (ISGPS) networks, various volcanic data like ash-, gas- and radar measurements from volcanic plumes, volcanic activity reports and guidelines, rock samples, geological maps, and collections of photographs and web-camera images for main eruptions of the last several decades. Emphasis is on constructing and providing state-of-the-art e-infrastructures for data services directly linked to the Integrated Core Services of EPOS ERIC to build up societal resiliency to volcanic hazards. The enhanced access to important, quality checked, and standardized geoscience data should provide greater opportunities for research and education.

The overarching aim of EPOS Iceland is therefore extremely important in the long-term and is of significant importance in terms of the advancement of knowledge, innovation and further utilization of research. EPOS Iceland is the most extensive development of data services for geoscience undertaken in Iceland.

942

Volcanism and Sedimentation at Havre and Macauley Submarine Caldera Volcanoes: the VULKA-22 Voyage to the Kermadec Arc/Rangitāhua

Dr Martin Jutzeler[1], Dr Steffen Kutterolf[2], Shannon Frey[1], Karin Orth[1], Acacia Clark[1], Emily Conn[3], Stanislaus Fabian[4], Yash Gimonkar[1], Malai Ila'ava[1], Luca Magri[1], Madison McLatchie[1], Hannah Moore[1], Issi Port[1], Chuang Wang[1], Eloise Wilson[1], Sally Watson[5], Susi Woelz[5], Richard Wysoczanski[5]
[1]University of Tasmania, Hobart, Australia, [2]GEOMAR, Kiel, Germany, [3]University of Queensland, Brisbane, Australia, [4]University of Melbourne, Melbourne, Australia, [5]NIWA, Wellington, New Zealand

Submarine calderas pose multiple hazards to coastal communities, and the multiple active calderas in the Kermadec Arc/Rangitāhua offer excellent opportunity to study mechanisms of eruption and sedimentation. Here we report on the outputs from the VULKA-22 voyage to the Kermadec Arc/Rangitāhua that investigated Havre and Macauley submarine caldera volcanoes. We conducted multidisciplinary surveys on the extra-caldera sediment sheets with piston coring, seismic reflection, deep-towed camera and bathymetry surveys. At Havre, the products of the 2012 eruption were specifically targeted to document syn- and post-eruptive transport and sedimentation mechanisms. Deep-towed camera footage allowed reconstruction of the isopleth and isopach map of the seafloor raft trail, whereas other locations showed strong sediment remobilization by ocean currents over the last decade. Life recovery correlates with isopleth and isopach maps. Seismic reflection surveys highlighted multiple generations of submarine landslides that dissected most of the caldera slopes, and seafloor footage suggest recent activity. At Macauley, the 5.7 ka caldera-forming eruption produced gigantic submarine sediment waves on the southern extra-caldera sector. Coring of the top surface of the sediment waves sampled remarkable cross-bedded, density graded pumice-lithic lapilli units that contained rounded pumices, confirming traction played an important role during transport in supercritical currents. Seafloor footage of the sediment waves exposed a homogeneous coarse pumiceous deposit, confirming it is primary.

1025

Magma diversity, differentiation and plumbing system beneath Nyamulagira volcano (North-Kivu, D.R. Congo)

Mr Ephrem KAMATE KALEGHETSO[1,2,3], Dr Olivier NAMUR[1], Dr Benoît SMETS[5,6], Dr Jacqueline VANDER AUWERA[4], Dr François LUBALA[7]

[1]Department of Earth and Environmental Sciences, Katholieke Universiteit Leuven, Leuven, Belgium, [2]Goma Volcano Observatory, Goma, D.R. Congo, [3]Département de Géologie, Université de Goma, Goma, D.R. Congo, [4]Department of geology, Liège University, Liège, Belgium, [5]Natural Hazards Service, Royal Museum for Central Africa, Tervuren, Belgium, [6]Department of Geography, Vrije Universiteit Brussel, Brussel, Belgium, [7]Département de Géologie, Université de Lubumbashi, Lubumbashi, D.R. Congo

Nyamulagira (D.R. Congo) is a Quaternary volcano located ~10 km north of the lake Kivu in the Eastern part of D.R. Congo. It is one of the 8 main volcanoes of the Virunga volcanic province in the western branch of the East African rift System. Nyamulagira differs from the other Virunga volcanoes by its shield-type morphology with a 2 x 2.3 km caldera.

In this study, we investigate lavas from Nyamulagira historical eruptions with the aim to understand related sub-volcanic processes and magma storage conditions.

Nyamulagira lavas compositionally range from basalt to basanite, bearing macrocrysts of clinopyroxene, olivine and plagioclase, as well as Fe-Ti oxides microcrysts. Clinopyroxenes and plagioclases are generally zoned while olivine shows less evidence for zoning. All samples show crystals embedded in a fine-grained matrix. Clinopyroxene is the major mineral phase in basalts and primitive basanites followed by Fe-Ti oxides and olivine, while plagioclase is dominant in the relatively evolved basanites.

Nyamulagira lavas are silica-undersaturated (SiO_2: 43,7 – 47,9 wt.%) with variable content of magnesium (MgO: 4,2 -14,1 wt%), iron (Fe_2O_3: 10,49 – 13,95 wt.%) and calcium (CaO: 8,81 – 14,13 wt.%). Overall, lavas erupted prior to 1912 and those from the 1912 eruption show a wide range of chemical composition, with the latter being the most primitive. Lavas emitted between 1938 and 2012 show a much more homogeneous composition. Compositional variability is mostly observed in the eruptions located away from the main crater while low variability is found in eruptions on the flanks of the main edifice and within the caldera.

Magma differentiation beneath Nyamulagira is most likely due to fractional crystallization and crystal accumulation. Evidence for magma mixing is also observed. Using geothermobarometers, the pre-eruptive processes beneath Nyamulagira happened in shallow depths but with variable P-T storage conditions (11 – 468 MPa).

1177

Common and individual magmatic processes in three caldera volcano, Aso, Aira, and Kikai volcanoes, SW Japan

Dr Katsuya Kaneko[1], Dr Ayumu Nishihara[1,2], Mr Ryohei Kikuchi[1], Mr Kento Shinjo[1], Dr Kimihiko Nishimura[1], Dr Jun-Ichi Kimura[3], Dr Qing Chang[3], Dr Takashi Miyazaki[3], Dr Takeshi Hanyu[3]
[1]Planetology, Graduate School of Science, Kobe University, Kobe, Japan, [2]Geological Survey of Japan, National Institute of Advanced Industrial Science and Technolog, Tsukuba, Japan, [3]Research Institute for Marine Geodynamics, Japan Agency for Marine-Earth Science and Technology, Yokosuka, Japan

Petrogenesis of voluminous magmas in caldera volcanoes is one of important problems to understand caldera volcanism that largely affects societies and environments and are concerned with continental crust evolution. In order to clarify magmatic processes common to and different between the caldera volcanoes, we carried out petrological and geochemical study of VEI-7-eruption ejecta in three volcanic-front caldera volcanoes, Aso, Aira, and Kikai volcanoes, on the same subduction system, Kyushu island, SW Japan. These three caldera volcanoes caused VEI-7 eruptions discharging a voluminous silicic magma and a relatively less voluminous mafic magma.

The most important analytical results are obtained by Sr isotope micro-analysis of plagioclase phenocryst; the silicic and mafic magmas for each VEI-7 eruption have plagioclase phenocrysts with the same Sr isotope ratios without excepton, suggesting that the silicic and mafic magmas were generated from the same source. The source material is inferred to be a mafic lower crust on the basis of compositional features of the magmas. Thus, it is concluded that in all the three caldera volcanoes, the silicic and mafic magmas for the VEI-7 eruptions are generated by low and high degree of partial melting of the mafic lower crust heated by mantle-derived hot basalts, respectively. On the other hand, magmatic processes are different between the three caldera volcanoes after the magma generation up to eruption. In Aso volcano the generated magmas erupted as they are; in Aira volcano the magmas assimilated a shallow crustal component before eruption; in Kikai volcano a mantle-derived magma mixed into the crustal magma. The three caldera volcanoes suggest that the generation of the silicic and mafic magmas by crustal melting is universal whereas magmatic processes after the generation are individual probably due to such as difference of crustal composition and condition.

792

History-dependent volcano deformation, frequency-dependent reservoir geometry, and other implications of broad-spectrum viscoelastic rheology around magma chambers

Dr Leif Karlstrom[1], Yang Liao[2], Brittany Erickson[1], Cody Rucker[1]
[1]*University of Oregon, Eugene, USA,* [2]*Woods Hole Oceanographic Institution, Woods Hole, USA*

Time-dependent ground deformation is a key observable in active magmatic systems, but is challenging to associate with underlying processes. We have developed a frequency-domain approach for modeling viscoelastic deformation around magma reservoirs to identify relationships between input and output signals of interest. Typically in volcano geodesy these signals are reservoir pressure timeseries and surface displacement but our transfer function approach is generalizable to any inputs and outputs of a linear time invariant viscoelastic model. We present both a robust and open-source finite element code for solving axisymmetric magma chamber problems, and an analytic approximation for thermoviscoelastic deformation in a halfspace that provides insight into the signatures of subsurface viscoelastic rheology. This overall framework gives rise to several implications for constraining viscoelastic material response in magmatic systems. First, the spectral approach implies that viscoelastic constitutive models, reservoir geometries, and thermal profiles may be distinguishable via their surface deformation patterns in the frequency domain at periods where long-duration geodetic observations are common. Phase lag spectra between surface deformation and reservoir pressure reflect the localized thermal, and hence viscosity, anomaly of the reservoir, through two distinct regimes of apparent elastic surface response at short and long periods, with a finite frequency band of viscoelastic response in between. With this modeling framework we study harmonic and broadband forcing functions, identifying history dependence in sequences of reservoir pressurization episodes that have implications for volcano monitoring, eruption triggering, and hazard forecasting. Finally, by considering long-period pressurization episodes of tens to hundreds of years we show that the spatial extent of viscoelastic crustal response varies significantly as a function of frequency. This suggests that inference of transcrustal magma system structure at long-lived volcanic centers depends on the timescale of observations being made, and implies a framework for validating viscoelastic constitutive models at volcanoes.

791

Resonance of small amplitude waves in volcanic conduit-reservoir systems and their observational signatures at Kīlauea volcano

Dr Leif Karlstrom[1], Josh Crozier[2], Brittany Erickson[1], Keel Wilde[1]
[1]University of Oregon, Eugene, USA, [2]USGS California Volcano Observatory, Moffett Field, USA

Transient flow in magmatic conduits can be viewed, at least on short timescales, as the excitation of characteristic eigenmodes which depend on intrinsic properties such as magma system geometry and multiphase magma characteristics. Identifying these eigenmodes in geophysical monitoring of volcanic unrest permits the remote inference of parameters such as bubble contents, effective viscosity, and the geometry of transport pathways (Crozier and Karlstrom, 2022, Science Advances). Here we extend the modeling framework of Liang et al., (2020, Journal of Geophysical Research), in which quasistatic stratified magma within a specified magma plumbing system geometry is perturbed by an impulsive, small amplitude mechanical forcing. Equations of motion, linearized around this background state, are solved numerically in the time domain with high order finite differences. We consider an axisymmetric conduit that is intersected by an arbitrary number of tabular branching cracks and a basal reservoir. Fluid properties are stratified in the conduit and uniform in cracks. Elastic deformation and viscous flow are fully coupled at the crack walls. We will discuss three results that stem from this modeling framework: (1) Frequency-domain signatures of eigenmodes associated with complex geometries of branching cracks with simplified magma properties, (2) Resonance and possible flow instability in conduits exhibiting steady background flow versus magmastatic pressure with joint H_2O/CO_2 solubility, and (3) an application to Very Long Period seismicity and GNSS data over the 2008-2018 summit eruption of Kīlauea Volcano. Changes over 10 years in a particular eigenmode (the 'conduit-reservoir mode') associated with excitation of the magma column and lava lake by rockfalls are interpreted in terms of evolving volatile mass, average magma temperature, and conduit/reservoir geometry.

708

Unraveling small-scale eruptions and lahar events by high-resolution stratigraphy of lacustrine deposits: Adatara and Bandai volcanoes and Lake Inawashiro, Japan

Professor Kyoko Kataoka[1], Professor Atsushi Urabe[1], Professor Yoshitaka Nagahashi[2]
[1]Niigata University, Niigata, Japan, [2]Fukushima University, Fukushima, Japan

Small-scale eruptions eject relatively small volume of primary tephra to the vicinity of the volcanic edifice. These proximal tephra deposits on steep volcanic slopes are prone to be degraded due to rainfall, snowmelt, and wind immediately after their deposition. Hence, the preservation potential as primary tephra layers derived from small-scale eruptions in the subaerial geological record is very low. This study aims to elucidate the history of small-scale eruptions and related lahars to evaluate the frequency of eruptions using distally deposited volcaniclastic successions.

We analyzed the five sedimentary cores (sampled by piston coring; up to 7 m long; deposited during the last 4,000 years) obtained from Lake Inawashiro situated in the lower catchment of Adatara and Bandai volcanoes in northeast Japan. The lacustrine sedimentary cores consist of hemipelagic background sediments, and intercalations of known widespread tephra layers (derived from other volcanoes than Adatara and Bandai) and of flow event deposits such as non-volcanic turbidites, and lahar runout deposits originated from Adatara and Bandai. Based on the radiocarbon ages, the flow event layers in the lacustrine deposits, correlated with previously known primary tephra layers and lahar deposits at Adatara volcano and debris avalanche deposits at Bandai volcano in the terrestrial records, are recognized. The difference in the numbers of intercalated event layers at individual sites was due to the shifting of river mouth of the delta, which supplied lahar runouts flows in to the lake. The chronology of these event deposits indicates the presence of unknown and more frequent eruption-associated lahar events than previously thought, and therefore, it is necessary to reassess the eruptive history and activity at these volcanoes.

406

Cascading process of debris avalanche, lahar, and sub-lacustrine density current associated with the AD1888 eruption of Bandai volcano, Japan

Professor Kyoko Kataoka[1], Professor Yoshitaka Nagahashi[2], Professor Atsushi Urabe[1]
[1]Niigata University, Niigata, Japan, [2]Fukushima University, Fukushima, Japan

The most recent eruption at Mt. Bandai occurred on July 15, 1888, when a catastrophic debris avalanche, surges (blasts) and lahars resulted in >477 fatalities. In the northern flank of the volcanic edifice, a debris avalanche flowed down, mixed with water of the Nagase River and transformed into a muddy lahar, which continued to travel further downstream and caused extensive disasters. On the southeast side, a rain-triggered lahar was also observed after blasts and ashfall during the eruption.

The authors collected lake sediment cores at > 40 sites in Lake Inawashiro (max. water depth 93.5 m), located downstream of the Nagase River, and recognised the 1888 eruption event flow deposits in the sedimentary cores. The 1888 event deposits are massive and are graded or ungraded. It is composed mainly of silty clay to clayey silt with a local coarser intercalation. It is denser and finer than background sediments and has high clay contents. The deposits are thick (7–20 cm) near the mouth of the Nagase River and at the lake center, and thin out laterally and southward (0.3–5 cm). The anisotropy of magnetic susceptibility of the deposits indicates preferred orientations of particle fabric, suggesting that the deposition was influenced by flow rather than suspension settling.

XRD analysis of the sub-lacustrine 1888 event deposits shows a similar mineral composition to those in the matrix of the debris avalanche deposits in the north of volcano, but differ from those of lahar deposits, surge deposits, and volcanic ash in the southeast. This implies that the source of the sub-lacustrine 1888 event deposits is a lahar from a distal part of the debris avalanche; a dense flow directly entered from the river mouth, which continued to flow as a hyperpycnal flow along the bottom of the lake leaving extensive event deposits in the lake.

304

A combined thermodynamic-seismic inversion strategy to image magmatic plumbing systems

Professor Boris Kaus[1], Dr. Nicolas Riel[1], Dr. Fabrizio Magrini[1], Professor Luca de Siena[1], Dr. Eleanor Green[2]
[1]Johannes-Gutenberg University Mainz, Mainz, Germany, [2]University of Melbourne, Melbourne, Australia

Linking seismic observations of magmatic systems with petrological constraints from past eruptions is a potentially powerful method to understand the magmatic plumbing system underneath volcanoes. Yet, doing this requires a well-calibrated melting model that is suitable for the magmatic system being studied, as well as a fast and robust computational method that can predict the most stable phase equilibria as a function of P,T and chemistry. Such a method is also of fundamental importance to model trace element partitioning and to extract essential physical properties such as fluid/melt/rock densities, heat capacity and seismic velocities.

There has been some recent progress in the development of thermodynamic melting models that are applicable to arc magmatism and can deal with systems that evolve from wet basalts to rhyolites [1]. Yet, there are only few thermodynamic computational engines available, most of which cannot directly make use of the most recent melting models or predict the relevant stable compositions in an automated manner.

We therefore developed a new, parallel, software package (MAGEMin), that uses a new solution strategy to perform single point calculations at given pressure, temperature and bulk-rock composition with no a priori knowledge of the system [2]. It has been developed for stability, performance and scalability in complex chemical systems, and directly integrates the latest melting models.

Here, we apply the method to the Toba magmatic system, where a recently derived, probabilistic, S-wave velocity model is compared with petrologically predicted velocities as a function of rock composition and temperature. A Bayesian inversion strategy is used to link seismic data with petrological models, which is shown to give constraints on the melt content, chemistry and temperature of the presently active magmatic system underneath Toba.

[1] Holland et al. J. Petrology 59, 881–900 (2018).
[2] Riel et al. Geochem Geophys Geosyst 23, (2022).

306

Towards integrated numerical models of lithospheric-scale magmatic systems

Professor Boris Kaus[1], Dr. Daniel Kiss[1], Dr. Albert de Montserrat[2], Dr. Nicolas Riel[1], Dr. Arne Spang[1], Nicolas Berlie[1]
[1]Johannes-Gutenberg University Mainz, Mainz, Germany, [2]ETH Zürich, Zurich, Switzerland

Understanding the dynamics of magmatic systems requires numerical models that take the physics of the involved processes into account and allows interpreting geophysical and geological data in a consistent manner. In climate science, a similar venture started over 5 decades ago with the generation of the first quantitative climate models, which has been indispensable in our understanding of the ongoing climate change. A similar effort for magmatic systems does not yet exist, even when many processes can already be described quantitatively.

Here, we will discuss recent progress towards creating a 2D/3D modelling framework to simulate magmatic systems, developed as part of the ERC MAGMA project. We initiated several open-source packages in the Julia programming language that significantly simplifies creating new codes that simulate different processes and run on both workstations and high-performance GPU systems.

This makes it straightforward to create a 3D model of a particular system taking available data into account (using GeophysicalModelGenerator.jl), use that as input for 3D models that link uplift/gravity data with dynamic models (using LaMEM), or simulate the thermal evolution and zircon age distribution following the intrusion of dikes & sills (using MagmaThermoKinematics.jl). One can easily switch the employed rheologies/parameterisations in the FEM or finite difference simulations, create synthetic seismic velocity models from the output (using GeoParams.jl) or account for the evolving chemistry of the magmatic system (using MAGEMin_C.jl).

We will give examples of how taking more physics into account affects the dynamics of the system, starting from classical kinematic thermal models to simulations that also include viscoelastoplastic deformation, or that take a 2-phase formulation with melt and solid rock into account. We also show that simulating the eruption itself is technically feasible, even when more work is required to link this self-consistently with the deeper magmatic system and many model parameters remains poorly constrained.

266

Equality, Diversity and Inclusion in volcanology - How are we doing?

Dr Janine Kavanagh[1], Dr Catherine Annen[2], Dr Steffi Burchardt[3], Dr Caitlin Chalk[1], Dr Elisabeth Gallant[4,5], Dr Julie Morin[4], Dr Jazmin Scarlett[6], Dr Rebecca Williams[7]

[1]University Of Liverpool, Liverpool, United Kingdom, [2]Czech Academy of Sciences, Prague, Czechia, [3]Uppsala University, Uppsala, Sweden, [4]University of Cambridge, Cambridge, United Kingdom, [5]USGS Hawaiian Volcano Observatory, , USA, [6]University of East Anglia, Norwich, United Kingdom, [7]University of Hull, Hull, United Kingdom

In this contribution, we reflect on the progress of Equality, Diversity and Inclusion (EDI) in volcanology by presenting accounts of witnessed and experienced discrimination from volcanologists around the world and statistical trends related to gender-identity, career stage and geographical distribution. We acquired membership data from the leading international organisations with a focus on volcanology (IAVCEI, AGU VGP division and EGU GMPV section). These data include self-identifying gender identity, career stage and geographical location of the members. Data from the leading volcanology journals (the Journal of Volcanology and Geothermal Research, and the Bulletin of Volcanology) is restricted to geographical location of the lead-author, but also documents the percentage of submission, rejection and acceptance of manuscripts. Our analysis also includes volcanology awards and positions on volcanology committees. Collectively these data document the sobering current state of EDI within the volcanology community and should be a call to action for organisations, scientific journals, and individuals. We share suggestions and recommendations from other disciplines on how individuals, research groups and organisations can promote, develop, and implement new initiatives to call out and tackle discrimination in volcanology work and study, and advance EDI in the volcanological community.

265

Up, down and round again: The effects of viscosity and flow rate on magma movement within a propagating dyke

Dr Janine Kavanagh[1], Dr Caitlin Chalk[1], Dr Alex Charogiannis[2], Dr Thomas Jones[1], Dr David Dennis[1]
[1]University Of Liverpool, Liverpool, United Kingdom, [2]LaVision UK Ltd, Oxford, United Kingdom

Scaled analogue experiments were conducted to explore the effect of the Reynolds number (Re) on the transit of magma in dykes. Re describes the relationship between the inertial forces (density x velocity x length) and resistive forces (viscosity) within a flowing fluid, with low Re characterising laminar flow and high Re turbulent flow. An elastic, transparent gelatine solid (the crust analogue) was injected by a fluid (magma analogue) to create a thin, vertical, and penny-shaped crack that is analogous to a magma-filled crack (dyke). Experiments were conducted using fluids with different viscosity and varying the volumetric flow rate of injection to explore a wide range of Re (spanning up to 6 orders of magnitude). Three different Newtonian fluids were used, each with similar density, but different viscosity: water (least viscous), glycerine solutions (mid viscosity) and silicon oil (highest viscosity). A laser sheet aligned with the dyke plane fluoresced passive-tracer particles suspended in the injected fluid, and particle image velocity (PIV) was used to map the magnitude and direction of flow within the growing dyke in two-dimensions, from its inception to its surface rupture.

1209

External fluid addition to introduce an eruption of the 2018 lava effusion event at Shinmoedake in Kirishima Volcano, Japan

Dr Masataka Kawaguchi[1], Dr Yasuhisa Tajima[2], Dr Toshiaki Hasenaka[1], Ms Natsumi Hokanishi[3], Dr Atsushi Yasuda[3], Dr Setsuya Nakada[4]

[1]CWMD, Kumamoto University, Kumamoto, Japan, [2]R&D Center, Nippon Koei Co., Ltd., Tsukuba, Japan, [3]ERI, University of Tokyo, Tokyo, Japan, [4]National Research Institute for Earth Science and Disaster Resilience (NIED), Tsukuba, Japan

Trigger of volcanic eruption is one of growing interests on volcanology to understand eruption dynamics for eruption prediction. The 2018 eruption of Shinmoedake, in Kirishima Volcano (Japan), after ~7 years break from the 2011 sub-Plinian VEI-3 eruption was characterized by the lava extrusion with Vulcanian explosions from the summit crater. To investigate the evolution and pre-eruptive processes of Shinmoedake magma since 2011, we analyzed whole rock, phenocryst minerals and groundmass glasses of tephra from the 2018 eruption and compared them with those of 2011 eruption. Major and trace element compositions of the 2018 products are nearly identical to those of 2011 andesite which was produced by the mixing of basaltic-andesite and dacite magmas, indicating the same parental-magma origin and no significant replenishment after the 2011 one. Phenocrysts include plagioclase, clinopyroxene, orthopyroxene and Fe-Ti oxides totaling 23–29 vol. %, similar to those of the 2011 eruption products excluding olivine. Pre-eruptive storage condition was estimated to be 0.5–1.4 kbar and 2.5–4.7 wt. % H_2O in melt from a mineral phase equilibrium. Estimated temperature using two-pyroxene thermometer was 1011 ±26 ˚C, significantly higher than the reported estimates of 2011 mixed andesite (e.g., 960–980 ˚C) using the same method. Adapting the thermomechanical mixing model of Sparks and Marshall (1986), a complete homogenization of mixture of silicic and mafic endmembers achieved similar high equilibration temperatures at observed mixing ratios considering latent heat release, meaning no need of external heating or hot magma injection.
Instead of new mafic magma replenishment, we propose that the addition of external fluid segregated from an ascending magma from a deep reservoir to introduce the 2018 eruption. In our case, the results of RhyoliteMELTS simulations showed a few wt. % of fluids added to an already water-saturated shallow magma reservoir was enough to decrease magma density at depth.

875

Variations in water saturation state during the build up to the Aso-4 super-eruption

Franziska Keller[1], Razvan-Gabriel Popa[1], Julien Allaz[1], Nobuo Geshi[2], Olivier Bachmann[1]
[1]ETH Zürich, Zürich, Switzerland, [2]Geological Survey of Japan, AIST, Tsukuba, Japan

Volatile exsolution in upper crustal magma reservoirs plays a key role in the growth of magmatic reservoirs, and can also strongly influence eruptive styles. Using the partitioning behavior of volatile elements between silicic melts, apatite, and an exsolved water-rich volatile phase, we evaluate the pre-eruptive physical state of magmas from pre-Aso-4 explosive eruptions and the subsequent Aso-4 caldera-forming event of the Aso volcanic system (Kyushu, Japan). Apatite is a common accessory mineral in many arc magmas, incorporating most of the major magmatic volatiles (OH, C, F, Cl, and S) in its crystal structure. Previous studies revealed that the measurement of halogens in apatite crystals are a powerful petrological tool to estimate the physical state of water in the magma chamber, complementary to measuring volatiles in melt inclusions, due to (1) the presence of halogens as major structural constituents in apatite along with other minor key elements (e.g., Mg, S, REE) and (2) the strong partitioning of Cl over F in apatite upon exsolution of a water-rich volatile phase.

The implementation of MgO and Ce_2O_3 contents in apatite as a differentiation index allowed the new interpretation of the F-Cl-OH record in apatite from the Aso-4 and pre-Aso-4 eruptions, indicating water-saturated storage conditions in Aso-4 magmas, as opposed to water undersaturated conditions in the pre-Aso-4 explosive eruptions. Similarly, the volatile contents of melt inclusions and matrix glasses give evidence for volatile outgassing during magma storage in the Aso-4 reservoir, strengthening the hypothesis of volatile exsolution in the magma reservoir prior to the Aso-4 event. Hence, we suggest that the physical state of volatiles in the upper crustal reservoir of the Aso-4 system changed prior to the catastrophic caldera-forming event, recording a transition from water-undersaturated to water-saturated conditions from pre-Aso-4 to Aso-4 magmas, helping the magma chamber to grow to a gigantic size.

874

Tracking caldera cycles in the Aso magmatic system

Franziska Keller[1], Marcel Guillong[1], Nobuo Geshi[2], Ayumu Miyakawa[2], Olivier Bachmann[1]
[1]ETH Zürich, Zürich, Switzerland, [2]Geological Survey of Japan, AIST, Tsukuba, Japan

Caldera-forming eruptions are among the most hazardous natural events on Earth and pose a significant risk for the human population as a whole. Recent petrological re-evaluations of caldera-forming and intercaldera deposits in several long-lived silicic volcanic systems suggest a cyclic behavior in the evolution of subvolcanic reservoirs, comprising maturation, fermentation and potential recovery phases. Each of these phases is characterized by distinct petrological patterns, which, combined with trends in intensive parameters and geophysical information, can be used to determine the current state of a reservoir within the caldera cycle framework. Here, we test this model on the Aso volcanic complex in Kyushu (Japan) by analyzing caldera and intercaldera activity between the Aso-4 and Aso-3 events and evaluate the recent activity of Aso volcano based on mineral and glass geochemistry.

Widely overlapping mineral and melt compositions as well as intensive parameters document extended magmatic differentiation, making it difficult to pinpoint chemical differences between pre- and post-caldera eruptions. Titanomagnetite, however, is an abundant mineral known to chemically re-equilibrate fast with melt and hence inherits average conditions prevailing just prior to eruption. Our case studies reveal clear evolutionary trends based on MnO content in titanomagnetite, recording low MnO contents during early pre-caldera stages or recovery, followed by an increasing trend during maturation and fermentation, right before a caldera formation. We suggest that MnO/Al_2O_3 ratios in titanomagnetite, which are analytically easy and quick to measure, can be used as a tracer of differentiation in the subvolcanic reservoir, giving valuable information about the current state of a system within the caldera cycle framework.

Evaluations of recent deposits lead to the assumption that the Aso volcano is currently in recovery after the Aso-4 eruption. Depending on magma supply the system can potentially enter renewed maturation or activity could decline leading to the cessation of the system.

927

The co-occurrence of ash deposition with phytoplankton blooms at Nishinoshima Volcano, Japan

Mr Liam Kelly[1], Dr Kristen Fauria[1], Dr Tushar Mittal[2], Mr Jan El Kassar[3], Dr Ralf Bennartz[1]
[1]Department of Earth and Environmental Sciences, Vanderbilt University, Nashville, United States, [2]Department of Geosciences, The Pennsylvania State University, State College, United States, [3]Department of Geosciences, Institute of Meteorology, WG Radiation & Remote Sensing, Freie Universität Berlin (FUB), Berlin, Germany

Volcanoes that erupt into water are sometimes known to trigger phytoplankton blooms near the area of deposition. The conditions and mechanisms that produce volcanically-triggered blooms are not yet fully understood. These blooms have been documented after effusive and explosive eruptions, but previous studies have only analyzed the impact after a short-lived eruption or one type of eruption. Nishinoshima is an ocean island volcano 1000 km south of Tokyo, and in June 2020, a long-lived bloom of possible phytoplankton, in the form of increased chlorophyll concentrations, was detectable by satellite imagery. During the eruptive activity of December 2019-August 2020, effusive eruptions occurred until mid/late-June, followed by explosive eruptions until the middle of August. It was during this explosive phase that increases in chlorophyll concentration were observed that spanned O(100 km). After the explosive activity at Nishinoshima ceased, these areas of heightened chlorophyll concentration ceased as well. We use aerial observations and satellite imagery to correlate these phytoplankton blooms in space and time with the explosive phase of Nishinoshima. We use fluorescence satellite remote sensing products to establish that these observed chlorophyll blooms were biologic in nature, making them phytoplankton blooms. Finally, we apply an understanding of the nutrients needed to supply phytoplankton blooms to suggest that blooms were of nitrogen-fixing phytoplankton. Overall, we provide a case study of fertilization of nutrient-poor ocean with volcanic ash and demonstrate a scenario where volcanic ash triggers extensive phytoplankton blooms.

471

Hydrothermal Cooling as a Requirement for Short

Storage of Silicic Magmas

Mr Liam Kelly[1], Dr Guilherme Gualda[1], Dr Darren Gravley[2], Dr David Dempsey[3]
[1]Department of Earth and Environmental Sciences, Vanderbilt University, Nashville, United States, [2]School of Earth and Environment, University of Canterbury, Christchurch, New Zealand, [3]Department of Civil and Natural Resources Engineering, University of Canterbury, Christchurch, New Zealand

Large (>50 km^3) magma bodies that contribute to caldera-forming eruptions in the Taupō Volcanic Zone (TVZ), New Zealand have shown evidence for crystallization and storage on the order of decades to centuries prior to eruption. We compare various conductive and convective heat extraction models to determine which is more likely to enable the heat loss required for short magma storage. We conclude that purely conductive models only account for heat loss on millennial or longer timescales. We also show that convective hydrothermal systems with heat output of 1,000 MW in magnitude are required for decadal heat extraction from a large, contiguous magma body; yet, heat output similar to present-day conditions would be suitable for cooling magma distributed as a patchwork of smaller magma bodies. This study shows the potential connection with heat flow at the surface and the presence of a magma body, providing future directions for monitoring restless calderas in environments with a wealth of hydrothermal activity like the TVZ.

307

Unraveling the eruptive history and hazards at a long-dormant Canadian volcano, Nch'kay (Mount Garibaldi)

Dr Melanie Kelman[1], Dr Yannick LeMoigne[1], Dr Alexander Wilson[2], Ms Ginny McLane[1], Dr Glyn Williams-Jones[3], Dr James Kelly Russell[4]
[1]Geological Survey Of Canada, Vancouver, Canada, [2]Minerva Intelligence, Vancouver, Canada, [3]Simon Fraser University, Burnaby, Canada, [4]University of British Columbia, Vancouver, Canada

Nch'kay (Mount Garibaldi), British Columbia, Canada is a highly dissected, at least 700,000 year-old glaciated stratovolcano surrounded by smaller, dominantly monogenetic centres. As one of Canada's two highest threat volcanoes, its history includes Holocene eruptions, with a dacite lava flow (18 km long) and block and ash flow deposits (located 16 km from the summit) both on the southwest, populated, side of the edifice. Although at least 20,000 people, plus infrastructure, and air traffic corridors, are nearby, and Nch'kay has a history of damaging landslides, there is little information about the timing, magnitude, style, and hazard footprints of recent eruptions, no hazard map exists, and regional awareness and concern appear low. There is no targeted seismic monitoring, and an InSAR deformation monitoring system under development is not yet operational. Through the three year Volcano Risk Reduction in Canada project, we conducted geologic mapping, photogrammetry, and geophysical analysis in summer 2022, with the goal of preparing hazard and risk assessments. Initial results revealed: significant volumes of dacite lavas and pyroclastics that may only be discernible through trace element analyses; at least 500 m thick block and ash flow deposits, representing hundreds of probable dome collapse events; the possibility that many centres, including the youngest, may be more complex than previously reported; significant hydrothermal alteration; significant recent ice loss; and previously unknown glaciovolcanic interactions that may provide paleoclimate information. Helicopter photogrammetry revealed complex structures and relationships in the significant inaccessible proportion of the edifice, and will permit better estimates of the total erupted volume, as large proportions of the pyroclastic sequence have been eroded. Unpublished lahar runout modeling with LAHARZ, and PDC modeling with VolcFlow, both indicate the potential for highly destructive hazards to impact inhabited areas. Currently available evidence suggests that the risk is high enough to merit dedicated monitoring.

840

What gives? Breaking and frictionally melting multiphase magmas

Dr Jackie Kendrick[1], Prof Yan Lavallée[1]
[1]*Ludwig Maximilian University Of Munich, Munich, Germany*

During volcanic eruptions, changes in explosivity may be attributed to the rheological response of the magma. The tendency for non-Newtonian magmatic suspensions to localise strain ensures that, in many scenarios, magmas shift from a regime controlled by viscous flow to that where they can fracture and fragment, owing to increasing viscosity of the degassing, crystallising magma and the elastic response of the melt when subjected to stress variations shorter than the structural relaxation timescale. If the conditions for magma failure are met over a protracted temporal or spatial scale, a shear zone may form around the ascending magma. Slip and traction along such conduit margin shear zones has been posited as the cause of cyclic inflation-deflation signals observed at differing timescales during volcanic eruptions, yet the complexities of such structural features are still poorly understood. Melt viscosity, crystal cargo, vesicularity and ascent rate all impact the type and scale of shear textures developed, and as temperature, strain rate and the presence of fluids fluctuate, fault products may repeatedly form and deconstruct in unison or in subsequent slip events. Moreover, alteration, recrystallisation, or hydration of the preserved textures we use to interpret these processes can further obscure our interpretation of syn-eruptive activity, such that an integrated structural, seismological and experimental approach is required. Here, we review the recent advances shaping our understanding of magma failure and the post-development influence of faulted magmas on ascent. We place particular emphasis on magmatic pseudotachylytes formed by frictional melting, which can alter the physical and chemical properties of the magma: driving mineral reactions; melting crystalline phases; triggering devolatilisation and vesiculation; inducing fragmentation; lowering interstitial melt viscosity; altering magnetic properties; efficiently healing fractures and redistributing permeable pathways. Such processes may be vital to understand shallow controls on eruptive behaviour.

922

Incorporating science communication and bicultural knowledge into teaching a large open online volcanology course

Professor Ben Kennedy[1], Dr Jonathan Davidson[1], Sylvia Tapuke[2], Kelvin Tapuke[3], Dr Abby Suszko[1], Bubs Smith[4], Kiharoa Milroy[6], Tim Martin[7], Pinelopi Zaka[1], Dr Dan Hikuroa[2], Rob Stowell[1], Pouroto Ngaropo[5]

[1]University Of Canterbury, Christchurch, New Zealand, [2]Auckland University, Auckland, New Zealand, [3]Massey University, Wellington, New Zealand, [4]Department of Conservation, Turangi, , [5]Iramoko Marae, , , [6]Te Arawa, , , [7]Mississippi State University, Mississippi,

Teaching volcanology frequently underutilises indigenous knowledge sources. We aimed to transform our volcanology course with new learning goals around science communication and bicultural competence. We created a UCX certificate in volcanology as two courses on the edX massive open online course (MOOC) platform. The vision was to use the courses as flexible knowledge resources to replace lectures and supplement hands on laboratory and tutorial sessions to teach volcanology at UC, but the course is also open globally to all to take online for free. The online content is interactive with mapping activities, communication exercises, animations, 360 videos, virtual rocks and fieldtrips, creating engaging volcano science content focussed on New Zealand and Iceland. We used cultural advisors from connections through NZ research programs and the University of Canterbury to identify and approach mana whenua (local) cultural experts. These experts ensured appropriate cultural guidance at specific volcanic sites and assessments. The course highlights the importance of integrating indigenous knowledge of areas studied, and the benefits that could come from shared knowledge. Mātauranga (Māori knowledge) of volcanoes are taught by listening to korero (oral knowledge) from members of local mana whenua in the areas that are visited in the course. Every module ends with a science communication activity and whenever students are assessed on science communication, one of the assessed points is whether the outputs are culturally appropriate.

The MOOC has so far had 1500 students from across the world registering for the course and will be used to teach volcanology at UC in 2022. Several students have already commented on positive aspects of the bicultural content. As instructors in the course, we continue to learn an incredible amount about the landscape and how to communicate effectively through ongoing relationships with mana whenua

1120

Potential implications for Taupo eruption wiggle match dates from off edifice radiocarbon series bracketing a distal lobe of the ignimbrite

Dr Richard Holdaway[2], Professor Ben Kennedy[1], Dr Brendan Duffy[3]
[1]University Of Canterbury, Christchurch, New Zealand, [2]Palaecol Research Ltd, , Christchurch, New Zealand, [3]GHD, Melbourne, Australia

The wiggle match date of the First Millennium eruption of Taupo volcano, in the North Island of New Zealand has been challenged based on the possibility that radiocarbon ages measured on organic material within and near the Taupo Volcanic Zone (TVZ) were biased by magmatic carbon. The possibility proved highly controversial. To test the hypothesis that radiocarbon measurements on material from within the TVZ can be biased, we performed Bayesian sequence analyses on different combinations of existing and newly measured AMS radiocarbon measurements on samples of bone, carbonised wood, and carbonised leaves stratigraphically bracketing the Taupo ignimbrite at its eastern limit, remote from the TVZ. Analyses without invoking contamination yielded an oldest possible date for the eruption considerably younger than the 234 CE wiggle match date. Initial results support the younger date. New dates will be presented that increase the robustness of the Bayesian sequence. If the present date is actually too old, it raises the question of an alternative date that fits both the wiggle match age series and the off edifice bracketing ages. A second, equally good, fit of the wiggle match exists at 540 CE. A date of 540 CE for the ignimbrite would allow a date of 536 CE for the major plinian episode in the eruption sequence, making that a candidate source for the 536 CE volcanic dust cloud in the Mediterranean.

1147

Thermal conditions of magma storage in caldera forming systems

Professor Adam Kent[1], Dr Richard Bradshaw[2], Dr Jordan Lubbers[3], Dr Kari Cooper[4], Dr Chad Deering[5], Dr Darren Gravley[6], Dr Shan de Silva[1], Dr Christian Huber[7]

[1]Oregon State University, Corvallis, United States, [2]Vanderbilt University, Nashville, United States, [3]USGS Alaska Volcano Observatory, Anchorage, United States, [4]University of California at Davis, Davis, United States, [5]Michigan Tech., Houghton, United States, [6]University of Canterbury, Christchurch, New Zealand, [7]Brown University, Providence, United States

Caldera forming eruptions demonstrate that large volumes of eruptible magma can exist within the Earth's crust and are capable of being erupted, although it remains less clear how long large magma bodies persist within the crust as relatively liquid-rich, rheologically eruptible – and geophysical detectable – bodies. The long-term thermal conditions of magma storage strongly influence rheology and the eruptiblity of magma, and also reflect the relative rates of heat gain via magma addition and loss via eruption and cooling, but until recently have been largely unknown.

Trace element diffusion in erupted mineral phases provides a means to empirically assess the thermal history of crustal magmas. We express these results as the maximum time for residence at temperatures > 750°C, the approximate temperature below which evolved calcalkaline and subalkaline magmas are sufficiently crystal-rich to be considered uneruptible. A global survey of caldera-forming eruptions with volumes between 10 and ~5000 km3 shows significant variability. Systems with erupted volumes less than ~100 km3 consistently show < 200 years maximum residence times at 750°C, and some larger volume eruptions such as the Fish Canyon Tuff and the Younger Toba Tuff also show similarly short residence. Other very large eruptions, mostly ignimbrites from the Great Basin and from the Central Andes show much longer maximum total residence times at > 750°C – up to ~50,000 years.

We interpret these results to suggest that smaller caldera systems erupt magma with relatively short crustal storage ("cold storage"). Such behavior is also evident in much larger systems, suggesting rapid accumulation of magma, or eruption mechanisms that rapidly defrost large volumes of cooler crystal rich mush. In contrast, other large volume eruptions show considerably longer periods of pre-eruptive accumulation of magma ("warm storage"), suggesting a variety of possible thermal histories and eruption mechanisms in "supereruption" scale caldera eruptions.

903

Field Tests in Support of a Mission to a Lunar Mare Pit: Exploring Lunar Lava Layers with the Axel Rover

Dr Laura Kerber[1], Dr Issa Nesnas[1], Dr Glenn Sellar[1], Dr Brett Denevi[2], Dr Laszlo Kestay[3], The Moon Diver Team[1]

[1]Jet Propulsion Laboratory / Caltech University, Pasadena, United States, [2]Applied Physics Laboratory / Johns Hopkins University, Laurel, United States, [3]United States Geological Survey, Flagstaff, United States

The Moon's lavas provide a rare window into planetary differentiation processes. However, lunar lavas are difficult to access because they are covered by a thick layer of regolith almost everywhere on the lunar surface. Moon Diver is a planetary mission concept aiming to use an extreme terrain rappelling rover called Axel to study the lava layers exposed in cross-section in a 125-m-deep pit in Mare Tranquillitatis . In order to prepare for this potential mission, the Moon Diver team has fielded several versions of the Axel rover at terrestrial analog terrains. In this presentation, we will discuss what can be learned about the lunar interior from observations of a lava stratigraphy, the challenges of doing petrology on a body where the composition and degree of mixing of the mantle is not known, and the lessons learned from deploying various instantiations of the Axel Rover over steep basaltic cliffs around the world.

413

Inferring ages from shapes – Scoria cone morphometry using Digital Terrain Models

Dr Gabor Kereszturi[1], Dr Pablo Grosse[2,3], Dr Drew T. Downs[4], Dr Melody Whitehead[1], Dr Marie-Noëlle Guilbaud[5], Dr Matthieu Kervyn[6], Dr Rina Noguchi[7]

[1]Volcanic Risk Solutions, School of Agriculture and Environment, Massey University, Palmerston North, New Zealand, [2]Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), , Argentina, [3]Fundación Miguel Lillo, Tucumán, Argentina, [4]U.S. Geological Survey, Hawaiian Volcano Observatory, , USA, [5]Departamento de Vulcanología, Instituto de Geofísica, Universidad Nacional Autónoma de México, México City, México, [6]Department of Geography, Vrije Universiteit Brussel, Brussel, Belgium, [7]Faculty of Science, Niigata University, Niigata, Japan

Scoria cones are abundant landforms on Earth and other terrestrial bodies. They are generally monogenetic in nature, and their eruptions are often characterised by discrete outbursts of bubble-rich magma. Mild to violent Strombolian eruptions can build up conical edifices with a crater on top, from medium to thickly bedded sequences of coarse-ash to lapilli deposits. Their narrow componentry and grain size variations and their relatively simple conical morphologies make such small-volume volcanoes great objects for global comparative studies. Monogenetic volcanoes have therefore received enormous research attention to understand volcano morphology, plumbing processes, and associated hazards. However, their size-frequency distribution is poorly constrained due to limited geochronological data arising from dating issues. Complete geochronology is critical for volcanic hazard assessments of monogenetic volcanic fields, especially for fields located close to populated areas, such as Auckland (New Zealand), Mexico City (Mexico), Portland, Oregon (USA), and Harrat Rahat (Saudi Arabia).

Our study presents a new morphometric global catalogue of scoria cones from >70 volcanic fields, covering wide temporal (from 9.9 Ma to historical), compositional, tectonic, geodynamic and climatic settings. The compiled catalogue contains >570 scoria cones, selected based on availability of radiometric ages (e.g., K-Ar, Ar-Ar, 14C and cosmogenic dating). The morphometric parameterisation has been performed at a nominal resolution of 12 m using SAR-based (e.g., WorldDEM) and LiDAR-based Digital Terrain Models. The morphometric parameters include geometric (e.g., height, basal width, crater depth and width, volume) and shape parameters (e.g., circularity, roundness, solidity, flank irregularity, slope angle), several of which are often qualitatively correlated with age. We employed unsupervised and supervised machine learning methods to explore the underlying data structure and to establish systematics of morphometric variability with age. Furthermore, we applied multivariate statistical methods (e.g., Partial Least Squares Regression) to develop a new numerical dating tool, complementing existing radiometric dating methods.

411

Porosity, strength, and alteration – Volcano stability assessment using VNIR-SWIR reflectance spectroscopy

Dr Gabor Kereszturi[1], Dr Michael Heap[2,3], Dr Lauren N. Schaefer[4], Dr Herlan Darmawan[5], Dr Frances M. Deegan[6], Dr Ben Kennedy[7], Dr Jean-Christophe Komorowski[8], Dr Stuart Mead[1], Dr Marina Rosas-Carbajal[8], Dr Amy Ryan[9], Dr Valentin R. Troll[6], Dr Marlène Villeneuve[10], Dr Thomas R. Walter[11]

[1]Volcanic Risk Solutions, School of Agriculture and Environment, Massey University, Palmerston North, New Zealand, [2]Institut Terre et Environnement de Strasbourg, Université de Strasbourg, Strasbourg, France, [3]Institut Universitaire de France, Paris, France, [4]Geologic Hazards Science Center, U.S. Geological Survey, Golden, USA, [5]Department of Physics, Faculty of Mathematics and Natural Sciences, Universitas Gadjah Mada, Yogyakarta, Indonesia, [6]Department of Earth Sciences, Section for Natural Resources and Sustainable Development, Uppsala University, Uppsala, Sweden, [7]Geological Sciences, University of Canterbury, Christchurch, New Zealand, [8]Université de Paris, Institut de Physique du Globe de Paris, Paris, France, [9]Department of Earth and Environmental Sciences, University of Minnesota, Minneapolis, USA, [10]Subsurface Engineering, Montanuniversität Leoben, Leoben, Austria, [11]GFZ German Research Centre for Geosciences, Potsdam, Germany

Volcanic rocks are characterised by pore and crack structures that can govern hydrothermal fluid transport, volcanic outgassing, and the strength and stability of a rock mass. Volcano slope stability analysis is a critical component of volcanic hazard assessments and monitoring. Here, visible to shortwave infrared (350–2500 nm; VNIR–SWIR) reflected light spectroscopy on laboratory-tested rock samples from Ruapehu, Ohakuri, Whakaari, and Banks Peninsula (New Zealand), Merapi (Indonesia), Chaos Crags (USA), Styrian Basin (Austria) and La Soufrière de Guadeloupe (Eastern Caribbean) volcanoes was used to design a novel rapid chemometric-based method to estimate uniaxial compressive strength (UCS) and porosity. Our Partial Least Squares Regression models return moderate accuracies for both UCS and porosity, with R2 of 0.427–0.493 and Mean Absolute Percentage Error (MAPE) of 0.212–0.391. When laboratory-measured porosity is included with spectral data, UCS prediction reaches an R2 of 0.82 and MAPE of 0.105. Our models highlight that the observed changes in the UCS are coupled with subtle mineralogical changes due to hydrothermal alteration at wavelengths of 360–438, 532–597, 1405–1455, 2179–2272, and 2460–2490 nm. Hydrothermal alteration can reduce the strength of the volcanic rocks by replacing strong volcanic glass and primary minerals in the groundmass with weaker secondary minerals, including sulfates and phyllosilicates, but it can also increase strength because of porosity-filling precipitation and/or silicification. Our approach highlights that spectroscopy can provide a first order assessment of rock strength and/or porosity or be used to complement laboratory porosity-based predictive models. VNIR-SWIR spectroscopy therefore provides an accurate non-destructive way of assessing rock strength and alteration mineralogy, even from remote sensing platforms.

1386

Mush dynamics, melt segregation, and chemical evolution of magma bodies through reactive melt transport

Dr Liudmila Khakimova[1], Dr Ivan Utkin[2,3], Dr Yury Podladchikov[1,3]
[1]University of Lausanne, Institute of Earth Sciences, Lausanne, Switzerland, [2]ETH Zürich, Zürich, Switzerland, [3]Lomonosov Moscow State University, Moscow, Russian Federation

Numerous field observations and laboratory measurements indicate that large magma bodies grow incrementally over the time periods spanning hundreds of thousands to millions of years. During formation, these magma bodies exist predominantly as "mush reservoirs" with high crystallinity or even cold-stored at sub-solidus temperatures. Large volumes with high melt fractions in such reserviors could be produced prior to eruption. Magma remobilization could occur through repeated injections of new magma from a deeper source, bringing sufficient heat to melt older crystals, also potentially changing chemical composition to lower the solidus temperature. Mechanisms governing magma transport and remobilization still remain largely unexplained.

Reactive melt transport through compacting crystal network becomes increasingly recognized as an important mechanism explaining melt segregation and differentiation in the Earth's crust. Gravitational instability created by the difference in density between crystals and melt causes buoyant rising of melt towards shallow subsurface. Melt percolation could spontaneously organize into vertically extended channels with high melt fraction and permeability. These channels are fed by the surrounding crystalline mush, efficiently extracting and transporting melt, thereby producing areas with increased melt fraction.

In this work, we present a mathematical model describing reactive melt transport in compacting crystal network. We use a consistent thermodynamical model predicting thermophysical properties of crystal, melt, and volatile phases, as well as amount and composition of these phases at thermodynamic equilibrium. We use Gibbs energy minimisation as a basis for thermodynamical calculations. We study numerically the incremental growth of a magma reservoir in a simplified problem setup approximating real volcanic plumbing system. We demonstrate that magma differentiation and remobilization could occur spontaneously as a result of reactive melt transport in the Earth's crust.

836

Controls on landscape evolution in ignimbrite terrains – Case study from the Mamaku Plateau, Taupō Volcanic Zone (New Zealand)

Ms Maia Kidd[1,2], Dr Darren Gravley[2], Dr Matthew Hughes[3]
[1]School of Agriculture and Environment, Massey University, Palmerston North, New Zealand, [2]School of Earth and Environment, University of Canterbury, Christchurch, New Zealand, [3]School of Civil and Natural Resource Engineering, University of Canterbury, Christchurch, New Zealand

The landscape of the central North Island, New Zealand, has been shaped by volcanic processes, in particular ignimbrite deposition and their associated caldera-forming eruptions. Ignimbrites are formed by rapid deposition of pyroclastic material via pyroclastic flows, modifying the underlying landscape-sometimes filling in stream and river valleys. The subsequent geometry of ignimbrites, and the variability in post-emplacement processes (i.e. welding and vapor phase alteration) mean that ignimbrites erode heterogeneously. Here, we present new geomorphic data as part of a study to unravel the landscape evolution of the ~1,700 km2 Mamaku Plateau, the largest non-caldera landform in the central Taupō Volcanic Zone (TVZ), New Zealand.

The Mamaku Plateau formed predominately during the short-lived central TVZ ignimbrite flare-up between 350 and 240 ka. During this time, there were eight ignimbrite-forming eruptions with a total erupted volume of ~3000 km3 magma. The plateau is situated in the western-central TVZ and is mostly comprised of four ignimbrites (Whakamaru, Chimpanzee, Pokai, and Mamaku). These ignimbrites have been previously mapped and are exposed in steeply incised stream valleys (up to 200 metres deep in places). Combining the previously mapped geology with high-resolution LiDAR digital elevation data, cross-sections perpendicular to the present-day streams were created to infer the geology between the modern valleys. From the cross-sections, we constructed three conceptual models for how the topography of the Mamaku Plateau evolved during the ignimbrite flare-up. These models emphasise the role of paleotopography over tectonics and climate in determining the post-eruptive landscape and subsequent erosion, with this influence repeated through multiple eruptions. Field analysis validated these models through the identification of paleotopography preserved in the valley sides.

412

Consideration on petrogenesis of voluminous magmas at Aso caldera volcano on the basis of melt inclusion analyses

Mr Ryohei Kikuchi[1], Professor Katsuya Kaneko[1]
[1]*Kobe University, Kobe, Japan*

Aso volcano in SW Japan arc caused four VEI-7 pyroclastic eruptions in the past and has a 20-km-diameter caldera. Each VEI-7 eruption basically began with discharge of silicic (dacitic-rhyolitic) magma, followed by mafic (andesitic) magma. Previous studies have concluded that both of the magmas were generated by melting of a mafic lower crust due to heat from mantle-derived hot magmas. In order to clarify the magma history from generation to eruption in detail, we analyze composition of melt inclusions (MI) in phenocrysts in the silicic and mafic magmas using SEM-EDS.

We observe three types of melt inclusions which are compositionally distinct: silicic High-K series type (HK-S) with poor water content (0-3.0 wt.%), mafic High-K series type (HK-M) with poor water content (0-3.0 wt.%), and Medium-K series type (MK) with rich water content (3.0-5.0 wt.%). The water contents are estimated by the hygrometer using melt-plagioclase equilibrium. The HK-S and HK-M MIs are included in all the phenocrysts, whereas the MK MI is only in olivine and high-An (An75-87) plagioclase phenocryst. All the rocks of Aso volcano belong to High-K series and the HK-S and HK-M MIs are compositionally similar to the groundmass of the silicic and mafic rocks, respectively, suggesting that these melt inclusions captured the melts of the silicic and mafic magmas in Aso volcano. On the other hand, the MK MI has composition that is not observed as whole-rock or groundmass in the Aso magmas, and may capture the melt of the mantle-derived magma that melted the lower crust as heat source. In this case, it is concluded that the voluminous magmas for the VEI-7 eruptions in Aso volcano were produced by melting of relatively dry lower crust by water-rich mantle-derived magma.

407

Reawakening volcanoes as self-regulating systems.progress

Christopher Kilburn[1,2]
[1]University College London, London, United Kingdom, [2]INGV-Osservatorio Vesuviano, Naples, Italy

Precursors to eruption describe how magma overcomes resistance to ascent. At long-dormant volcanoes, this resistance comes from the need to break open a new pathway through the crust and then to drive magma to the surface. The pathway is created as the crust stretches over a body of pressurizing magma. It does not form instantaneously, but develops as a collection of fractures that link together before bulk failure. The process is detected by changes in local seismicity and ground movement that follow well-constrained variations with time. At andesitic-dacitic volcanoes, in particular, magmatic eruptions often follow hyperbolic increases in the rates of precursory signal. A first interpretation is that stretching ruptures the crust and that rupture allows magma ascent. The interpretation, however, is incomplete. Phreatic explosions are often observed before final rupture, indicating that magma is able to reach into the volcanic edifice at an earlier stage in the fracturing process. Apparently, therefore, major rupture is required for magma to break the surface, but not for it to reach shallow levels underground. The combination can be explained by the progressive widening of breaches in the pressurizing magma body. For a given source pressure and magma rheology, wider fractures allow magma to rise greater distances. At andesitic-dacitic volcanoes, the critical width for eruption occurs with bulk failure. The coincidence is characteristic of a self-regulating magmatic system and provides confidence that, for volcanoes reawakening after long repose, reliable forecasts of eruption are a feasible goal.

410

Drama and volcanoes: uniting two worlds to improve warnings of eruptions at large calderas.

Christopher Kilburn[1,2], Karen Holmberg[3], Ellada Evangelou[4,1], Kristin Horton[3], and the WAVE:SPICE Consortium
[1]University College London, London, United Kingdom, [2]INGV - Osservatorio Vesuviano, Naples, Italy, [3]New York University, New York, USA, [4]University of Cyprus, Nicosia, Cyprus

Communities on long-quiescent volcanoes are rarely prepared for an eruption. Experience of previous volcanic activity has been lost and, as a result, warnings of eruption during renewed unrest are often viewed with suspicion. Large calderas are especially problematic because they frequently show repeated episodes of short-term unrest before an eruption. The episodes occur decades apart and are popularly viewed as false alarms, even if an eruption had in fact only narrowly been avoided. Conventional methods for increasing trust favour an educational approach. They aim to teach communities about how volcanoes behave and how to understand technical jargon. A common assumption is that the technical jargon is understood and accepted. This is a fundamental mistake. Our studies show that misunderstandings are common but pass unrecognised, because non-specialists learn volcanological terms without appreciating their meaning and so give the false impression that specialist information has been properly understood. We are complementing traditional methods by using participatory theatre for warnings to be co-designed by principal stakeholders, including exposed communities, volcano scientists, emergency managers and political decision makers. Advantages of this strategy are that it gives voice to people who do not normally have a platform; it drives active learning; and it creates a dialogue that encourages specialists and non-specialists to recognise and resolve misunderstandings before a crisis occurs. Engagement with each other's narratives fosters new levels of trust and critical thinking and provides the basis for a common vocabulary for presenting information during an emergency.

1195

Are chilled basaltic magmas more susceptible to earthquake triggering? Evidence from the 2015 Ambrym, Vanuatu dyke intrusion

Dr Geoff Kilgour[1], Dr Ian Hamling[2]
[1]GNS Science, Wairakei, New Zealand, [2]GNS Science, Avalon, New Zealand

Despite the growing number of observations that indicate a correlation between the occurrence of volcanic eruptions and moderate to large earthquakes, the reason why only some volcanoes seem affected remains an enigma. The Vanuatu volcanic archipelago hosts some of the most frequently erupting volcanic centres in the world. At its centre lies Ambrym Island, which has witnessed multiple eruptive episodes in the last 5-10 years. Here we use synthetic aperture radar data to analyse the deformation associated with 3-m-wide dyke in 2015 that was preceded 30 hours earlier by a moment magnitude (Mw) 6.4 earthquake only 10 km away. Unlike the more recent 2018 eruption which shows evidence of uplift in the preceding year, there is little evidence for magma accumulation in the months before the eruption in 2015. However, modelling suggests that the stress changes induced in the source region by the nearby earthquake were likely too small to account for the expected overpressure in the dyke. To generate a sufficient volume to feed the intrusion, decompression models indicate that the magma must be both H2O-saturated and cooler than a typical basaltic melt. These observations suggest that fresh basaltic material intruded into shallow magmatic systems may be too hot to generate significant volume increases for low pressure drops, implying that partially cooled and crystallised basalts are more susceptible to eruption triggering by earthquakes.

1201

Massive sulfur release from an explosive basaltic eruption: a multi-disciplinary analysis of the 2017-2018 eruption of Ambae, Vanuatu

Dr Geoff Kilgour[1], Dr Michael Rowe[2], Dr Ian Hamling[3], Dr Andrew Prata[4], Dr Naoya Sakamoto[5], Dr Hisayoshi Yamamoto[5], Dan Tari[6], Esline Garaebiti[6], Dr Georg Zellmer[7]

[1]GNS Science, Wairakei, New Zealand, [2]University of Auckland, Auckland, New Zealand, [3]GNS Science, Lower Hutt, New Zealand, [4]University of Oxford, Oxford, United Kingdom, [5]Isotope Imaging Laboratory, Hokkaido University, Sapporo, Japan, [6]Vanuatu Meteorology and Geohazards Department, Port Vila, Vanuatu, [7]Massey University , Palmerston North, New Zealand

Explosive basaltic eruptions are relatively rare and comparatively understudied, yet their impacts can be significant. Here we utilize a multi-disciplinary approach to assess the magmatic processes and atmospheric consequences of the most violent phase of the 2017-2018 eruption episode at Ambae, Vanuatu. During this eruption, ash-rich plumes ascended to at least 10 km above the vent, causing extensive acid rain and significant damage to villages, and led to island-wide evacuations. Combining data from satellite remote sensing and petrological microanalysis, we constrain the magmatic system, tropospheric SO2 loading, and the reason for the high explosivity of this event. Specifically, we identify two subsurface regions responsible for driving the eruption through surface deformation modeling, 1) a magmatic reservoir at ~ 3.5 km depth and 2) a gas pressurized hydrothermal system at 1.5 km depth. This is in good agreement with geobarometry data obtained from phenocryst-hosted melt inclusions. We find that melt inclusions are relatively S-poor, whereas atmospheric SO2 loading is very high. We suggest that pre-eruptive SO2 exsolution resulted in pressurization, with the hydrothermal system providing an efficient barrier to SO2 leakage, and that periodic magma-lake water interaction led to highly efficient fragmentation. This study demonstrates how magmatic systems can be constrained over a range of depths through integration of multiple data sets.

681

Petrological Constraints on the Magma Fragmentation Pressure of the 1707 Hoei eruption of the Fuji Volcano and Inferred Eruption Dynamics

Mr Kyungmin Kim[1,4], Dr. Michihiko Nakamura[1], Dr. Tomofumi Kozono[2], Dr. Mitsuhiro Yoshimoto[3]
[1]Department of Earth Science, Graduate School of Science, Tohoku University, Sendai, Miyagi, Japan, [2]National Research Institute for Earth Science and Disaster Resilience, Tsukuba, Ibaraki, Japan, [3]Mount Fuji Research Institute, Fujiyoshida, Yamanashi, Japan, [4]Geophysical Institute, Alaska Volcano Observatory, University of Alaska Fairbanks, Fairbanks, USA

The fragmentation mechanism and dynamics of basaltic Plinian and sub-Plinian eruptions are puzzling, and are still debatable due to the low viscosity of basaltic magma. One of the plausible mechanisms of basaltic magma fragmentation is the rapid crystallization of the microcrystals and substantial increase of apparent viscosity. The 1707 CE Hoei eruption of Fuji Volcano is one example of the sub-Plinian eruptions of basaltic magma containing abundant groundmass micrometer-size crystals. Therefore, we focused on two open questions regarding the dynamics of the Hoei eruption and its implication for the other basaltic Plinian eruption: (1) Can the final equilibrium condition of temperature and pressure of the Hoei eruption be constrained by petrological analysis and experiments? and (2) Based on the pressure and temperature constrained from petrology, can conduit flow dynamics explain the Hoei basaltic explosive eruption? To explore these questions, we conducted a petrological analysis and experiments on the near-equilibrium condition present in the final part of the volcanic eruption (< 15 MPa). The final equilibrium pressure-temperature conditions were constrained at 1060°C and ~6 MPa based on the comparison between Hoei scoria and experiment products based on the groundmass crystallinity and pyroxene thermobarometry. These constrained results were applied to the conduit flow model and revealed that suitable steady-state conditions of eruption dynamics are unable to satisfy the magma discharge rate (10^6 to 6×10^6Kg/s) constrained by the geological survey. Instead, geometrical parameters that changed from conduit to dike-to-conduit transition can constrain the appropriate geometrical conditions of the Hoei eruption, thereby satisfying both the final equilibrium pressure-temperature conditions and the discharge rate. The result suggests the potential importance of coupling between conduit geometry and meeting fragmentation criteria for basaltic Plinian and sub-Plinian eruptions.

498

Characterization of the 2021–2022 Great Sitkin dome-building eruption through Bayesian inversion of LP seismicity

Mr Kyungmin Kim[1], Dr. Társilo Girona[1], Dr. Kyle Anderson[2]
[1]Geophysical Institute, Alaska Volcano Observatory, University Of Alaska Fairbanks, Fairbanks, USA, [2]California Volcano Observatory, , USA

Long period (LP) volcanic seismicity and tremor are thought to be triggered by the subsurface transport of magmatic and/or hydrothermal fluids. A mechanistic model of LP events and tremor, called the “leaky gas pocket model”, was proposed by Girona et al. (2019). This model shows that the transport of gas through permeable materials (e.g., lava domes) triggers spontaneous LP/tremor-like pressure oscillations, and thus the inversion of LP/tremor waveforms can inform understanding of shallow volcanic activity. In this project, we focus on two open questions regarding LP seismicity and its relation to volcanic activity: (1) To what extent can the leaky gas pocket model be applied to actual volcanoes for interpreting the physical properties of volcanic vents? (2) Can the physical characteristics of volcanic eruptions, and their temporal evolution, be characterized through the inversion of LP seismicity? To explore these questions, we integrate the leaky gas pocket model with a Bayesian Markov Chain Monte Carlo (MCMC) framework to invert the LP seismicity recorded from July to early August 2021 at Great Sitkin volcano (Alaska), during an ongoing dome-building eruption. With this approach, we aim to quantify the probability density function of the model parameters, which include dome thickness and permeability; gas flow rate and temperature; and seismic attenuation factor, among others. Our preliminary results show that most of the LP events recorded at Great Sitkin volcano during the period analyzed can be accurately described with the leaky gas pocket model, and suggest an increase of seismic attenuation during July 23-25. This increase of seismic attenuation may result from the accumulation of gas (and consequent increase of pore pressure) in the volcanic edifice during the onset of the eruption. Our analysis will be expanded to investigate the full evolution of the ongoing Great Sitkin dome-building eruption.

232

The Nature, Geochemistry, and Tectonic Controls of Distributed Cenozoic Alkaline Volcanism in Northern Victoria Land, Antarctica

Dr Jihyuk Kim[1], Dr Mi Jung Lee[2], Dr Jong Ik Lee[2], Prof Philip Kyle[1], Dr Matthew Heizler[1], Prof Jung-Woo Park[3]
[1]New Mexico Institute of Mining and Technology, Socorro, United States, [2]Korea Polar Research Institute, Incheon, South Korea, [3]Seoul National University, Seoul, South Korea

The West Antarctic Rift System (WARS) which extends across the Antarctic continent is one of the largest intracontinental rifts on Earth. As part of the WARS, the Melbourne Volcanic Province in Northern Victoria Land (NVL) sits on the thick crust of the uplifted Transantarctic Mountains. It comprises three active volcanoes (Melbourne, The Pleiades, and Rittmann) and several older volcanic fields. There are over 50 small isolated volcanic vents, known as the Northern Local Suite (NLS) spread over 400 km across the province. A suite of older (50-30 Ma) alkalic intrusive rocks (Meander Intrusive Group) represent an earlier phase of magmatism presumably associated with the initial stages of extension of the WARS and uplift of the Transantarctic Mountains. We report new $^{40}Ar/^{39}Ar$ ages and geochemical data on the lavas, to refine the spatiotemporal evolution of the Cenozoic magmatism around NVL.

Each volcanic field shows its own spatial migration of volcanic activity. The Overlord Volcanic Field is 20 Ma to present, the Mt. Melbourne Volcanic Field 13 Ma to present, the Malta Plateau Volcanic Field 15 to 6.5 Ma and The Pleiades Volcanic Field is <1 Ma. The NLS lavas are mainly basanitic scoria cones and small vents that share many geochemical features with the major volcanic fields. The NLS shows co-variations between their alkalinity and Sr-Nd-Pb isotopic ratios, but these do not correlate with eruptive age or location. The source of the NVL magmatism is metasomatized mantle that has a focal zone (FOZO) component. The degree of partial melting and subsequent reaction with mantle peridotite caused the compositional spectrum of the parental magmas. Temporal-spatial-compositional relationship suggests that the main location of the lithospheric extension has been changing in association with the regional structural pattern but tapped a similar lithospheric mantle source throughout at least 20 Ma of the WARS evolution.

1052

Numerical modeling of reactive magmatic transport processes, using the pseudo-transient method

Dr Daniel Kiss[1], Prof. Dr. Evangelos Moulas[1], Prof. Dr. Boris Kaus[1], Mr. Nicolas Berlie[1], Dr. Nicolas Riel[1]
[1]*Institute of Geosciences, Johannes Gutenberg University of Mainz, Mainz, Germany*

One of the continuing trends in geodynamics is to develop codes that are suitable to model magmatic processes with an increasing level of self-consistency. Developing such models is particularly challenging as most magmatic processes are multiphysics problems, and require coupling between thermal, porous, mechanical and chemical processes.

Here we consider reactive flow in a deformable porous medium coupled to thermo-mechanical processes. We present a thermodynamically self-consistent set of governing equations, describing such processes. The governing equations consists of the conservation of mass, momentum, and energy in two phases. One phase represents the solid skeleton, which deforms in a visco-elasto-plastic manner. The second phase represent low viscosity melts, percolating through the solid skeleton, that is described by Darcy's law. As melt migrates through the rock skeleton, mass transfer between the two phases is quantified using thermodynamic look-up tables, hence we can quantify the chemical evolution of melts due to partial melting and crystallization. The system of equations is solved numerically, using the pseudo transient method, that is well suited to solve highly non-linear problems. We will show a few key results, such as melt migration along dykes and shear zones, along self-localized channels or by magmatic diapirism. We will discuss under which rheological conditions each of these melt transport modes is expected to occur. We will also demonstrate how the coupling between thermo-mechanical processes and melt migration affects the chemical evolution of percolating melts.

All the codes presented here are written within a modular Julia framework, developed within the MAGMA ERC project, that permits easy future integration of the currently stand-alone software.

1059

Thermal stresses result in decompression and the development of fracture networks around magmatic intrusions in the visco-elasto-plastic upper crust

Dr Daniel Kiss[1], Prof. Evangelos Moulas[1], Prof. Boris Kaus[1], Mr. Arne Spang[1]
[1]*Institute of Geosciences, Johannes Gutenberg University of Mainz, Mainz, Germany*

Studies of host rock deformation near magmatic intrusions typically focus on stresses directly related to the intrusion process, either by directly considering inflating volumes or by considering two-phase deformation related to magma transfer. Thermal processes, especially volume changes due to thermal expansion/deflation or volume changes during partial melting/crystallization are typically often neglected. Here we show that thermal stresses around a rapidly emplaced upper crustal intrusion can be significant and likely sufficient to create an extensive fracture network around the intrusion by brittle yielding.

We present 2D numerical simulations of an upper crustal magma (or mush) body in a visco-elasto-plastic host rock, with coupled thermal, mechanical and chemical processes, accounting for thermodynamically consistent material parameters. The magma body is isolated from deeper sources of magma hence it is cooling, and thus shrinking. We quantify the pressure changes and stresses induced by such volume changes, and resolve fracture networks potentially developing as a result.

We present solutions based on a self-consistent system of conservation equations for coupled thermo-mechanical-chemical processes, under the assumptions of slow (negligible inertial forces), visco-elasto-plastic deformation and constant chemical bulk composition. The thermodynamic melting/crystallization model is based on a granitic composition. We will briefly discuss the numerical implementation of thermodynamic data and volumetric plasticity (including tensile and dilational shear plasticity) in a self-consistent manner and illustrate the effect of volume changes due to temperature changes (including the possibility of melting and crystallization) on stress and pressure evolution in magmatic systems.

609

Decision making and choices during the 2021-2022 Kilauea land buy-out

Amy Kitchener[1], Bruce Houghton, Karl Kim
[1]*University Of Hawaii At Manoa, Honolulu, United States*

The unprecedented cost of the 2018 eruption in Hawaiʻi reflects the intersection of physical and social events: infrequent but highly destructive eruptions and exceptionally high population growth. Kīlauea is one of the most active volcanoes on our planet. The heightened threat from lava flows from the East Rift Zone of Kīlauea ensured that land values were always depressed within USGS's three highest hazard lava zones. In April 2021, a 'buy-out' program was put in place to acquire residential properties affected by the 2018 eruption. Landowners are not able to use these grants for house construction and infrastructure in lava hazard zones. Will this encourage people to move to land outside of these zones? This study investigates whether the 2021 Hawaii land buy-out scheme will result in a better, more resilient community by determining which factors will drive acceptance or rejection of the buyout scheme for properties offered to landowners affected by the 2018 eruption of Kīlauea? Decision-making during and following natural disasters is complex, reflecting physical, social, and behavioral factors. This study considers the condition of the land and infrastructure after the eruption, financial resources, length of land ownership, spiritual connection to the land, sense of community, desire to live in a dynamic landscape, and wish to be off-the-grid physically and emotionally. The project will accomplish this goal by (1) consulting with State and County officials and (2) taking an interactive discursive approach with the community. Background data will be collected from the U.S. Census, the county of Hawaiʻi, and insurance agencies, including how many homes were damaged, partially damaged, or isolated by lava. I will then survey a representative subset of the affected communities' residents to learn how individual families arrived at their decisions. Decisions made today will affect the long-term safety of future generations.

554

Monitoring glacially covered volcanoes with fibre-optic sensing

Ms Sara Klaasen[1], Dr. Solvi Thrastarson[1], Dr. Yeşim Çubuk-Sabuncu[2], Dr. Kristín Jónsdóttir[2], Lars Gebraad[1], Prof. Dr. Andreas Fichtner[1]
[1]ETH Zürich, Zürich, Switzerland, [2]Icelandic Meteorological Office, Reykjavik, Iceland

We present the results of an experiment with Distributed Acoustic Sensing (DAS) on Grímsvötn in Iceland. DAS is a novel detection method that samples the strain wavefield due to ground motion along a fibre-optic cable with high temporal (kHz) and spatial (m) resolution. Consequently, it has the potential to increase our understanding of physical volcanic processes.

We deployed a 12 km long fibre-optic cable for one month (May 2021) on Grímsvötn, Iceland's most active volcano, which is covered by the large Vatnajökull glacier. The cable was trenched 50 cm into the ice, following the caldera rim and ending near the central point of the caldera on top of a subglacial lake.

We have discovered previously undetected levels of seismicity, with around one hundred local events per day, using an automated earthquake detection algorithm that is based on image processing techniques. We identified first arrival picks with an automated cross-correlation based algorithm, developed specifically for complex and local events recorded with DAS. The first arrival times, combined with a probabilistic interpretation and the Hamiltonian Monte Carlo algorithm, yield event locations, their respective uncertainties, and effective velocities along ray paths, even in the absence of a detailed velocity model. Finally, we determine local magnitudes of all recorded events, and compare them to local catalogues.

The dataset reveals details of earthquake clusters under the Grímsvötn volcano with unprecedented definition. We identify nearly 2000 events in total, of which ~1% was detected by the local network. This local microseismicity shows spatio-temporal clusters, with centres of activity near the fumarole fields. The preliminary results of our experiment highlight the potential of DAS for studies of active volcanoes covered by glaciers, and we hope that this research will contribute to the fields of volcano monitoring and hazard assessment.

616

Increased Quaternary magma flux imprinted on patterns of mountain building and fluvial incision in the Columbia River Gorge, USA

Nathaniel Klema[1], Leif Karlstrom[1], Charles Cannon[2], Ray Wells[2], Jim O'Connor[2]
[1]*University Of Oregon, Eugene, United States,* [2]*U.S. Geological Survey, Portland, United States*

In volcanic arcs topography is built through a combination of magmatic and tectonic processes offset by erosion. In these settings the highest elevations generally occur where mantle-derived magma reaches the surface, resulting in voluminous emplacement of both erupted and intruded material. Both modes of magma emplacement contribute to topographic growth, however little is understood about how these forcings interact with background tectonics and erosion to shape topography. Here we utilize the exposed cross section of the Cascade Arc produced by persistent incision of the near-sea-level Columbia River to isolate the intrusive and extrusive components of uplift and show that arc-scale topography can be built through persistent magmatism.

Having bisected the Cascade Volcanic arc since at least the onset of Columbia River Flood Basalt Volcanism at ~17 Ma, the Columbia has experienced multiple channel avulsions leaving stratigraphic horizons that record subsequent deformation. One such unit is composed of arc-derived hyaloclastite and basalt emplaced into the Columbia between 3.6 and 2.4 Ma, now uplifted as much as 900 m relative to the present river. We model this deformation as the elastic response of a plate subject to basal forcing from magmatic intrusion. Our results show that the existence of magma required to generate such uplift is supported by correlated anomalies in bouguer gravity, heat flow, and surface wave tomography data. Stream profile modeling for 15 Columbia tributaries reveal knickpoints that are consistent with the modeled pattern of uplift and indicate a step increase in uplift rates.

We conclude that uplift in the Columbia River Gorge is driven by magmatism with an intrusive:extrusive ratio of ~3:1, and that this increased magmatism is steady and ongoing today. Finally, we show that patterns of faulting and monogenetic eruptions east and west of the arc-axis are consistent with deviatoric stress concentrations implied by our model.

667

Topographic curvature invariants to identify signatures of volcanic landscape evolution

Nathaniel Klema[1], Leif Karlstrom[1], Josh Roering[1]
[1]*University Of Oregon, Eugene, United States*

A primary goal of geomorphology is linking quantitative metrics of topographic form to physical processes to recognize landscape signatures of past and present forcing. This approach has proven powerful for studying co-evolving tectonics and climate, and signatures of erosion. However there are few tools for identifying evolutionary trajectories in volcanic topography, where rapid episodic landform growth and complex hydrology challenges surface process models. In these settings topography is built through emplacement of mantle-derived magmas that are initially out of equilibrium with the surface environment. High initial chemical weathering rates, low mechanical weathering rates, and high permeability evolve through time as pore space is filled with ash, glacial sediment, and products of chemical weathering. Soil and overland flow develop, and erosion works to dissect topography.

This state shift in hydrologic and geomorphic processes has been well documented in ocean island settings such as Hawaii and the Galapagos, and is increasingly recognized in arcs. In the Oregon Cascades, an eastward migration of the arc front over >30 Myr has created a chronosequence of basaltic bedrock that becomes increasingly dissected by fluvial channels as bedrock ages to the west. We quantify the surface expression of this transition using a new set of tools that utilize the fundamental forms of the topographic curvature tensor to classify digital elevation model (DEM) pixels into 8 shape classes. We show that this transition is recorded in the relative magnitude of curvatures associated with certain shape classes, and that by looking at the magnitude and distribution of curvature we can differentiate drainage networks, constructional landforms such as lava flows, and volcanic edifices. In particular, we recognize a characteristic timescale of 1-2 Myr for the transition from primary volcanic to fluvially dissected topography in the Cascades, which reflects rates of climate driven processes common to many volcanic landscapes.

954

Vesiculation induced by shallow syn-eruptive carbonate assimilation: how does it affect magma ascent and eruptive style?

Mr Marco Knuever[1], Prof Daniela Mele[1], Prof Roberto Sulpizio[1], Prof Diego Perugini[2], Dr. Alessandro Pisello[2], Dr. Francesco Vetere[3,2], Dr. Antonio Costa[4]
[1]University of Bari, Department of Earth and Geoenvironmental Sciences, Bari , Italy, [2]University of Perugia, Department of Physics and Geology, Perugia, Italy, [3]University of Siena, Department of Physics, Earth and Environmental Sciences, Siena, Italy, [4]INGV - Bologna, Bologna, Italy

The vesiculation of magmas is driving volcanic eruptions by providing the necessary buoyancy for the magmatic mixture to ascent from the crustal storage to Earth's surface. Bubble nucleation, bubble growth and bubble coalescence modify the rheology of magmas and modulate the style and intensity of an eruption. The ingestion of carbonate-bearing wall-rocks into the ascending magma provides an, often neglected, additional source for volatile phases (esp. CO2). Previous studies suggest that the assimilation of carbonate wall-rocks might happen in syn-eruptive timescales (minutes), even at shallow depths (i.e., within the feeding dyke). Since the solubility of CO2 in magmas at shallow depths is extremely low, almost all released CO2 is bound to form an additional vapour phase. This surplus of volatiles will increase the vapour phase (over-)pressure and cause a more intense magma fragmentation. It might even be the cause for transitions from effusive to explosive eruptive behaviour.

Our magma-carbonate interaction experiments provide new insights on how carbonate assimilation adds volatiles (esp. CO2) to the ascending magma and how that might influence eruptive style. Therefore, we investigated the influence of temperature, limestone composition and melt composition on decarbonation timescale and vesiculation. The experiments were conducted at atmospheric pressure to account for the upper part of the volcanic plumbing system, and span an interaction timescale of 1-30min, which is in line with magma ascent rates. The experimental products were then scanned using X-Ray Computed Microtomography to create 3D models of the experimental samples, from which important parameters like bubbles size distribution, bubble volume and shape could be retrieved. Our results show how the vesiculation and especially bubble coalescence critically depend on magma viscosity and hence how carbonate assimilation at shallow depth can contribute to modifying eruptive style for various magma compositions.

607

The submarine monogenetic volcanic field East of Mayotte: multidisciplinary oceanographic campaigns reveal an exceptional diversity of effusive and explosive processes

Professor Jean-Christophe Komorowski[1], Professor Lucia Gurioli[2], Dr Carole Berthod[1,3], Dr Etienne Médard[2], Pauline Verdurme[2], Valentine Puzenat[1], Emeritus Professor Patrick Bachèlery[2], Dr Magdalena Oryaëlle Chevrel[2,4], Dr Fabien Paquet[5], Dr Elodie Lebas[1], Dr Emmanuel Rinnert[6], Professor Nathalie Feuillet[1], Dr Yves Fouquet[6], Dr Isabelle Thinon[5], Dr Cécile Cathalot[6], Dr Stephan Jorry[6], Dr Pascale Besson[1], Professor Anne Le Friant[1], Professor Andrea Di Muro[7], Tristan Lacombe[2], Associate researcher Christine Deplus[1], Associate researcher Carla Scalabrin[6], Researcher Anne Lemoine[5], Research engineer Delphine Pierre[6], Research engineer Benoît Loubrieu[6], Research engineer Paco Ferrand[6], Research engineer Sylvain Bermell-Fleury[6], Research engineer Mathilde Pitel-Roudaut[6], Research engineer Arnaud Gaillot[6], Research engineer Gwenaël Jouet[6], Researcher Aude Lavayssière[1], Associate researcher Lise Retailleau[1,4], Researcher Océane Foix[8], Associate researcher Eric Jacques[1], PhD student Manon Mastin[6], Professor Javier Escartin[9], Associate technician Samia Hidalgo[1], Associate technician Sophie Nowak[11], Research engineer Pierre Burckel[1], Associate professor Charles Le Losq[1], Research engineer Jean-Marie Augustin[6], Research engineer Arnaud Lemarchand[1], Research engineer Jean-Marie Saurel[1], Professor Aline Peltier[1,4], Research engineer Charlotte Mucig[10]

[1]Institut De Physique Du Globe De Paris, Université Paris Cité, CNRS, Paris, France, [2]Université Clermont Auvergne, CNRS, IRD, OPGC, Laboratoire Magmas et Volcans, Aubière, France, [3]Observatoire volcanologique et sismologique de la Guadeloupe, Institut de physique du globe de Paris, Gourbeyre, France, [4]Observatoire volcanologique du Piton de la Fournaise, Institut de physique du globe de Paris, La Plaine des Cafres, France, [5]BRGM DGR/GBS, Orléans Cedex 2, France, [6]Géo-Océan, Univ Brest, CNRS, Ifremer, Plouzané, France, [7]Laboratoire de Géologie de Lyon : Terre, Planètes, Environnement, CNRS, UMR 5276, Ecole Normale Supérieure de Lyon, Université de Lyon, Université Claude Bernard Lyon 1, Villeurbanne, France, [8]Géosciences Montpellier, CNRS, Université de Montpellier, Université des Antilles,, Montpellier, France, [9]Laboratoire de Géologie - CNRS UMR 8, Ecole Normale supérieure de Paris, Paris, France, [10]BRGM DAT/OMR/MAY, Mamoudzou, France, [11]Université Paris Cité, CNRS, Paris, France

Submarine monogenetic volcanic fields are poorly known. Moreover, understanding deep-sea explosive volcanism remains highly challenging. In 2018, the new Fani Maoré volcano formed 50 km East of Mayotte by an exceptional major subma-rine effusive eruption. A permanent monitoring network and a series of 26 oceanographic monitoring and research cam-paigns were conducted and funded by the French government. The resulting large multidisciplinary data revealed an unprec-edented view of a major submarine volcanic field stretching East over 50 km from Petite-Terre island (Mayotte) to Fani Maoré. Located in water depths of 400-3500 m, this volcanic field is characterized by an exceptional diversity of volcanic edifices, magma compositions, erupted volume, and eruptive dynamics including effusive and explosive activity. We focus here on the numerous (≥ 250 – 300) volcanic cones that were produced by explosive and/or effusive volcanic activity be-tween 400–3000 m depth, particularly in a zone within 5 to 15 km East of Petite-Terre Island (Mayotte). We carried out a first analysis of the morphometric characteristics of these volcanic cones

(lava, scoria and pumice cones) based on an analy-sis of new high-resolution bathymetric and reflectivity data. We discuss eruptive processes and products (including abun-dant pyroclastic deposits) coupled with extensive dredging and sampling by ROV. Our study thus provides some initial geological constraints on the construction of this major submarine monogenetic volcanic field. This work has implications for improving our understanding of deep-sea explosive volcanism, developing efficient multidisciplinary monitoring and early-warning strategies, and elaborating volcanic risk assessment for the heavily populated island of Mayotte. Implications are paramount given the context of Holocene explosive subaerial volcanism on Petite-Terre and the current continuing unrest in the area between 5 – 15 km from Mayotte where persistent volcanic seismicity is recorded along with an extending field of active submarine CO2-rich fluid emissions.

638

The relationship between ignimbrite facies and topographical features on tilted Miocene pyroclastics – a case study from Northern Hungary

Dr Tamás Biró[1], Dr Mátyás Hencz[1], Dr Támás Telbisz[1], Dr Szabolcs Kósik[1,2], Mr Zoltán Cseri[1], Prof Dávid Karátson[1]

[1]*Department of Physical Geography, Eötvös Loránd University, Budapest, Hungary,* [2]*Horizons Regional Council, Palmerston North, New Zealand*

Ignimbrite units with extremely variable erodibility are typical in the succession of silicic caldera systems. Welded ignimbrites are usually characterized by low erodibility, thus they often appear as positive landforms, i.e. mesas or cuestas, after millions of years of denudation. The Bükkalja Volcanic Field, which is part of the most extended foothill region in Northern Hungary, is composed predominantly of Early to Middle Miocene ignimbrites. Here, the frequency distribution of elevation a.s.l., slope, aspect, as well as topographic openness, was investigated using the 30 m resolution SRTM-based digital surface model for four sample areas, located at ~5-15; ~15-20; ~20-35; and ~35-40 km distance respectively from the assumed source regions of the ignimbrites. The studied ignimbrites show both non-welded and slightly welded facies. The degree of dissection was also examined along swath profiles. The topography of the sample area closest to the source localities is dominated by tilted plateaus of moderately dissected welded ignimbrites, gently dipping towards SE. Farther away from the source the topography consists of erosional valleys and ridges, resulting in a narrower typical elevation range, a higher proportion of pixels with slope greater than 5°, higher frequencies of NE and SW exposures, and more significant incision which resulted in more frequent pixels with positive topographic openness less than 1.5 radians here. In general, greater thicknesses and emplacement temperatures of ignimbrites, which often show welded facies, are more common closer to the source vent. Thus, the erosional pattern around calderas can be used to draw conclusions on the spatial extent of the most intense ignimbrite accumulation, with implication to the location of eruption centres even in deeply eroded ignimbrite fields.

208

Volcanic architecture and eruptive history of the peralkaline Mayor Island (Tūhua) volcano, New Zealand, based on high-resolution LiDAR survey

Dr Szabolcs Kósik[1,2], Prof Károly Németh[3,4,5], Dr Callum Rees[3]
[1]Horizons Regional Council, Palmerston North, New Zealand, [2] Department of Physical Geography, Eötvös Loránd University, Budapest, Hungary, [3]Massey University, Palmerston North, New Zealand, [4]Institute of Earth Physics and Space Science, Sopron, Hungary, [5]Saudi Geological Survey, Jeddah, Kingdom of Saudi Arabia

Tūhua (Mayor Island), located off New Zealand's Bay of Plenty coastline, is a compound, shield-like volcano dominated by peralkaline rhyolite lavas and pyroclastic rocks. Previous studies established a chronostratigraphic framework for the island, yet detailed geomorphic interpretation has been hindered by the rugged, shrub covered terrain. Here we present a revised geological map, stratigraphic framework and geological history based on existing work, based on a 1 m digital elevation model, 100 m bathymetry and new field observations. Three caldera/crater structures are recognised; the 36 ka C1 caldera, 9.2 ka C2 caldera and a newly identified 7.6 ka C3 crater. Our analysis suggests that the 7.6 ka Tūhua eruption is not related to collapse and formation of the C2 caldera, as interpreted by previous studies. Instead, we attribute the Tūhua eruption to the C3 crater and associated ejecta ring identified in this study. Geomorphic assessment, field observations and volume estimates suggest the C2 caldera collapse event occurred at c. 9.2 ka. The upper Taumou Pa and 9.2 ka spatter-fed lava flows are both observed to be flowing into and outward of the C2 caldera, suggesting they were both active during the collapse event. The lack of volumetrically significant eruptions at the time of the two collapse events is leading us to attribute caldera collapses to magma inflation and drawdown at Tūhua. Coastal exposures include thick cone building pyroclastics and deposits of pyroclastic density currents alternating with lava flows exhibit the dominance of hydrovolcanism for explosive activity. Consequently, explosive interaction between magma and water is the most probable scenario for the initial stage of future eruptions.

422

Magma evolution and estimation of fluid amount from melt inclusion studies and numerical modeling in Naruko caldera, NE Japan.

Mr Alexey Kotov[1], Dr Satoshi Okumura[1], Dr Kenji Shimizu[2], Dr Isoji Miyagi[3], Dr Masaoki Uno[1], Dr Noriyoshi Tsuchiya[1]

[1]Tohoku University, Sendai, Japan, [2]JAMSTEC, Kochi Institute for Core Sample Research, Kochi, Japan, [3]National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Japan

Naruko caldera is an active volcano, located in NE Japan, associated with the extended sub-vertical magmatic system from 5 to >30 km in depth, and is suitable for investigating the volatile accumulation processes in the upper crustal magma chamber. Two eruptions formed Caldera: the Nizaka (c.72ka) and the Yanagisawa pyroclastic flows (c.45ka). Variations in the mineral assemblage and MI's composition of both eruptions indicate a variable evolution of magmas preceding these eruptions. Phenocrysts are plagioclase, hypersthene, quartz, and Fe-Ti oxides. Low-Al Mg-Hornblend occurs as phenocryst in Yanagisawa but is absent in Nizaka tuff. Nizaka magmas has been formed under 790-830°C and fO of ΔNNO to ΔNNO-0.45. However, significant heating of magmas to a level of 870°C at the early stages of formation initiated the crystallization of high-Ca plagioclase and High-Mg orthopyroxene and removed amphibole from its stability field. The subsequent drop in temperature did not lead to the resumption of amphibole crystallization. Formation of Yanagisawa magmas continued under similar PT conditions. It was accompanied by the repeated heating induced through the ascent of more primitive magmas, which is expressed in the inverse rhythmic zoning of minerals and olivine finds, under temperature variations between 800-840°C, in slightly more oxidized conditions (ΔNNO+0.5), which allowed the amphibole to stabilize in the last stages of evolution. The proposed petrological model has continuously repeated intrusion of hot mafic magmas into the upper crust, which results in partial melting of upper crustal rocks without significant mixing between the melted magma and intruded mafic magmas. As a result, a chamber was formed that continued to grow throughout the Late Pleistocene and produced in situ water-saturated rhyolitic magmas. Based on petrographic observation, known erupted volume (12.5km^3), mass-balance calculation, and Rhyolite-MELTS results, the total amount of H_2O stored in the chamber (dissolved in the melt) is 1.15*10^{3}tons

1173

Scoria cone evolution at the Ngāuruhoe summit in Aotearoa/New Zealand: using observational records to constrain eruptive history

Dr Janine Krippner[1], Adrian Pittari[1], Geoff Kilgour[2], Roger Briggs[1], Amilea Sork[3]
[1]University Of Waikato, Hamilton, New Zealand, [2]GNS Science, Taupō, New Zealand, [3]University of Canterbury, Christchurch, New Zealand

The scoria cone at the summit of Ngāuruhoe formed during the 1954-55 and 1974-1975 eruptions that were characterized by alternating explosive and effusive activity, including Strombolian and Vulcanian eruptions that produced ballistic ejecta, ash plumes, lava flows, avalanches, shock waves, and pyroclastic density currents. Here, we combine observational records and photographs with stratigraphic analysis to determine the sequence of alternating eruption styles that formed the summit cone. The evolving geomorphology in turn influences or controls the dispersal of volcanic flows and ballistic ejecta that pose a hazard to those within the adjacent Tongariro Alpine Crossing. This ongoing work contributes to quantifying the hazards associated with eruptions at Ngāuruhoe, which was Aotearoa/New Zealand's most active volcanic centre until it entered a dormant phase in 1977.

639

Volcanic sulfate deposition to Greenland and Antarctica: A modeling sensitivity study with CESM(WACCM)

Mrs Kirstin Krüger[1], Herman Fuglestvedt[1], Zhihong Zhuo[1], Dr. Mike Mills[2], Associate Professor Michael Sigl[3]
[1]University of Oslo, Oslo, Norway, [2]NCAR, Boulder, USA, [3]University of Bern, Bern, Switzerland

Reconstructions of the atmospheric sulfate aerosol burdens resulting from past volcanic eruptions are based on ice core-derived estimates of volcanic sulfate deposition and the assumption that the two quantities are directly proportional. Toohey et al (2013) modelled that the Antarctic and Greenland volcanic sulfate deposition is nonlinear for very large sulfur rich tropical eruptions (Tambora magnitude and larger), with significantly less sulfate deposition to Antarctica than to Greenland using the MAECHAM5-HAM aerosol-climate model.

Here we test the relationship for simulations of explosive tropical and extratropical Northern Hemisphere volcanic eruptions by co-injecting sulfur and halogens into the stratosphere with the CESM2(WACCM) model including aerosol, chemistry, climate, and earth system processes. We consider different eruption parameters varying composition, latitude, season, injection height and magnitude. We run the model injecting 17 Tg and 200 Tg of SO_2, together with scaled halogens, at 24 km altitude 15° N and 64° N during January and July pre industrial 1850 conditions. We will analyse the modelled sulphate deposition signals over Greenland and Antarctica and compare them to the volcanic ice core records of known eruptions of comparable strength during the Common Era and the Holocene. The analysis will focus on the deposition fluxes and their Greenland/Antarctica efficiencies in relation to the eruption parameters, sulphate aerosol transport, and the atmospheric circulation and deposition. With the help of the model data we will learn more about the volcanic sources to the sink processes, which will be helpful to better interpret volcanic signals in bipolar ice core records.

References:
Toohey, M., K. Krüger, and C. Timmreck (2013), Volcanic sulfate deposition to Greenland and Antarctica: A modeling sensitivity study, J. Geophys. Res. Atmos., 118, doi:10.1002/jgrd.50428.

1397

Developing Sparrow as a key laboratory-based component for a future FAIR tephra data information system

Professor Stephen Kuehn[1], Research scientist Daven Quinn[2], Associate Research Specialist Casey Idzikowski[2]
[1]Concord University, Athens, United States, [2]University of Wisconsin, Madison, United States

The global tephra research community has recently published best practice recommendations (https://doi.org/10.1038/s41597-022-01515-y) as part of a larger effort toward open science and FAIR practices - Findable, Accessible, Interoperable, and Reusable data. As a next step in this process, a future multi-component data system is being proposed to support researcher needs at all stages of tephra science from the field to the laboratory to publication and data archiving (see companion abstract, this meeting).

An implementation of the Sparrow data system (https://sparrow-data.org) is under development to support laboratory components of tephra research and local data and metadata storage including sample cataloging and curation, sample preparation, grain size analysis, componentry, geochemical analysis, optical imaging, and SEM imaging along with people, projects, and analytical methodologies. Sparrow's architecture includes a PostgreSQL database, Python-based API server, data import and export pipelines, and a web-based user interface. Implementing tephra best practices in Sparrow will (1) cover laboratory workflows between field sample collection and final project data archiving and (2) address a key researcher pain point in tephra studies and petrology. As re-emphasized by participants in the Tephra Fusion 2022 workshop, the huge workload currently needed to capture and organize data and metadata in preparation for archiving in community data repositories is a major obstacle to achieving FAIR practices. By capturing this information on the fly during laboratory workflows and integrating it together in a single data system, this challenge may be overcome. When fully-developed, Sparrow-tephra will provide a key building-block for a future tephra data system and will complement parallel efforts for field data via StraboSpot (https://strabospot.org/files/StraboSpotTephraHelp.pdf) and for samples, analytical methods, and geochemistry via SESAR and EarthChem (https://earthchem.org/communities/tephra/).

660

White pumice clasts: Peculiar felsic products of the 2021 basanitic Tajogaite eruption, La Palma

Ms Sophia Bachmayer[1], Dr Ulrich Kueppers[1], Prof. Peter Schaaf[2], Dr. Francisco Cáceres[1], Dr. Corrado Cimarelli[1], Dr. Luca D'Auria[3,4], Prof. Donald B. Dingwell[1], Dr. Dirk Müller[1], Dr. Matthew Pankhurst[3,4], Dr. Nemesio Perez[3,4]

[1]Department of Earth and Environmental Sciences, Ludwig-Maximilians-Universität (LMU), Munich, Germany, [2] Instituto de Geofísica, Universidad Nacional Autónoma de México (UNAM), Mexico City, Mexico, [3]Instituto Volcanológico de Canarias (INVOLCAN), La Laguna, Santa Cruz de Tenerife, Spain, [4]Instituto Tecnológico y de Energías Renovables (ITER), Granadilla de Abona, Santa Cruz de Tenerife, Spain

The 2021 Tajogaite fissure eruption on La Palma, Canary Islands was a mixed effusive-explosive event. It produced a complex lava flow field, a vast tephra blanket and an elongated cone.

Albeit volumetrically subordinate, highly porous ash and lapilli clasts of predominantly white and grey colour (more rarely pink, green, and yellow) were observed. They were ejected throughout the entire eruption, yet the average size at repeatedly visited sampling points decreased over time. We present textural, petrographic, geochemical, and isotopic data to elucidate their origin.

The clasts are highly porous (up to 90%), angular and range chemically from rhyolite to phonolite. They are mostly glassy, aphyric and the few crystals show signs of dissolution. Owing to the observed features and composition, atypical for La Palma, we propose these clasts are sedimentary in origin, hence we refer to them as xeno-pumices (XP). Characteristics of similar samples from the 1949 and 1971 eruptions on La Palma as well as El Hierro in 2011 make a common genetic process likely. Backed up by isotopic analyses (Nd, Sr, Pb), we interpret that XP are pre-La Palma oceanic sediments with continental signature, originating from the African shelf. This stack of sediments appears chemically heterogeneous with variable content in clay minerals, mica, quartz, and feldspar. Upon ingestion into the basanitic magma, the claystone, quartzitic sandstone, arkose and greywacke lithologies were heated and progressively melted. Sharp and diffuse contact between XP and basanite evidence repeated break-up of the XP to the observed size range in the deposit.

The presence of XP throughout the duration of the eruption proves the turbulent magma ascent through the sedimentary cover of the oceanic crust, causing repeated direct magma-country rock contact. This indicates dynamic and changing magma ascent conditions during this variably intense yet continuous eruption.

776

The porosity of pyroclasts: a hands-on approach to reveal magma textures

Alessandro Pisello[1,2], Dr Ulrich Kueppers[1], Kai Dueffels[3], Donald B. Dingwell[1], Diego Perugini[2]
[1]LMU, Muenchen, Germany, [2]Università degli Studi di Perugia, Perugia, Italy, [3]Microtrac Retsch GmbH, Haan, Germany

Volcanic eruptions are driven by magma rising through Earth's crust. The style of an eruption depends on intrinsic and extrinsic parameters and is commonly a dynamic process. Thorough investigation of the related products is key to understanding eruptive phenomena.

In this context, quantitatively constraining the dispersal area, grain size distribution and pyroclast textures is essential. Volume determination of pyroclasts is fundamental to constrain density and porosity. However, volume determination of irregularly shaped pyroclast cannot be done with geometrical laws but hat to be assessed with different methodologies. In this study, we have collected a set of clasts from Santorini, Greece, to test three methodologies: a manual methodology to measure three orthogonal axes with a calliper; an optical methodology to measure longest and shortest axis through multiple photographs; and the Archimedean methodology.

All three methodologies found similar volume results with little impact on the subsequent assessment of porosity and density. The discrepancy between Archimedean and manual/optical methodologies is observed to be smaller than the revealed natural variability. For this reason, we advertise the manual methodology to be used for future field campaigns as a simple and fast yet reliable approach to gain insights into the textural state of magma at eruption.

606

Fast modulation of topography and eruptive activity

Dr Ulrich Kueppers[1], Dr. Benjamin Jacobs[2], Prof. Donald B. Dingwell[1], Prof. Bruce F. Houghton[3], Prof. Jeff Johnson[4], Prof. Michael Krautblatter[2], Dr. Tullio Ricci[5], Prof. Maurizio Ripepe[6], Dr. Bryan Rosenblatt[4], Dr. Markus Schmid[1], Dr. Jacopo Taddeucci[5], Dr. Piergiorgio Scarlato[5]
[1]Earth and Environmental Sciences, LMU Munich, Munich, Germany, [2]Landslide Research Group, Technische Universität München (TUM), Munich, Germany, [3]University of Hawaii at Manoa, , USA, [4]Boise State University, Boise, USA, [5]Istituto Nazionale di Geofisica e Vulcanologia, Roma, Italy, [6]Laboratorio Geofisico Sperimentale (LGS), Università di Firenze, Florence, Italy

Volcanic explosions are inherently dynamic events, modulated by the vent from which they erupt, yet their eruptive activity modulates vent geometry. Constructive and destructive processes may take place simultaneously or alternate on short time scales. Here we show these processes qualitatively and quantitatively by using Uncrewed Aerial Systems (UASs) and Laser Scanner measurements at Stromboli volcano, Italy.

During repeated observational campaigns, a wide range of eruptive activity was observed, both simultaneously from neighbouring vents or successively from an individual vent. The activity ranged from low-energetic ash venting, through “normal” Strombolian eruptions with the ejection of primarily incandescent bombs, to impulsive jets with variable content of pyroclasts and lithics. Style likely depends on 1) gas release rate, 2) magma surface conditions and 3) magma free-surface depth. Repeated UAS surveys can quantify the amount of material deposited in the proximity of vents and/or removed by explosive and/or gravitational processes. Deposit accumulation is reliably resolvable with DEMs that are several days apart while excavation has been quantified from UAS missions less than 24 h apart.

In May 2019 the deployment of a Riegl VZ400 terrestrial laser scanner caught a rare glimpse into the dynamic evolution of a Strombolian cone shortly after partial destruction in an explosion. The conduit was vertically dissected and exhibited a faintly flaring vertical shape. Furthermore, the high resolution of the laser scan survey revealed interior textures of the conduit showing centimetric lining of dense lava along the margins that seemingly stabilised the cone.

In recent years, unusually strong and unforeseen explosions have negatively impacted on access (for monitoring and tourist purposes) to active volcanoes. Our observations add unprecedented detail to our knowledge of Strombolian eruptions and foster better understanding of eruption intensity variations.

555

A comparative experimental study of pyroclast sintering across temperature, time, and melt composition space

Dr Ulrich Kueppers[1], Prof. Jonathan M. Castro[2], Dr. Daniele Andronico[3], Dr. Christoph Helo[2], Dr. Matt Pankhurst[4,5], Prof. Fabian Wadsworth[6]

[1]Earth and Environmental Sciences, LMU Munich, Munich, Germany, [2]Johannes Gutenberg Universität (JGU), Mainz, Germany, [3]Istituto Nazionale di Geofisica e Vulcanologia (INGV), Osservatorio Etneo, Catania, Italy, [4]Instituto Volcanológico de Canarias (INVOLCAN), La Laguna, Santa Cruz de Tenerife, Spain, [5]Instituto Tecnológico y de Energías Renovables (ITER), Granadilla de Abona, Santa Cruz de Tenerife, Spain, [6]Earth Sciences, Durham University, Durham, UK

Tephra deposits of explosive activity may be affected by volcanic sintering, a process which comprises the coalescence of pyroclasts under the influence of temperature, grain size, surface tension, load, and time. There is evidence from observed eruptions and eruptive products that sintering in conduits, during atmospheric transport, and after deposition, can all alter primary grain size distributions.

We performed sintering experiments using natural pyroclasts with different compositions to map the sintering rates and examine the associated textures. Our starting materials were mafic ash from Etna (Italy, trachybasalt) and Tajogaite (La Palma, Spain, basanite), and rhyolitic ash from Chaitén and Cordón Caulle (Chile). Grain sizes were 250 µm – 1 mm for all samples except for Cordón Caulle, which was < 106 µm.

Four series of sintering experiments were performed under anhydrous, oxidizing 1-atm conditions at 1050˚C, 1100°C and 1150˚C, and for durations from five minutes to ~1 day. Salient findings of the mafic experiments highlight differences in the ability for the melts to sinter under the same thermal and time conditions. The Tajogaite basanite ash has a propensity to sinter, even at the shortest time scales, resulting in nearly pore-free continuous melt. By comparison, Etna is reluctant to sinter under the same conditions, requiring much longer times to attain a subtle sticking of grains. Rhyolite ash sintered thoroughly regardless of temperature and time. The slightly less-silicic Cordón Caulle ash always sintered to low-porosity glass whereas Chaitén's ash yielded highly porous, rounded grain networks.

Preliminary results show a sintering sequence across the compositional spectrum: 1.) oxidation of the grain boundaries manifested as the growth of Fe-oxides; 2.) rounding of grains and formation of melt necks 3.) entrapment of pore space and vesicle rounding; 4.) growth of new vesicles due to volatile exsolution (only in Chaitén); 5.) volume loss/contraction; 6.) microlite crystallization.

832

Forecasting explosions at Sinabung Volcano, Indonesia, based on SO2 emission rates

Mrs Syegi Kunrat[1], Dr. Christoph Kern[2], Mrs. Hilma Alfianti[1], Dr. Allan H. Lerner[2]
[1]Center for Volcanology and Geological Hazard Mitigation, Geological Agency, Ministry of Energy and Mineral Resources , , Indonesia, [2]U.S. Geological Survey, Volcano Disaster Assistance Program, Vancouver, USA

Dome-building volcanic eruptions are often associated with frequent Vulcanian explosions, which constitute a substantial threat to proximal communities. One proposed mechanism driving such explosions is the sealing of the shallow volcanic system followed by pressurization due to gas accumulation beneath the seal. We investigate this hypothesis at Sinabung Volcano (Sumatra, Indonesia), which has been in a state of eruption since August 2010, extruding a lava dome and experiencing frequent explosions that send ash columns many kilometers into the atmosphere. A network of scanning DOAS was installed on the volcano in 2016 to continuously monitor SO2 emission rates during daytime hours. Analysis of the DOAS data from October 2016 to September 2017 revealed that passive SO2 emissions were generally lower in the 5 days leading up to explosive events (~100 t/d) than was common in 5-day periods leading up to days on which no explosions occurred (~200 t/d). The variability of passive SO2 emissions, expressed as the standard deviation, also took on a slightly wider range of values before days with explosions (0–103 t/d at 1-sigma) than before days without explosions (43–117 t/d). These observations are consistent with the aforementioned seal-failure model, where the sealing of the volcanic conduit blocks gas emissions and leads to pressurization and potential Vulcanian explosions. We develop a forecasting methodology that allows calculation of a relative daily explosion probability based solely on measurements of the SO2 emission rate in the preceding days. We then calculate forecast explosion probabilities for the remaining SO2 emissions dataset (October 2017—September 2021). While the absolute accuracy of forecast explosion probabilities is variable, the method can inform the probability of an explosion occurring relative to that on other days in each test period. The SO2 emissions-based forecasting method is likely applicable to other open vent volcanoes experiencing dome-building eruptions.

1395

Cryptotephra surprises in a South Pole ice core

Andrei Kurbatov[1], Laura Hartman[1], Meredith Helmick[1], Nelia Dunbar[2], Nels Iverson[2], Martin Yates[1]
[1]University Of Maine, Orono, United States, [2]New Mexico Institute of Mining and Technology, Socorro, United States

A large number of climate significant volcanic eruptions have been identified in Antarctic ice core records based on sulfate concentrations spikes and eruption timing. The majority of developed Antarctic ice core records use developed glaciochemical time series for precise stratigraphic synchronizations of time scales, and for calculating the contribution of volcanic forcing to the state of the climate system. Since the 1980's every major ice core program, in addition to using visible tephra deposits in ice cores, has tried to extract and measure very fine, invisible volcanic particles (cryptotephra) from intervals with large sulfate spikes to confirm proposed volcanic source identification using geochemical fingerprinting of volcanic glass. Relatively poor cryptotephra recovery rates in past studies have hampered unambiguous source volcanic event attributions. In the last decade, several tephra extraction methods were developed and tested. We applied a new methodology and sampled most of the volcanic sulfate intervals reported in the SPC-14, South Pole Ice core, for the last several thousand years. All tephra particles extracted from ice cores and mounted in epoxy were preselected for the semi-quantitative EDAX Genesis PhiRhoZ internal quantification procedure using a Tescan Vega-II XMU scanning electron microscope. We found a broad range of ultra fine minerals and volcanic glass particles in the studied intervals. We will discuss particle geochemical signatures for specific historical volcanic eruptions: e.g. Tambora 1815, Tarawera 1886, Huaynaputina 1600 CE, along with several unknown eruption sources. The developed conceptual model explains random mineral assemblages observed in many large historical volcanic eruption intervals in ice cores. This study aligns with the results of previous reports from Greenland and Antarctica on the complexity of volcanic products captured in polar ice cores.

Research was supported by NSF grants 1142007, 1142069, 1543361, and 1543454.

240

Deep low-frequency earthquakes with various waveform characteristics related to volcanic activity in Kirishima and Hakone volcanoes in Japan

Dr Ryo Kurihara[1]
[1]*Hot Springs Research Institute of Kanagawa Prefecture, Odawara-shi, Japan*

Deep low-frequency (DLF) earthquakes (or sometimes called as deep long-period earthquake) are occurred at the depth of 15-50 km in the volcanic regions, while most inland crustal earthquakes occur at depths shallower than approximately 15 km. Recent studies showed that DLF earthquakes increased before and after the eruption of volcanoes (e.g., Shapiro et al., 2017). In this study, I investigated DLF earthquakes in 52 regions of Japan over 14 years through relocations of their hypocenters, detection from continuous waveform data based on matched filter technique (Kurihara and Obara, 2021), and quantification of waveform characteristics and introduce the results in Kirishima and Hakone volcanoes.

In Kirishima volcano, south-west Japan, activation of DLF earthquakes at the depths of 25 km had been observed in 2010–2011 with sub-plinian and other type eruptions (Kurihara et al., 2019). Small activation of DLF earthquakes had also been observed in 2017–2018 with eruptions (Kurihara and Kato, submitted). The activated DLF earthquakes in 2010–2011 mostly had low dominant frequencies. These results suggest that DLF earthquakes might occur near conduits and could be triggered by moving of magmatic fluid in the deep crust. The fluid paths of the 2018 eruptions might be different from those of the 2011 eruptions.

In Hakone volcano, east Japan, activation of DLF earthquakes had been observed in 2015 with phreatic eruption (Yukutake et al., 2019). However, waveform characteristics of DLF earthquakes in 2015 have large variety and those are almost same as DLF earthquakes in the other period. These results suggest that DLF earthquakes were triggered not only by fluid movement itself but also stress disturbance with fluid movement.

387

20 Years of Surveillance of Deformation at Erebus volcano, Antarctica using a GPS network

Dr Ronni Grapenthin[1], Dr Philip Kyle[2], Dr Richard Aster[3], Mario Angarita[1], Dr Terry Wilson[4], Dr Julien Chaput[5]
[1]University Alaska - Fairbanks, Fairbanks, USA, [2]New Mexico Inst. Mining & Technology, Socorro, USA, [3]Colorado State University, Fort Collins, USA, [4]Ohio State University, Columbus, USA, [5]University of Texas-El Paso, El Paso, USA

Erebus volcano is the most active volcano in Antarctica. It is 50 years since the first direct observations of a convecting phonolite lava lake in the 200 m-deep Inner Crater. Small Strombolian eruptions from the lava lake and adjacent vents are a characteristic feature of the eruptive activity. The low power consumption and robustness of Global Navigation Satellite System (GNSS) geodetic stations allows for year-round observations of Erebus deformation even under the extreme conditions found on the 3794 m high volcano. Campaign GPS observations on the flanks and summit area of Erebus started in the late 1990's. Seven continuous GPS stations were installed in the 2000's, some of these were collocated with seismic stations. The network provides a record of more than 20 years of geodetic observation. These data show long-term subsidence of Ross Island that modeling shows is consistent with the lithospheric response to Erebus loading over the last 20 ka. The data also resolve multi-year inflation and deflation cycles of the summit area. These cycles are principally related to transient dynamics of the shallow magmatic system which feeds the lava lake by convection via a narrow conduit, but some features may also reflect deeper magmatic system evolution. The most recent inflation event, which started in October 2020, is presently on-going. Based on prior such inflation periods this might herald an increase in the number and size of Strombolian eruptions.

963

Role of water and carbon dioxide in highly explosive basaltic eruptions: A numerical investigation

Dr Giuseppe La Spina[1,2], Dr. Fabio Arzilli[3,2], Prof. Mike Burton[2], Dr. Margherita Polacci[2], Prof. Amanda Clarke[4,5]
[1]Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo, Catania, Italy, [2]The University of Manchester, Manchester, UK, [3]University of Camerino, Camerino, Italy, [4]Arizona State University, Tempe, USA, [5]Istituto Nazionale di Geofisica e Vulcanologia, Pisa, Italy

Water and carbon dioxide are the most abundant volatile components in terrestrial magmas. As they exsolve into magmatic vapour, they promote magma buoyancy, accelerating ascent and modulating eruptive dynamics. It is commonly thought that an increase in pre-eruptive volatile content produces an increase in eruption intensity. Using a conduit model for basaltic eruptions, covering the upper 6 km of conduit, we investigate the role of water and carbon dioxide for highly explosive basaltic eruptions, assuming the Etna 122 BC Plinian eruption as a test case. We studied magma ascent dynamics as a result of the increase in volatile content caused by: i) an internal redistribution of the pre-eruptive bubbles towards the top of the magma chamber; ii) an injection of volatiles due to an external source. We find that an increase in H_2O content due to bubbles accumulation at the top of the magma reservoir results in an increase in magma ascent velocity at depth, whereas this is not observed for a similar increase in CO_2 content. The enhanced magma buoyancy due to the increase in CO_2 content is counterbalanced by an increment in magma viscosity, which is not occurring for a similar increase in H_2O content. For the same chamber conditions mass eruption rate is not affected by CO_2 content, whereas an increase in H_2O up to 10 wt.% produces an increase in eruption rate of an order of magnitude. It is only when CO_2 is injected in the magma reservoir from an external source that the resulting pressurisation will generate a strong increase in eruption rate. Results also show that fragmentation depth is strongly affected by pre-eruptive volatile contents demonstrating a link between volatile content and eruptive style.

970

Experiments, Numerical moDelling and field observations of basaltic maGmA fragMEntation (ENDGAME)

Dr Giuseppe La Spina[1,2], Dr. Laura Spina[3], Dr. Piergiorgio Scarlato[3], Dr. Jacopo Taddeucci[3]
[1]Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo, Catania, Italy, [2]The University of Manchester, Manchester, UK, [3]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Roma1, Roma, Italy

For low viscosity magmas such as basalts, rapid and unpredictable transitions between effusive and explosive activity may occur. These transitions dramatically alter the impact of an eruption and pose a real challenge to policymakers tasked with mitigating the risks associated with basaltic eruptions. Mechanisms controlling these transitions, however, are not well understood, mainly due to the lack of a clear understanding of basaltic magma fragmentation.

The new Marie Skłodowska-Curie Individual Fellowships ENDGAME aims to investigate transitions in eruptive styles at basaltic volcanoes by studying fragmentation of basaltic magmas through a combination of targeted cutting-edge fluid dynamics experiments, new holistic numerical modelling of magma ascent and brand new field observations collected during a basaltic eruption.

In this work we will present preliminary results of jet flow and shock-tube experiments with a bubble- and particle-bearing analogue material in combination with high-speed Schlieren shadow photography. For both type of experiments, we will use either a cylindrical conduit (3D geometry) or a fissure made by two close parallel plates (2D geometry). By adopting at first a 2D geometry we will simplify the visualization of the phases within the fluid, allowing a better understanding of the fragmentation process. As a result, the quantification of the internal properties of the fluid will become more accessible, allowing us to formulate an initial set of constitutive equations for basaltic magma fragmentation. These equations will be then adjusted/validated using the 3D cylindrical conduit and field observations (such as particles exit velocity and/or grain size).

The interdisciplinary approach that characterizes ENDGAME, e.g. linking cutting-edge fluid-dynamics experiments with state-of-the-art 3D magma ascent modelling and field observations of an active eruption, will allow us to shed light on one of the biggest challenges in volcanic hazard assessment: what parameters and how they control the transition in eruptive style at basaltic volcanoes?

1093

Remote predictive mapping of volcanic terrain in the High Arctic Large Igneous Province, Nunavut, Canada

Ms Stephanie Lachance[1], Mrs Myriam Lemelin[1], Mrs Marie-Claude Williamson[2]
[1]Université De Sherbrooke, Montreal, Canada, [2]Geological Survey of Canada, Ottawa, Canada

Remote predictive mapping (RPM) is a methodology used to identify regions of interest for future fieldwork and to fill knowledge gaps in frontier regions. Remote predictive maps are usually derived from supervised classifications performed on multispectral satellite images acquired in the visible, near infrared and shortwave infrared. However, the use of a supervised classification requires a priori knowledge of bedrock geology thus contradicting the underlying objective of predictive mapping. The objectives of our research project are to (1) generate a geological map at 1:10 000 scale for our region using emerging satellite imagery and classification methods (i.e., PRISMA hyperspectral satellite images and the self-organizing maps method); and (2) compare our results with those obtained using traditional remote sensing approaches (e.g., multispectral imagery and Random Forest). The study area is in the Sverdrup Basin, at the head of Expedition Fiord, on Axel Heiberg Island, Nunavut, Canada. Characterized by volcanic and intrusive rocks of the High Arctic Large Igneous Province and by active and paleo-hydrothermal systems, this region is an analogue site to hydrothermal systems found on Mars. Methods developed in this project could then be used again in the search for life on Mars. A preliminary validation of the classifications using the available 1:100 000 scale bedrock geology map has been completed with the objective of ground truthing the results during fieldwork in July 2022. Portable field instruments were used to validate the RPM approach for mapping at a 1:10 000 scale with the goal of providing a higher resolution of geological units in the vicinity of the McGill Arctic Research Station. In this presentation, we introduce the methods, geological context and results associated with the two classification methods and showcase the remote predictive geological map.

1268

The explosive phonolitic volcanism of Petite-Terre (Mayotte, Western Indian Ocean) and its hazard quantification.

Mr Tristan Lacombe[1], Pr. Lucia Gurioli[1], Dr. Andrea Di Muro[2], Dr. Etienne Médard[1], Dr. Carole Berthod[3,4], Pr. Jean-Christophe Komorowski[3], Dr. Pascale Besson[3], Pr. Patrick Bachèlery[1], Dr. Julien Bernard[5], Ludivine Sadeski[6]

[1]Université Clermont Auvergne, CNRS, IRD, OPGC, Laboratoire Magmas et Volcans, Clermont-Ferrand, France, [2]Laboratoire de Géologie de Lyon : Terre, Planètes, Environnement, Lyon, France, [3]Université Paris Cité, Institut de physique du globe de Paris, Paris, France, [4]Observatoire volcanologique et sismologique de la Guadeloupe, Institut de physique du globe de Paris, Gourbeye, France, [5]BRGM-French geological survey, Orléans, France, [6]BRGM DAT/OMR/MAY, Mamoudzou, France

Four young volcanic phonolitic maars containing mantle xenoliths have been described on Petite-Terre Island (Mayotte, Indian Ocean) which deposits cover older basaltic activity. The discovery in May 2019 of a new active submarine volcano, 50 km off Mayotte, raises the possibility of a renewal of volcanic activity on land and therefore the need to quantify the hazard of these past eruptions. Geomorphology, stratigraphy, grain size and componentry measurement were used to establish the stratigraphy and understand the eruption/s of those unique objects. These maars represent a monogenetic complex due to the absence of paleosoil, and the homogenous chemistry of the products. The eruptive sequences of these maars are composed of alternations of few, relatively thin fallouts layers coupled to ballistic component, and thick deposits emplaced by dilute pyroclastic density-current (PDCs) rich in very fine ash (< 64 µm). The deposits are dominated by juvenile phonolitic material (pumices, stony phonolite and rare obsidian) but also contains non-juvenile clasts from the underlying coral reef and basaltic shield of Mayotte. The fine ash surface texture do not show any evidence of Molten-Fuel Coolant Interaction suggesting that fragmentation was essentially magmatic, despite the deposits show evidence of interaction with liquid water (accretionary lapilli, plastering). Therefore, the erupted magma, first experienced a purely magmatic fragmentation at depth (≈1 km deep) as evidenced by the absence of sedimentary material from the reef barrier in the juvenile component and the presence of highly vesiculated pumices. Sequentially, the fragmented pyroclasts underwent a second, hydromagmatic, fragmentation event at the surface where hot pyroclastic material encountered liquid water, producing very fine ash and the tuff ring morphology. We suggest that these maars formed through short-lived but intense explosions with transient eruptive columns and diluted PDCs.

763

What is the carbon isotope composition of the mantle beneath Oldoinyo Lengai?

João Lages[1], Guillaume Boudoire[2,3], Andrea L. Rizzo[3,4], Alessandro Aiuppa[1], Valentin Casola[5], Lyderic France[5,6]

[1]DiSTeM - University of Palermo, Palermo , Italy, [2]Université Clermont-Auvergne, CNRS, IRD, OPGC, Laboratoire Magmas et Volcans, Clermont-Ferrand, France, [3]Istituto Nazionale di Geofisica e Vulcanologia, INGV, Sezione di Palermo, Palermo , Italy, [4]Istituto Nazionale di Geofisica e Vulcanologia, INGV, Sezione di Milano, Milano , Italy, [5]Université de Lorraine, CNRS, CRPG, Nancy , France, [6]Institut Universitaire de France (IUF), Paris, France

Recent studies on the carbon cycle in the lithospheric mantle far from typical subduction-related settings emphasize the enrichment of CO2-rich fluids originating from the recycling of carbonate materials. However, whether these products are directly responsible for the formation of carbonatitic melts is still a matter of debate. At present, Oldoinyo Lengai is the only active volcano where carbonatite magmatism occurs. The CO2-rich nature of its lavas poses the question of whether mantle-derived fluids are formed from (i) a typical mantle assemblage; or (ii) an unusual carbon-rich mantle source. Olivine and clinopyroxene phenocrysts from 2007 erupted products exhibit a very large compositional range (Mg# in olivine and clinopyroxene between ~80-94 and ~48-97, respectively), and markedly distinguish shallow and deep cumulate enclaves, from mantel xenoliths. Isotopically, however, our new dataset shows little variability across our sample group. 3He/4He ratios yield averages of 6.3 (n=8) and 6.5 RA (n=6) in olivine and clinopyroxene, respectively. These are in the range of previously reported helium isotope ratios in Oldoinyo Lengai fumaroles and mineral inclusions and are characteristic of a sub-continental lithospheric mantle in which the recycling of U-Th-bearing crustal materials is responsible for lowering the 3He/4He of typical DMM mantle. Carbon isotope analysis (n=4) of fluid inclusions in clinopyroxene phenocrysts suggest heavier δ13C signatures at the depth of the main magma reservoir (20-25 km). Clues from CO2/Ar ratios, which increase towards shallower ponding regions, denote the crucial role of magmatic degassing in the lighter carbon isotope compositions (down to -5‰) measured at depths of ~5 km. This line of evidence opens new discussions on the possible presence of a recycled carbonate component below this sector of the East African Rift Valley and contributes new information on the genesis of Oldoinyo Lengai carbonatites and the complex chemical and isotope heterogeneities amongst geochemical reservoirs on Earth.

768

Shallow magma degassing drives long-term volcanic unrest at Nevado del Ruiz.

João Lages[1], Zoraida Chacón[2], Julian Ramirez[2], Alessandro Aiuppa[1], Santiago Arellano[3], Marcello Bitetto[1], Julián O. Peña[2], Diego Coppola[4], Marco Laiolo[4], Francesco Massimetti[4], Carlos Laverde[2], Lina Castaño[2], Giancarlo Tamburello[5], Gaetano Giudice[6], Cristian Lopez[2]

[1]DiSTeM, University of Palermo , Palermo , Italy, [2]SGC - Observatorio Vulcanológico y Sismológico de Manizales, Manizales, Colombia, [3]Department of Space, Earth and Environment, Chalmers University of Technology, Gothenburg, Sweden, [4]DST - University of Turin, Turin , Italy , [5]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Bologna, Bologna , Italy , [6]Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo, Catania, Italy

In 2018 a MultiGAS station was installed at Nevado del Ruiz (Colombia), providing daily volcanic gas compositions of the main plume. Here, those measurements are coupled with SO2 flux data acquired by the NOVAC network, and satellite thermal emissions derived from MIROVA to evaluate the role of magma degassing as a crucial driver of the current unrest at Nevado del Ruiz. CO2/ST ratios up to 7.7 likely reflect the input of CO2-rich fluids from a deeper, less-evolved magma source. The hypothesis of two distinct magmas in play beneath Nevado del Ruiz was tested by modelling our volcanic gas compositions within the wide range of SiO2 and volatile contents (H2O, CO2 and S) reported for 1985 and 1989 erupted products. The volatile saturation code shows that in open-system conditions the CO2/ST ratio varies more drastically upon pressure decrease, which may justify the CO2/ST upper range (7.7) at pressures of approximately 40 MPa (~2 km depth). Contrarily, decreasing CO2/ST ratios are better fitted to a closed-system model, with such conditions yielding a highly confined range of volatile exsolution depths (~0-20MPa), most probably representative of the degassing of the top of the magma column. The gas is efficiently transferred through the conduit system given that less than 1% of the intruded magma reaches the surface (Vsupplied >> Vthermal >> Verupted). Additionally, the lack of deformation supports that counterflows of ascending non-degassed and descending degassed magma, which coexist in the volcanic conduit, are responsible for the continuous exchange of magma between the 1-3 km-deep reservoir and the top of the conduit. Occasional inputs of volatile-rich magma (high CO2/ST ratios) from deep may disturb normal rates of shallow magma convection and cause conduit overflow, resulting in the dome extrusion events recorded in this study between 2018 and 2021.

397

Acoustic observations and analysis of the 2021 eruption of Fagradalsfjall, Iceland

Oliver Lamb[1,2], Julia Gestrich[3], Talfan Barnie[4], Kristín Jónsdóttir[4], Cécile Ducrocq[5], Michael Shore[1], Jonathan Lees[1], Stephen Lee[6]

[1]University of North Carolina at Chapel Hill, Chapel Hill, USA, [2]Te Pū Ao - GNS Science, Taupō, New Zealand, [3]University of Alaska Fairbanks, Fairbanks, USA, [4]Icelandic Met Office, Reykjavik, Iceland, [5]University of Iceland, Reykjavik, Iceland, [6]Army Research Office, Durham, USA

The 2021 eruption of Fagradalsfjall in south-west Iceland provided a rare opportunity to observe and describe eruptive activity from a persistent fissure event. The eruption, which began on 19th March, initially featured strombolian activity across multiple vents. After 2nd May, activity became focused at one vent which displayed highly periodic lava fountain eruptions for approximately 6 weeks. This was followed by an extended period of pulsating effusive activity punctuated by temporary pauses of up to a week, before the eruption halted in early September 2021 and lava flows had covered an area of approximately 4.8 km2. Here we describe key observations and analysis conducted on acoustic data recorded by a four-element infrasound microphone array deployed 800 m from the vents. We investigated the characteristics of the acoustics during the various eruptive phases and compared them with complementary geophysical and observational data in order to illustrate the nature of the acoustic sources, with a particular interest on the acoustics generated during the repetitive lava fountaining. We observed a complex eruptive sequence during each lava fountain event: acoustic tremor during peak fountaining was followed by Strombolian-style activity with distinct high-amplitude impulsive waveforms. Quantitative comparisons to jet noise spectra finds complex turbulence acoustics during each event, with evidence of variations in the wavefield centred on peak lava fountain heights. Strombolian explosions could mostly be modelled by oscillations of bursting gas slugs, with a minor number of events exhibiting Helmholtz resonance behaviour instead. We find an increase in bubble radii between early and late May, suggesting a widening of the upper conduit during the lava fountain sequence. Acoustic recordings of basaltic fissure eruptions are rare and this study demonstrates their value in providing insights into the dynamics of high-velocity multiphase volcanic eruptions.

640

Development of permeability anisotropy in externally loaded sintering volcanic systems

Dr Anthony Lamur[1], Dr Fabian B. Wadsworth[2], Dr Jackie E. Kendrick[1], Prof Yan Lavallée[1], Doctor Jérémie Vasseur[1]

[1]Department of Earth and Environmental Sciences, Ludwig Maximillian University, Munich, Germany, [2]Department of Earth Sciences, Durham University, Durham, United Kingdom

Sintering of pyroclasts is inherent to volcanic systems: pyroclasts may weld, for example, during transport, at conduit margins, in tuffisite veins, or during and after deposition from pyroclastic density currents (PDCs), forming rheomorphic flows. This phenomenon affects the evolution of permeability as loosely packed pyroclasts in a gas phase progressively evolve into isolated pores surrounded by a molten matrix. In recent years, sintering has been explored at isotropic conditions, whereby the surface tension controls densification and the resultant pore geometry that controls permeability. In contrast, the evolution of permeability of sintering systems under anisotropic conditions (i.e., under an applied differential stress) has received less attention. Here, we characterise the degree and development of permeability anisotropy in samples sintered under differential stress. Samples of sintered glass beads of controlled porosity were prepared, and then heated to 660 ˚C, after which a constant uniaxial stress (> 130 kPa) was applied for different durations. Subsequently, gas permeability, both parallel and perpendicular to the applied stress, was measured and micro-structures were imaged and analysed, to quantify the anisotropy development. We find that in the presence of a high applied stress: (1) overall sintering rates (~porosity reduction rates) increase relative to the surface tension dominated regime; and (2) anisotropic textures develop, with pores elongated perpendicular to the applied stress. Such fabrics cause anisotropy of permeability. In volcanic systems, the development of such textural anisotropy will govern the overall rheology of the deposit, as well as impacting the outgassing directionality and rate. Our results suggest that we must account for the impact of anisotropic stress fields on the sintering process when considering porosity-permeability evolution of densifying granular systems such as tuffisites or PDCs.

641

The influence of earthquakes on volcano stability

Dr Anthony Lamur[1], Dr Jackie E. Kendrick[1], Dr Lauren Schaefer[2], Prof Yan Lavallée[1], Prof Ben M. Kennedy[3]
[1]Department of Earth and Environmental Sciences, Ludwig Maximillian University, Munich, Germany, [2]U.S. Geological Survey, Golden, United States, [3]School of Earth and the Environment, University of Canterbury, Canterbury, New Zealand

Mechanical oscillations are a common manifestation of volcanic and tectonic processes (e.g., earthquakes swarms caused by magma migration and tectonic earthquakes); however, their influence on the evolution of unstable masses such as volcanic edifices and their properties (e.g., strength, permeability) remain poorly explored and understood. The variations in stress, and resultant strain, imposed by earthquakes may manifest in lowering the rock mass cohesion by reducing its fatigue limit and in modifying its permeability, thus potentially impacting volcano structural integrity. Here, we simulate the stress cycles experienced during earthquakes to investigate how damage accumulates as a result of mechanical oscillations. We prepared a suite of 27 andesitic samples from Colima volcano, Mexico and subjected them to 3 different test types: 1) uniaxial compressive strength (UCS) tests to constrain the average rock strength; 2) 6h-long creep deformation tests at 60, 65 and 70% of the estimated UCS; and 3) 6h-long creep deformation tests at the aforementioned conditions with the addition of a series of 15 mechanical “earthquake” oscillations (of ±2.5, 5.0 and 7.5% of the creep condition) at regular intervals. We found that as the intensity of creep increases, the amount of inelastic strain (damage) increases as micro-fractures nucleate, propagate and coalesce. We also further demonstrate (and quantify) that mechanical oscillations amplify damage in rocks otherwise subjected to creep deformation. We surmise that the additional damage caused by such mechanical oscillations may be sufficient to enhance the mechanical weakening and lower slope stability. Additionally, it can create permeable damage zones that impact hydrothermal activity by redistributing pore pressure that could potentially lead to periods of volcanic unrest.

536

Volcanic Tsunamis: bringing together experimental and numerical studies to better understand their near-field effects.

Dr Emily Lane[1], Dr William Power[2], Dr Colin Whittaker[3], Prof James White[4], Dr Stephane Popinet[5], Dr Paraskevi Nomikou[6], Dr Yaxiong Shen[3], Dr Lily Battershill[3], Mr Matthew Hayward[3], Ms Natalia Lipiejko[3]
[1]NIWA Taihoro Nukurangi, Christchurch, Aotearoa New Zealand, [2]GNS Science, Avalon, Aotearoa New Zealand, [3]Department of Civil and Environmental Engineering, University of Auckland, Auckland, Aotearoa New Zealand, [4]Department of Geology, University of Otago, Dunedin, Aotearoa New Zealand, [5]Institut Jean le Rond d'Alembert, CNRS & Sorbonne Université, Paris, France, [6]Dept. Of Geology and Geoenvironment, University of Athens, Athens, Greece

The 2022 eruption of Hunga Tonga–Hunga Ha'apai (HTHH) and the tsunami it generated was a graphic reminder of the power of volcanic tsunamis. While the volcanic meteotsunami (measured around the globe) was the most far-reaching, the near-field tsunami caused runup exceeding ten metres on several islands in the Tongan archipelago. This near-field tsunami was undoubtedly driven by multiple volcanic tsunami mechanisms including submarine explosive eruptive bursts, pyroclastic density currents (PDCs) generated by column collapse and the near-field pressure anomaly. Flank and caldera collapse may have also contributed. Understanding volcanic tsunami mechanisms is an important step in protecting people and communities from their effects. This is not a simple task as volcanic eruptions, especially submarine volcanic eruptions, are difficult to measure in ways that reveal their tsunamigenic potential. Even in the case of HTHH (probably the best measured volcanic tsunami in the world), the timeline of the eruption is not obvious. Likewise, volcanic tsunamis are infrequent, making collecting field data even more difficult.

While we cannot set off volcanoes in the lab, idealised physical and numerical experiments can increase our understanding of volcanic-tsunami mechanisms, and the size and characteristics of the waves they generate. This, in turn, can help us understand the hazards they pose. This presentation reports on the results of a 4-year project which studied volcanic tsunamis using both laboratory experiments and numerical modelling to understand how explosive submarine volcanoes and PDCs generate tsunamis. These include an in-depth look at PDCs generating tsunami waves, including the transfer of energy into waves and the factors that influence wave heights. We also consider the essential physics numerical models must capture to correctly simulate volcanic tsunamis and consider field-scale scenarios of potential volcanic tsunamis in Lake Taupō (a volcanic caldera and the largest lake in the North Island of New Zealand).

1043

New DTi (quartz-melt) thermometer applicable to rutile-free rhyolites: Ti-rich quartz rims in Late Bishop Tuff reflect cooler (not hotter) temperatures

Professor Rebecca Lange[1], Dr. James Jolles, Dr. Owen Neill, Dr. Juliana Mesa, Bryanne Gordon, Mackenzie Taylor
[1]*University of Michigan, Ann Arbor, United States*

Quartz phenocrysts are common in high-SiO2 rhyolites and resist post-eruptive weathering, which makes quartz an excellent phase for thermometry. Previous researchers have experimentally calibrated an effective thermometer (TitaniQ), based on the standard state reaction, TiO2 (quartz) = TiO2 (rutile). The high-entropy side of the reaction (favored by increasing temperature) is TiO2 in quartz, which is confirmed by negative fitted standard state ΔH° and ΔS° values of -60.952 (±3.177) kJ/mol and -1.520 (±0.39) J/mol-K (Thomas et al., 2010). While an excellent thermometer to apply to quartz + rutile-bearing assemblages, TitaniQ cannot be applied to rutile-free rhyolites because the standard state reaction is different, namely TiO2 (quartz) = TiO2 (melt). The high-entropy side of the quartz-melt reaction is TiO2 (melt), and thus increasing temperature should lead to a TiO2 decrease in quartz. Here, a quartz-melt Ti-based thermometer was calibrated using high-resolution Fe-Ti two-oxide thermometry applied to thirteen rhyolites from the Long Valley, CA volcanic field (660-800°C). Both temperature and activity of TiO2 were obtained from two Fe-Ti oxides (Ghiorso and Evans, 2008; Ghiorso and Gualda, 2013) and TiO2 concentrations in quartz by analysis (SIMS and microprobe). From the results, a linear fit (R2= 0.97) to ln[XTiO2(qtz)/aTiO2(melt)] versus inverse temperature gives positive ΔH° and ΔS° values for the quartz-melt standard state reaction of 52.184 (±2.196) kJ/mol and 105.0 (±2.2) J/mol-K, opposite the negative values for quartz-rutile reaction. The quartz-melt thermometer recovers Fe-Ti oxide temperatures in Long Valley rhyolites within ≤ ±14 (average ±7) °C. For the Late-type Bishop Tuff samples, which underwent magma mixing, the results show the 2-fold Ti enrichment in quartz rims (~95 ppm) relative to cores (~53 ppm) reflects rim growth at lower temperatures (~700°C) relative to their cores (~770°C), which likely occurred during ascent. These thermometry results account for changes in the activity of TiO2 due to magma mixing.

264

Identifying fluids, faults and fractures: Insights into the post-eruptive period at Nabro volcano, Eritrea from an enhanced machine-learning-based seismic catalogue

Dr Sacha Lapins[1], Prof Michael Kendall[2], Prof Katharine Cashman[3], Mr Kevin Davidson[4], Dr Berhe Goitom[1], Dr Maximilian Werner[1], Prof James Hammond[4], Prof Ghebrebrhan Ogubazghi[5]
[1]University Of Bristol, Bristol, United Kingdom, [2]Oxford University, Oxford, United Kingdom, [3]University of Oregon, Eugene, United States, [4]Birkbeck, University of London, London, United Kingdom, [5]Eritrea Institute of Technology, Asmara, Eritrea

Machine learning models for earthquake phase arrival detection are generating enhanced, high-precision catalogues of seismicity that reveal exceptionally detailed seismogenic processes, such as slow-moving swarm fronts and complex rupture sequences. Here, we present findings from a machine-learning-based catalogue (~34,000 earthquakes over 14 months) for Nabro volcano in Eritrea, an obscure 'off-rift' caldera located in the Afar Triangle that erupted with little warning for the first time in historical record in June, 2011. The eruption is significant for the rarity of recorded historical eruptions along the wider Nabro Volcanic Range (NVR), the vast amount of SO2 emitted, and the humanitarian crisis it triggered. Assessment of moment magnitude distributions, Vp/Vs, seismic attenuation and spatio-temporal trends from this new machine-learning-based catalogue reveal a number of distinct and evolving processes during the study period (3 – 16 months after eruption onset), including stress transfer between Nabro and neighbouring Mallahle caldera, fluid-fault interaction along the axis of the NVR (oblique to regional rift axis), a highly-fractured, partially fluid-saturated zone beneath Nabro, and the migration of fluids above and below a highly-attenuative, aseismic magma storage region. Regular pulses of the deepest observed seismicity (9 – 11 km depth bsl) continue throughout and, presumably, beyond the full duration of this seismic deployment, indicating the potential for ongoing 'recharge' at this currently unmonitored volcano. Other findings include a clear 1:1.5 scaling between local and moment magnitude estimates at magnitudes below ~3.5, consistent with several previous empirical and theoretical studies of small-magnitude seismicity, which leads to strong discrepancies in b-value estimates and subsequent physical interpretations. The rich level of detail presented by this large seismic catalogue demonstrates the effectiveness and efficiency of deep learning models for volcano-seismic monitoring, and that the development of such applications is a readily attainable and worthwhile endeavour.

1451

Final Results of the Hawaii Play Fairway project, a Statewide Geothermal Resource Assessment

Dr. Nicole Lautze[1,2], Dr. Donald Thomas[1,2]
[1]Hawaii Groundwater And Geothermal Resources Center, Honolulu, USA, [2]University of Hawaii, Manoa, Honolulu, USA

Hawaiʻi spends ~$5B USD per year importing fossil fuels and pays ~3x the national average for electricity, yet surprisingly little is known about the state's geothermal resource. Geothermal exploration in the 1970s was concentrated within the most active rift zone of the most active volcano - Kīlauea's East Rift Zone (KERZ) - located on Hawaiʻi Island. Outside of Kīlauea's summit and ERZ, Hawaiʻi's geothermal resources are blind, and previously, little work has gone into exploration of blind resources over the rest of the state. This PFA derived a sophisticated methodology to integrate all data relevant to Hawaiʻi's geothermal resource into a statewide resource probability map in Phase 1, and updated this map with data collected during Phases 2 and 3. The results of the first two project phases are summarized across four publications in the journal Geothermics. This presentation will focus on project Phase 3. Phase 3's main task was to execute a drilling project on Lānaʻi Island. We opted to deepen an existing well proximal to our target area on Lānaʻi due to funding constraints that precluded the spudding of a new well that would exceed 1km depth. Drilling occurred 24/7 the entire month of June 2019, over which time the well 10 was deepened from 427 to 1057m, with continuous core collected. We measured a roughly linear temperature gradient averaging 42°C/km and a maximum bottom hole temperature of 66°C. This gradient is > twice the background for Hawaiʻi and within a range of gradients measured in this depth range for some exploration wells within KERZ. In Phase 3, we also collected updated our thoughts on the probabilities of fluid and permeability at resource depths, ultimately, advocating for using our final probability of heat, and confidence in this probability, to drive the next phase of exploration.

1318

Krafla Magma Testbed (KMT): linking volcanology and geothermal research for future hazard and energy solutions

Professor Yan Lavallée[1], Professor John Eichelberger[2], Professor Paolo Papale[3], Professor Freysteinn Sigmundsson[4], Doctor Philippe Jousset[5], Professor Ben Kennedy[6], Doctor Marlène Villeneuve[7], Professor Donald B. Dingwell[1], Mr. Sigurdur H. Markusson[8], Ms. Anette K. Mortensen[8], Ms. Vordís Eiríksdóttir[8], Doctor Bjarni Pálsson[8], Professor Jeff Tester[9], Professor Sigrún Nanna Karlsdóttir[10], Mr. John Midgley[11], Professor John Ludden[13], Mr. Hjalti Páll Ingolfsson[12], KMT consortium[14]

[1]Department of Earth- and Environmental Sciences, Ludwig Maximillian University, Munich, Germany, [2]International Arctic Research Center, University of Alaska Fairbanks, Fairbanks, USA, [3]Instituto Nazionale di Geofisica e Vulcanologia, Pisa, Italy, [4]Nordic Volcanological Center, Institute of Earth Sciences, University of Iceland, Reykjavík, Iceland , [5]GFZ Potsdam, Potsdam, Germany, [6]School of Earth and the Environment, University of Canterbury, Christchurch, New Zealand, [7]Subsurface Engineering, Montanuniversität Leoben, Leoben, Austria, [8]Landsvirkjun, Reykjavík, Iceland, [9]Cornell University, Ithaca, USA, [10]Mechanical Engineering, University of Iceland, Reykjavík, Iceland, [11]Energy Geoscience, Huddersfield, United Kingdom, [12]GEORG Geothermal Research Cluster, Reykjavík, Iceland, [13]Lyell Centre IGE-EGIS, Heriot-Watt University, Edinburgh, United Kingdom, [14]KMT Consortium, ,

Magmatism generates the strongest heat fluxes in the Earth's crust, powering geothermal resources and volcanic hazards. In 2009, the Icelandic Deep Drilling Project's IDDP-1 serendipitously intersected a 2.1-km deep, rhyolitic magma at Krafla volcano. Whilst this points to our inability to accurately locate magma with current geophysical practices, IDDP-1 has revealed an unprecedented wealth of information as 1) we know where magma is located, 2) the magma quenched rapidly and was not prime to erupt, and 3) near magma flow test reached ~450 °C, generating 5-10 times more energy than the average geothermal well output in in Iceland. This information lends a unique opportunity: we know how and where to drill to access, study, and understand magma.

The Krafla Magma Testbed (KMT) aims to establish the first magma observatory – an international, open access, scientific platform to advance ductile zone to magma research via drilling. This frontier undertaking will enable direct, in situ sampling, instrumentation, monitoring and manipulation of magma and its interface with solid Earth's crust, vastly advancing models of high-temperature crustal processes, in order to develop new volcanic hazard monitoring strategies and next-generation magma energy solutions.
Here we will review key findings of IDDP-1 and recent research that enable the KMT vision, including constraints on magma location, energy potential of magma, and fluid flow in thermally stimulated superhot rocks (400-850 °C). We will present the goal and timeline of this infrastructure, and invite the IAVCEI community to join KMT to advance our understanding of magma.

1317

Conduit permeability evolution resulting from cyclic shifts between compactant shear and dilatant rupture at Unzen volcano, Japan

Professor Yan Lavallée[1], Doctor Takahiro Miwa[2], Mr. James D. Ashworth[3], Doctor Paul A. Wallace[4], Doctor Jackie E. Kendrick[1], Doctor Rebecca Coats[3], Doctor Anthony Lamur[1], Doctor Adrian Hornby[5], Doctor Kai-Uwe Hess[1], Doctor Takeshi Matsushima[6], Professor Setsuya Nakada[7], Doctor Hiroshi Shimizu[7], Doctor Bernhard Ruthensteiner[8], Doctor Hugh Tuffen[9]

[1]Department of Earth- and Environmental Sciences, Ludwig Maximillian University, Munich, Germany, [2]Volcano Research Group, Earthquake Research Department, National Research Institute for Earth Science and Disaster Resilience (NIED), Tsukuba, Japan, [3]Earth, Ocean and Ecological Sciences, University of Liverpool, Liverpool, United Kingdom , [4]Department of Geosciences, Environment and Society, Université Libre de Bruxelles, Brussels, Belgium , [5]Earth and Atmospheric Sciences, Cornell University, Ithaca, USA, [6]Institute of Seismology and Volcanology, Faculty of Sciences, Kyushu University, Shimabara, Nagasaki, Japan , [7]National Research Institute for Earth Science and Disaster Resilience, Tennodai, Tsukuba, Japan , [8]Staatliche Naturwissenschaftliche Sammlungen Bayerns (SNSB), Zoologische Staatssammlung München, Munich, Germany, [9]Earth Sciences, University of Lancaster, Lancaster, United Kingdom

We present a study of the permeability distribution across two conduit shear zones (marginal and central) developed in the dacitic spine that extruded in 1994-1995 at Unzen volcano, Japan. The marginal shear zone is approximately 3.2 m wide and exhibits a 2-m wide, moderate shear zone with porosity and permeability similar to the conduit core, transitioning into a ~1-m wide, highly-sheared region with relatively low porosity and permeability, and an outer 20-cm wide cataclastic fault zone. The low porosity, highly-sheared rock further exhibits an anisotropic permeability network with slightly higher permeability along the shear plane (parallel to the conduit margin) and is locally overprinted by oblique dilational Riedel fractures. The central shear zone is defined by a 3-m long by ~9-cm wide fracture ending bluntly and bordered by a 15-40 cm wide damage zone with an increased permeability of ~3 orders of magnitude. We interpret the permeability and porosity of the marginal shear zone to reflect the evolution of compactional (i.e., ductile) shear during ascent up to the point of rupture, estimated at ~500 m depth via seismic analysis. At this point the compactional shear zone would have been locally overprinted by brittle rupture, promoting the development of a shear fault and dilational Riedel fractures during repeating phases of increased magma ascent rate, enhancing anisotropic permeability that channels fluid flow into, and along, the conduit margin. In contrast, we interpret the central shear zone as a shallow, late-stage dilational structure, which partially tore the spine core with slight displacement. We explore constraints from monitored seismicity and rheological experiments, to evaluate the conditions which accompanied the upward shift from compactional toward dilational shear as magma approached the surface, and discuss their importance in controlling the permeability development of magma evolving from overall ductile to increasingly brittle behaviour during ascent and eruption.

1039

Hydroacoustic monitoring of Mayotte underwater volcanic eruption

Dr Aude Lavayssière[1], Dr. Sara Bazin[1]
[1]IUEM, Brest, France

Mooring networks of autonomous hydrophones is an effective way to monitor the ocean soundscape and its sources, and it is particularly efficient to better understand underwater volcanic eruptions. In October 2020, four continuous hydrophones were moored in the SOFAR channel around Mayotte to monitor a submarine eruption that started in 2018. This eruption created a new underwater volcano at 3500 m below sea level 50 km east of Mayotte Island, in the northern part of the Mozambique Channel. Surrounding the volcano, the hydrophones record sounds generated by the volcanic activity and the first two years of hydroacoustic data evidenced earthquakes, underwater landslides, and impulsive signals that we related to steam bursts during lava flow emplacement. After these preliminary results, an automatic detection of these specific signals is being developed for a better analysis of their source(s) and to better understand their relationship to lava emplacements. The hydroacoustic catalogs obtained characterize the Mayotte volcano activity and will help quantify the risk for the Mayotte population. Our detection will discriminate the broad variety of signals present in the soundscapes and could be used by Mayotte’s and other volcano observatories to monitor active submarine eruptions in the absence of regular seafloor imaging.

1243

Co-designing a new crowdsourcing volcano observation survey, data sharing capacity and public maps for Aotearoa New Zealand:

Miss Rachel Lawson[1], Dr Sally Potter[2], Dr Sara Harrison[1], Dr Danielle Charlton[3], Dr Mary Anne Thompson Clive[1]

[1]GNS Science, 1 Fairway Drive, Avalon, Lower Hutt 5011, New Zealand, [2]GNS Science, 1 Elizabeth Street, Tauranga 3110, New Zealand , New Zealand, [3]GNS Science, 12 Madden St, Auckland 1010, New Zealand ,

Crowdsourced observations about geohazard events can fill monitoring gaps, verify instrumental records, build situational awareness for response agencies and increase public awareness of and participation with science. Efforts to crowdsource hazard impact data about events in Aotearoa include earthquake felt reports, post-event tsunami surveys, and landslide reporting tools, among others.

Here we present a project that aims to develop a coordinated and collaborative approach to collect and share public observations during volcanic unrest and eruptions. Previous approaches to collecting volcanic data using crowdsourcing in Aotearoa have focused on event response data collection. However, these insights can be limited by issues such as geolocation accuracy, slow or delayed data collection (Harrison et al., 2022).

This project builds on the international ash fall observation survey 'Is ash falling?' previously used by the Alaska Volcano Observatory and GNS Science. It follows the vision of better connecting real-time observations about hazards and impacts between the public, scientists, and stakeholders (Potter et al., 2020). It aims to includes multiple volcanic hazards, stages of activity, and potential impact. Using expert elicitation workshops and stakeholder feedback, we are co-developing an online survey template, interactive web maps and data sharing repository using ArcGIS Online. The crowdsourced results will be available to stakeholders in near real time. This poster presents our proposed design, and data sharing workflow, and seek feedback for question design, data needs and software preferences.

Harrison SE, Potter SH, Lawson RV, Griffin A. In prep. Understanding the data management needs for crowdsourcing New Zealand's hazards. GNS Science Report.

Potter, S. H., Harrison, S., Thomas, K.-L., Leonard, G. S., Skilton, J., Apiti, M., Balfour, N. J., Harvey, S., Coomer, M. A Kilgour, G. N. (2020). Connecting real-time hazard and impact data with users: proof of concept of a visualisation tool. GNS Science Report 2020-22. Lower Hutt NZ.

989

Performance and limits of a shallow-water model for landslide-generated tsunamis: from laboratory experiments to simulations of instabilities at Montagne Pelée

Dr Pablo Poulain[1], Professor Anne Le Friant[1], Professor Anne Mangeney[1], Dr Sylvain Viroulet[1,2], Professor Enrique Fernandez-Nieto[3], Professor Manuel Castro-Diaz[4], Dr Marc Peruzzetto[1,5], Professor Gilles Grandjean[5], Professor François Bouchut[6], Dr Rodrigo Pedreros[5], Professor Jean-Christophe Komorowski[1]
[1]Université Paris Cité - Institut de Physique du Globe de Paris, Paris, France, [2]Institut de Mécanique des Fluides de Toulouse (IMFT) - Université de Toulouse, Toulouse, France, [3]Dpto. Matematica Aplicada I, ETS Arquitectura - Universidad de Sevilla, Sevilla, Spain, [4]Departamento de Analisis Matematico, Estadística e Investigación Operativa y Matemática Aplicada. Universidad de Malaga, , Spain, [5]BRGM, , France, [6]Laboratoire d'Analyse et de Mathématiques Appliquées, Université Gustave Eiffel, Marne-la-Vallée, France

We investigate the dynamics and deposits of granular flows and the amplitude of landslide-generated water waves using the HySEA depth-averaged shallow-water numerical model, both at laboratory and field scales. We evaluate the different sources of error by quantitatively comparing the simulations with (i) new laboratory experiments of granular collapses in different conditions (dry, immersed, dry flow entering water) and slope angles and (ii) numerical simulations made with the SHALTOP code that describes topography effects better than most depth-averaged landslide-tsunami models. For laboratory configurations, representing the limits of the shallow-water approximation in such models, we show that topography and non-hydrostatic effects are crucial. When topography effects are accounted for empirically - by artificially increasing the friction coefficient and performing non-hydrostatic simulations - the model is able to reproduce the granular mass deposit and the waves recorded at gauges located at a distance of more than 2-3 times the characteristic dimension of the slide with an error ranging from 1% to 25% depending on the scenario, without any further calibration. Taking into account this error estimate, we simulate landslides that occurred on Montagne Pelée volcano, Martinique, Lesser Antilles as well as the generated waves. Multiple collapse simulations support the assumption that large flank collapses on Montagne Pelée likely occurred in several successive sub-events. This result has a strong impact on the amplitude of the generated waves and thus on the associated hazards. In the context of the ongoing seismic volcanic unrest at Montagne Pelée volcano, we calculate the debris avalanche and associated tsunamis for two potential flank-collapse scenarios.

312

Remote mapping of basaltic lava flow morphologies using LiDAR: Preliminary results from the Tseax lava flow, British Columbia, Canada

Dr Yannick Le Moigne[1], Pr. Glyn Williams-Jones[1], Dr. Jeffrey Zurek[2], Sarah Aufrère[1]
[1]Simon Fraser University, Burnaby, Canada, [2]Initial Exploration, Vancouver, Canada

The surface morphologies of lava flows are controlled by their emplacement mechanisms. Indeed, while platy pāhoehoe lavas are formed when the shear rate is low, rubbly pāhoehoe result from higher shear rates. This work aims to provide a method for remotely identifying basalt lava flow morphologies based on their surface roughness. The ~1700 CE eruption of Tseax volcano, a monogenetic cone located in British Columbia, Canada, produced a 0.5 km³ basanite to trachybasalt lava flow field including a ~25 km² lava plain with surface morphologies typical of an inflated pāhoehoe (e.g., lava rises, hummocky, slabby, platy, rubbly pāhoehoe). This lava flow has undergone negligible post emplacement erosion, making it an excellent site to quantify and classify surface morphologies. Using ArcGIS, a DEM with a consistent resolution of 1 m was derived from high resolution LiDAR data. Flow morphology classification is tested using different surface roughness indices including aspect ratio (AR), residual topography, terrain ruggedness, topographic position index, and RMS height or Hurst exponent. Standard deviation of these surface roughness indices is performed within a moving window with size ranging from 1 × 1 m to 20 × 20 m across homogeneous surface morphologies of at least 0.04 km². Using Matlab, histograms of roughness are computed, and their moments of distribution (mean, standard deviation, skewness, and kurtosis) are compiled for the different moving window sizes. Our preliminary results show that the different lava morphologies present distinctive and characteristic moments of distribution for the considered window sizes. For example, we estimate that platy pāhoehoe, indicating high eruption rates, presents AR indices 1-3 order of magnitudes higher than other surface morphologies. Such characteristic moments of distribution will allow remote mapping and characterization of older lava flows on Earth (e.g., Carrizozo, Craters of the Moon), leading to new insights on their emplacement mechanisms.

914

Trace metal variations in volcanic glasses across a subduction zone: Melt inclusion and groundmass glasses from the southern Kermadec arc

Mr Jacob Leath[1], Dr Monica Handler[2], Dr Richard Wysoczanski[3], Dr Ian Schipper[2], Dr Christian Timm[1]
[1]GNS Science, Wellington, New Zealand, [2]Victoria University of Wellington, Wellington, New Zealand, [3]NIWA, Wellington, New Zealand

Hydrothermal mineralization, such as volcanogenic massive sulfide (VMS) deposits, are notable features of volcanic arcs and are characterised by high concentrations of base and precious metals (e.g., Au, Cu, Zn, Pb). Metal contents of VMS deposits are in part tied to metal contents within underlying magmatic systems, but the controls on the metals in arc lavas remains poorly constrained. This study reports major, trace, and volatile element concentrations in basaltic groundmass glasses and olivine-hosted melt inclusions from lavas from four locations within the southern Kermadec Arc – Havre Trough (KAHT) back-arc. The sample locations span a broad arc-perpendicular transect extending from the arc front into the back-arc that permits evaluation of geochemical spatial heterogeneity. Base metals (Cu, Zn, Pb, Mo, and V) are variably enriched in the southern KAHT melts compared with typical mid-ocean ridge basalts with relative enrichments in the order Pb >> Cu > Mo, V > Zn. Lead, and to a lesser extent Cu and Mo, can be enriched in the source by hydrous shallow subduction components. Vanadium and Zn are mobilized from the mantle wedge either because of higher oxygen fugacity and/or higher degrees of partial melting (caused by the addition of aqueous fluids). Glass chemistry indicates that variations in source compositions can be as significant along the strike of the trench, as they are perpendicular to the trench. Furthermore, single volcanoes can tap compositionally distinct sources, reflecting both relatively enriched and depleted mantle melts with variable subduction-related enrichments. Although other factors such as heat, magmatic longevity, hydrothermal flow, fault systems, and magma venting are key in the development of VMS deposits, this study shows that variations in subduction parameters can significantly affect metal concentrations in arc magmas and the associated volcanic rocks that may host hydrothermal system.

1423

Access to Multi-disciplinary Volcanological Data: The Volcano Portal at the Interdisciplinary Earth Data Alliance (IEDA)

Dr Kerstin Lehnert[1], Neville Shane[1], Lucia Profeta[1]
[1]*Lamont-Doherty Earth Observatory, Columbia University, Palisades, United States*

Volcanology is inherently interdisciplinary. Many disciplines that generate different types of observations contribute to research into the processes that create and shape volcanoes and the impact they have on the environment, on physical infrastructure, and on human lives. Volcanologists therefore need to access a wide range of different data types that are curated in independent, distributed data systems. We here present the In 2015, the Interdisciplinary Earth Data Alliance IEDA developed the DECADE (Deep Carbon Degassing) Portal with support from the Deep Carbon Observatory as a powerful search engine that allows researchers to simultaneously access data in multiple data systems that store and manage data for volcanoes, including the Smithsonian Institution's Global Volcanism Program database (VOTW) of volcanic activity data, the EarthChem Library and the EarthChem Portal (geochemical data for volcanic rock samples), the System for Earth Sample Registration that catalogs samples collected from volcanoes (rocks, gases, tephra, etc.), and the MaGa database, which contains compositional and flux data of gases released at volcanic and non-volcanic degassing sites.

Since 2020, the Community Network for Volcanic Eruption Response (CONVERSE), an NSF-funded Research Coordination Network, has supported the expansion of the DECADE Portal into the Volcano Portal, with additional data types becoming accessible via the portal, including earthquake data from IRIS, LIDAR data from OpenTopography, and various types of time-series data from UNAVCO. New functionality has been added to allow users to define locations (polygons), for which they want to access data available at the participating data systems. This presentation will demo the current functionality and describe the vision for the future volcano portal.

457

Spectral, geochemical and biological investigations of gossans in the Canadian Arctic as analogs to potential biosignature-preserving formations on Mars

Professor Myriam Lemelin[1], Marie-Claude Williamson[2], Richard Léveillé[3], Stéphanie Lachance[1], Éloise Brassard[1], Hiba Aoid[3], Cassandra Marion[4], Sean Clark[5]
[1]Université de Sherbrooke, Sherbrooke, Canada, [2]Geological Survey of Canada, Ottawa, Canada, [3]McGill University, Montreal, Canada, [4]Canada Aviation and Space Museum, Ottawa, Canada, [5]Sacred Heart High School, Stittsville, Canada

The T-MARS project, Terrestrial Mineral Analysis by Remote Sensing, aims to study reactive gossans in the permafrost as an analogue to similar formations that could be found on Mars. Gossans are the weathered superficial expression of underlying sulfide intrusions. They are of high interest as they can host life on Earth and, if formed on Mars, could potentially have recorded microbial activities that occurred in the past and the environment in which they developed. Minerals such as jarosite, present in many gossans, and which preserves these records, degrades in humid and warm climate. Studying gossans in the permafrost is thus key to understand the role they can play in the preservation of biosignatures on Earth and on present-day Mars.

The T-MARS project involves (1) the analysis of remote sensing imagery of volcanic landscapes to identify gossans and the surrounding geological formations (remote predictive mapping), (2) sampling and spectral analysis of gossans in the field and the validation of the remote predictive map, and (3) the spectral, geochemical and biological analysis of returned samples in the laboratory.

Here we report the results of fieldwork carried out on Axel Heiberg Island, Nunavut, in July 2022. The analysis of WorldView and PRISMA imagery has enabled us to generate a remote predictive map of the area and identify gossans prior to the field campaign. During the field campaign, we ground truthed the predictive, identified previously unreported lithologies, and refined the local extent and attributes of mapped bedrock. The diversity of the field site allowed us to investigate gossans in different environmental settings (e.g., perennial spring, paleohydrothermal system, gypsum diapir). The spectral, geochemical and biological characteristics of the returned samples will be discussed in the context of comparative studies of gossans on Earth and Mars.

784

Volcanic ash aggregation and settling-driven gravitational instabilities: nonlinear simulations using the Lattice Boltzmann method

Dr Jonathan Lemus[1,2], Dr Allan Fries[1], Dr Eduardo Rossi[1], Pr Costanza Bonadonna[1], Pr Jonas Lätt[2], Pr Bastien Chopard[2]
[1]Department of Earth Sciences, University Of Geneva, Geneva, Switzerland, [2]Department of Computer Science, University of Geneva, Geneva, Switzerland

Explosive volcanic eruptions inject large quantities of volcanic ash particles (tephra) in the atmosphere. The dispersion and sedimentation of tephra represent a serious threat to communities, as it can notably affect human health, damage infrastructure, pollute ecosystems, and paralyse economic and transport sectors. Several field observations have shown how tephra often sediments collectively in the form of particle aggregates and/or within ash fingers generated by settling-driven gravitational instabilities (SDGIs). On the one hand, volcanic ash aggregation occurs after the collision of several particles, resulting in the clustering into bigger structures. On the other hand, particle settling across the lower interface between the volcanic cloud and the atmosphere leads to the development and detachment of an unstable boundary layer, forming downward-moving ash columns called fingers. Both processes can increase particle settling velocities and enhance the premature sedimentation of fine ash. Although they have similar impact on tephra fallout, and have been observed to occur simultaneously, interactions between these processes have not been addressed.

We have developed a 3D model able to simulate the collective settling of volcanic ash, by coupling a Lattice Boltzmann scheme, which solves the fluid motion, with a Weighted Essentially Non Oscillatory (WENO) finite difference scheme, which simulates the particle transport. We consider a configuration consisting of a buoyant ash layer overlaying a denser ambient, allowing the formation of the unstable boundary layer that generates fingers. The ash layer contains several particle size bins in order to study the effect of aggregation that is included through source and sink terms determined by implementing the Smoluchowski coagulation equation. Results reveal the presence of mutual interactions between particle aggregation and SDGIs. Indeed, ash aggregation tends to enhance the sedimentation rate associated with SDGIs while the turbulence generated inside fingers promotes ash aggregation.

1456

High-resolution mapping and geochronology of the Taupō Volcanic Zone (TVZ)

Dr Graham Leonard[1], Dr Andrew Calvert[2], Prof Colin Wilson[3], Prof Bruce Houghton[4], Dr Dougal Townsend[1], Dr Chris Conway[5], Dr Leo Pure[6], Kate Mauriohooho[3], Dr Marvin Lanphere[2], Assoc Prof Darren Gravley[7], Dr Drew Downs[8], Dr Pilar Villamor[1], Dr Michael Rosenberg[9], Dr Bruce Charlier[3]

[1]GNS Science, P.O. Box 30-368, Lower Hutt, New Zealand, [2]U.S. Geological Survey, California Volcano Observatory, 345 Middlefield Road, Menlo Park, USA, [3]School of Geography, Environment and Earth Sciences, Victoria University, P.O. Box 600, Wellington, New Zealand, [4]Department of Geology and Geophysics, SOEST, University of Hawai'i, 1680 East-West Road, Honolulu, USA, [5]Volcanic Activity Research Group, Geological Survey of Japan, AIST, Central 7, 1-1-1 Higashi, Tsukuba, Japan, [6]Environment Approvals Division, Department of Climate Change, Energy, the Environment and Water, PO Box 787, Australia, [7]Department of Geological Sciences, University of Canterbury, Private Bag 4800, Christchurch, New Zealand, [8]U.S. Geological Survey, Hawaiian Volcano Observatory, 1266 Kamehameha Avenue, Hilo, USA, [9]GNS Science, Private Bag 2000, Wairakei, New Zealand

We summarise results and discoveries obtained from more than 200 40Ar/39Ar ages combined with two decades of mapping for the QMAP regional geological mapping programme (1:250,000 scale), the Geology of Tongariro National Park map (1:60,000 scale) and the Geology of Taupō Volcanic Zone Area map (1:130,000 scale) underpinned by dozens of journal publications. These data shed light on the tempo, style, and hazards of volcanism at all scales from the four largest supereruptions (Ongatiti, Kidnappers, Whakamaru, Ōruanui) to the frequent smaller magmatic (millennial to decadal frequency) and hydrothermal (decadal) eruptions.

In the southern end of the TVZ, Ruapehu and Tongariro have been recently revealed as substantially glacially-controlled stratovolcanoes due to coincident glaciation and volcanism through most of their histories. These two centres appear to act magmatically and eruptively independently of one-another, and with little coincidence to magmatism and volcanism to the vast Ahi Tupua, central TVZ, to the north. Ahi Tupua can be considered in terms of its overall evolution as a single rhyolitic caldera complex of comparable longevity and scale to Yellowstone. It also has the largest time-averaged eruption rate on the planet since ~27 ka. There appears to be not only spatial but also temporal clustering of smaller explosive and effusive eruptions around caldera-forming events, as well as some unrelated to these largest events.

Mapping and correlating volcaniclastic deposits have been critical to better understanding and interpreting the full history of volcanism. The vast ring plain around Ruapehu and Tongariro comprises the majority of preserved erupted material. To the north, rates of post-caldera volcanic and sedimentary infilling are remarkably rapid (kilometres thick in >10,000 years) and the distal landscape response to sedimentation has been equally dramatic. Work on the offshore volcanoes of Tuhua Mayor Island and Whakaari White Island at the northern end of the TVZ is ongoing.

519

Assessing the ore-forming potential of adakites via melt inclusion analysis

Mr Timothy Leong[1], Professor John Mavrogenes[1], Professor Richard Arculus[1]
[1]*Australian National University, Harrison, Australia*

Most commercially available copper is sourced from porphyry copper deposits (PCDs), which have commonly been linked – albeit tenuously - to adakites (andesitic rocks with high La/Yb, Sr/Y). Intrinsic predisposition for adakite magmas to form PCDs is invoked on grounds of spatial/temporal association. Adakitic magmas represent the product of partial melting of subducted, hydrothermally-altered mafic crust within the eclogite stability field, generating oxidized andesitic magmas with garnet geochemical signatures. Alternate formation models are typically compromised by use of whole-rock compositions (as opposed to melt inclusions), leading to spurious invocation of partial melting of lower crustal, garnet-bearing sources or extensive intra-crustal amphibole fractionation. Here we utilize adakitic glass (formerly) melt inclusions from submarine volcanoes in the southern New Hebrides arc to investigate processes relevant to the generation of PCDs. These inclusions are oxidized (+1.9 to +3.2 ΔFMQ) relative to most island arc and all mid-ocean ridge basalts, H2O-S-Cl-rich, and moderately enriched in Cu. The sulfur is likely present as dissolved sulfate. Inclusion H2O/Ce as well as host mineral two-pyroxene geothermometry give temperatures of 900-1000°C±20°C, consistent with uppermost subducted slab melting. Additionally, we demonstrate that chondrite-normalized polynomial fitting of rare earth element abundance patterns clearly discriminate between the various potential REE-fractionating phases in fractional crystallisation and melt-residue partitioning. We establish the adakite precursor melts were unequivocally derived from the partial melting of subducted slab, and subsequently experienced further garnet fractionation. Although these observations do not in and of themselves prove a causal connection between adakites and PCDs, their compositional characteristics render them excellent candidates for PCD formation, and highlights the importance of analysing glass/melt inclusions rather than whole rocks, which are not equivalent to melt compositions.

622

Spatial and temporal evolution of lava effusion rate and rheology recorded in the 2018 Kīlauea fissure 8 lava channel

Jasper Baur[1], Dr Einat Lev[1], Janine Birnbaum[1], Brenna Halverson[2], Dr Hannah Dietterich[3], Dr Alan Whittington[2], Dr Julia Hammer[4], Dr Edward Llewellin[5]

[1]Lamont Doherty Earth Observatory, New York, United States, [2]University of Texas at San Antonio, San Antonio, United States, [3]USGS, Anchorage , United States, [4]Univeristy of Hawaii at Manoa, Manoa Valley, United States, [5]Durham University, Durham , UK

The 2018 Kīlauea lower East Rift Zone (KLERZ) eruption emplaced 1.4 km^3 of lava, causing significant damage to local communities. The fissure 8 vent (Ahuʻailāʻau) was responsible for the majority of the lava effusion and was active from late May to early August. To understand the spatiotemporal variability in flow dynamics during the eruption, we extract detailed surface velocities from >200 syn-eruptive videos taken above the main lava channel by uncrewed aerial vehicles (UAV). We solve Jeffreys equation to infer viscosity and find that effective viscosity increases linearly with distance from the vent at a rate of 500 Pa s / km in response to textural evolution and cooling. We observe an apparent scaling relationship of the local maximum lava velocity Vmax ~(ρg(h^2)sin(α))/D, D is vent distance, h is flow depth, and ρ(D) is lava density derived from the measured vesicularity of samples from the flow. We compare this model to the thermo-rheological model PyFLOWGO and find that PyFLOWGO cannot match the observed velocities unless modified to account for changes in density with distance.

The temporal variability of the fissure 8 lava flow velocities is dominated by surges in effusion that have been linked to near-daily cyclic collapse events of Kīlauea's summit caldera. The surges are characterized by a few-hour period of steep acceleration reaching peak volumetric flux >2 hours after the caldera collapse (depending on distance from the vent), followed by a gradual deceleration that could last over 40 hours. We model surges as a pressure diffusion problem allowing us to hindcast the timing and location of channelized lava overflows driven by transient increases in volumetric flux following a caldera collapse. Quantifying the controls of the 2018 KLERZ lava flow velocities and rheology, along with understanding the propagation of surges, can help with hazard mitigation for future effusive eruptions.

598

VICTOR – A new Cyber-infrastructure for Volcanology

Dr Einat Lev[1], Sam Krasnoff[1], Dr. Abani Patra[3], Dr. Charles Connor[2], Dr. Sylvain Charbonnier[2], Laura Connor[2]
[1]Columbia University, Palisades, United States, [2]University of South Florida, Tampa, USA, [3]Tufts University, Medford, USA

Forecasting the impact of active or future volcanic eruptions and correctly interpreting the remnants of past eruptions requires access to models of eruptive processes. The volcano modeling community recognizes a need for more equitable access to robust, verified, validated, and easy-to-use models. To answer this need, we are building VICTOR (Volcanology Infrastructure for Collaboration, Tools, and Resources), a new cyberinfrastructure for the volcano modeling community. To date, we have established a steering committee that advises the development team on community needs and best practices. VICTOR is connected with larger, national efforts including CONVERSE and SZ4D's Modelling Collaboratory for Subduction (MCS). We formed a collaboration with a non-profit organization (2i2c, part of Code for Science and Society) that will manage VICTOR's back-end in the form of a JupyterHub placed in the cloud. We are now developing Jupyter notebooks for the hub, that call existing volcano models such as the lava flow code MOLASSES, the tephra dispersal code Tephra2, and the pyroclastic flow code TITAN2D.

VICTOR will not only provide access to the modeling tool themselves, but also to workflows that utilize these forward models for inversion, benchmarking, and uncertainty quantification. For example, we augmented a workflow for assessing forecasts of volcanic ash transport and dispersal using the PUFFIN tool using remote sonde data and will transfer this workflow to VICTOR once it is ready. We also explored the use of surrogate models based on convolutional neural networks for debris flow computations and uncertainty analysis using the TITAN2D model. To ensure continuity of service for our community, during the transition to VICTOR, the existing Vhub.org platform is still available, as a stub group inside a separately supported new ghub.org. Lastly, we plan on teaching a graduate-level multi-institutional course on volcanic hazard modeling using VICTOR and creating multilingual tutorials for the workflows.

596

Controls of eruption cycles at geysers – insights from laboratory experiments and numerical models

Dr Einat Lev[1], Akshat Yaparla[1], Dr. Max Rudolph[2], Uthkarsh Das[2], Dr. Rob Sohn[3]
[1]Columbia University, Palisades, USA, [2]University of California -- Davis, Davis, USA, [3]Woods Hole Oceanographic Institute, Woods Hole, USA

Geysers are hydrothermal features that are often characterized by the periodic eruption of steam and water plumes. The factors that control the magnitude and frequency of eruptions, including the size and shape/geometry of the subsurface conduits, and the thermal balance between the flux of fluids and heat into the system vs. heat lost to the host rock and the atmosphere, are difficult to observe in natural systems. As a result, the relationship between eruption intervals and sizes with subsurface processes is unclear. Improving our understanding of these relationships can contribute to our understanding of plumbing, mass transport, and eruptions at volcanoes, given the similarities between the systems.

We present results from experiments in a large analog lab geyser setup where we trigger multiple consecutive eruption cycles by the addition of water, heat, and steam, at various combinations and at different reservoir-conduit geometry settings. Our system is unique compared with past geyser models as it includes a continuous addition of steam as well as a bubble trap geometry, which was recently identified at multiple natural geysers.

We analyze pressure and temperature data as well as video to relate inputs and outputs into/from the system and complement the experimental results with a numerical model of the energy in the system that captures the phase transitions between water and steam and the bubble trap geometry. Together, these observations and models inform eruption observations at natural geysers, and, with some modifications, volcanoes.

501

Insights into the explosive 1913 eruption of Ambrym (Vanuatu, SW Pacific): an investigation of volatiles in melt inclusions

Ms Kristen Lewis[1], Dr. Alex Nichols[1], Dr. C. Ian Schipper[2], Dr. Karoly Németh[3,4,5]
[1]School of Earth and Environment, University Of Canterbury, Christchurch, New Zealand, [2]School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand, [3]Massey University, Volcanic Risk Solutions, Institute of Natural Resources, Palmerston North, New Zealand, [4]Saudi Geological Survey, Jeddah, Kingdom of Saudi Arabia, [5]Institute of Earth Physics and Space Science, Sopron, Hungary

Increasingly, the nature of mafic volcanism has come under scrutiny as eruption styles can fluctuate from low intensity lava flows to explosive plinian columns, and interpretations of the driving mechanisms of these changes are limited. Understanding how mafic volcanoes transition from effusive to explosive eruptions has implications for hazard management and mitigation for surrounding communities and volcano tourism. The 1913 eruption of Ambrym demonstrates how a new vent opening on a basaltic island arc volcano can quickly transition from a fissure eruption to an explosive phreatomagmatic event. The historic eruption commenced with initial explosions in the central caldera region of Ambrym (Benbow) that later shifted to fissure eruptions and lava flows along a propagating rift. Once the new eruptive center reached the coastal margins of the island, the eruption quickly turned to an explosive phreatomagmatic event. Vesicle poor matrix glass analyzed from this eruption show low volatile contents (<0.5% H2O), leading to the suggestion that fragmentation was driven by interaction with meteoric water in saturated soils along the coastal margin of the island. Naturally quenched glassy melt inclusions (MIs) hosted in early crystallizing phases (Ol, Pl, Cpx) from tephra (Hospital tuff ring) deposited by the phreatomagmatic phase of the eruption are being studied to constrain melt compositions and volatile abundances deeper in the magmatic system. Whether magmatic volatiles played any role in the change in eruption style will be assessed through quantification of volatiles using FTIR analysis. This investigation will determine a volatile budget for Ambrym and place constraints on source compositions, conditions of melt extraction and storage. These will provide insights into the mechanisms driving shifting eruption activity and thus will aid mitigating future hazards that may affect the local populace.

464

Using numerical models to investigate open magma system behavior at Veniaminof Volcano, Alaska

Ms Yuyu Li[1], Patricia Gregg, Zhong Lu, Jiahui Wang
[1]*University Of Illinois Urbana-champaign, Urbana, United States*

Although Veniaminof Voclano in Alaska experiences frequent eruptions and currently has eight permanent seismic stations, only 2 of the past 13 eruptions have had precursory phases that prompted a pre-eruption warning from the Alaska Volcano Observatory (AVO; Cameron et al., Frontiers in Earth Sci., 2018). Seismic data from Venianimof (the USGS catalog; Power et al., USGS Series No. 2019–5037, 2019) show that most eruptions from 2000-2017 do not coincide with an increase in seismicity. Additionally, analyses of InSAR data available from 2015 which covers the pre-, syn-, and post-eruption periods of the 2018 and 2020 eruptions do not show clear signs of deformation. Given the lack of precursory signals, it is hypothesized that Veniaminof is an open volcanic system. In this study, we utilize a finite element, fluid injection approach (LeMével et al., JGR, 2016) to investigate the magma system at Veniaminof and its ability to erupt with no geophysical precursors. Specifically, a series of numerical experiments are conducted to determine what model configurations produce a ground deformation signal that remains below the detection threshold for InSAR (< 10 mm/yr) and produces no seismicity (as calculated by shear failure) while assuming a minimum flux of magma needed to produce the 2018 and 2020 eruptions. Initial results indicate that ground deformation is most sensitive to the depth and shape of the magma reservoir, with oblate, shallow reservoirs creating the greatest deformation signal. Furthermore, deformation increases linearly with an increase in magma flux, which has the greatest impact on whether or not shear failure is produced along the injection column or around the magma reservoir. We find that a prolate source inflating with a low magma flux may produce a “stealthy” eruption without clear seismic or deformation precursors.

284

Prolonged fissure-fed eruption scenarios for future eruptions within the Arxan-Chaihe Volcanic Field (ACVF), NE China

Mr Boxin Li[1], Prof Karoly Nemeth[1,2,3]
[1]Massey University, Palmerston North, New Zealand, [2]Saudi Geological Survey, Jeddah, Kingdom of Saudi Arabia, [3]Institute of Earth Physics and Space Science, Sopron, Hungary

At least 47 vents of the ACVF have been recognized in a 2000 km2 area. The volcanoes are typically tuff rings, scoria cones, fissure-controlled vents, and complex but small volcanic cones. The youngest known eruption occurred at Yanshan (~ 2000 years BP), and it is located in the centre of the volcanic field along an elevated normal-fault bounded, SW-NE-aligned zone. The lava flows (mostly rubble, slabby pahoehoe) filled a north-westward steeply inclined rift shoulder and reached the Halaha River valley within 8 km, in about 230 m elevation drop. Present-day lacustrine systems are inferred to be formed after the emplacement of major lava flows from Yanshan modifying the fluvial channels. Sentinel satellite imagery revealed that the Halaha River lava field is complex and not exclusively derived from the Yanshan vents. A large crater (~1.1-km across), Dahei Gou, just ~5 km to the SW from Yanshan, hosts a young solidified lava lake. Slightly older lava filled an adjacent valley down to the the Halaha River. Q-LavHA simulation produced the best-fit results through fissures or elongated field sources of lava emission following the same NE-SW trending zone, similar to the vent distribution of ACVF. The fissure-controlled lava effusion simulation on smaller scales, such as the Dichi Lake system, produced similar results. The combination of volcano-morphological and lava flow simulation works indicates the strong structural control of eruptions following the major structural elements of the basement. This study reveals an important volcanic hazard aspect of this region and makes the youngest volcanic event a key eruption scenario that future volcanic hazard planning needs to consider.

466

Evolution and Eruptibility of Rift Zone Magmatic Systems on Venus

Rudi Lien[1], Dr. Josef Dufek[1]
[1]University Of Oregon, Eugene, United States

Volcanic features are abundant on the surface of Venus, and many of these features are spatially correlated with tectonic-like structures. Proposed volcano-tectonic interactions on Venus, such as extension-driven melting and volcanism at rifts, are potentially driven by mantle upwelling. In this work, we investigate volcano-tectonic interactions at rift zones to understand how extension and crustal thinning affect the concentration of magmatism, melt distribution, and lifetimes of active magmatic systems in the Venusian lithosphere. Well-studied rift zones on Venus, including Ganis, Devana, and Hecate Chasma, are used to inform initial conditions and parameters.

We use a magma dynamics model in parallel with the Multiphysics Object-Oriented Simulation Environment (MOOSE) software to simulate extension-driven crustal melting as well as fractionation and solidification of melts intruded into the lithosphere of Venus. With the magma dynamics model, we investigate where and when magma reservoirs form in the crust, compositional evolution of generated melt, melt fraction, and total reservoir volume. Simulations run over time periods corresponding to estimates for active lifetimes of coronae and rift zones on Venus (10s of millions of years) to allow for analysis of the surrounding stress conditions and chemical evolution within a magma reservoir as it develops.

Melt fraction and temperature distribution outputs from the magma dynamics model are imported into MOOSE to compute thermomechanical stress and deformation at multiple time points. Analysis of stress resulting from coupled thermal and mechanical responses during magma reservoir development allows us to predict dike trajectories. The results of this work will provide implications for the thermal evolution of the Venusian interior and eruption detectability during future missions to Venus.

1357

Field- and experimental-based probabilistic assessment of crop risk to tephra hazard

Miss Noa Ligot[1], Mr. Sébastien Biass[2], Mr. Benjamin Bernard[3], Mr. Patrick Bogaert[1], Mr. Pierre Delmelle[1]
[1]UCLouvain, Louvain-la-Neuve, Belgium, [2]2, Geneva, Switzerland, [3]3, Quito, Ecuador

Tephra fall poses serious challenges to rural livelihoods in less-economically developed countries where agriculture is often the main sector of activity. Crops are particularly vulnerable to tephra, with impacts ranging from reduced yield to total destruction. Existing relationships between tephra accumulation and crop damage level rely on a relatively small number of field-based studies. However, these relationships overlook other volcanic and non-volcanic controls of crop vulnerability to ash, hindering our capacity to explain and evaluate prediction uncertainty. In order to contribute to fill this deficit in knowledge, we collected a large set of observations on crop yields by interviewing farmers in the region exposed to repeated tephra fall from the recent eruptive activity (1999-2016) of Tungurahua volcano, Ecuador. The database was further expanded with our own experimental estimates of production loss in crops exposed to tephra in a controlled environment. Collectively, inspection of the data revealed that tephra accumulation, crop type, and crop phenological stage are the main factors dictating crop damage from tephra. We then used our impact database to construct new empirical relationships allowing yield loss prediction and associated uncertainty for various crop types. By combining these relationships with a probabilistic assessment of the tephra hazard in a volcanic area, we are able to assess the temporal and spatial evolution of tephra risk to crops. Our approach can be implemented in volcanic risk analysis aimed at informing disaster risk reduction strategies.

1358

Simulated ash fall on potato and corn highlights reduction in yields at low ash mass loads

Miss Noa Ligot[1], Mr. Patrick Bogaert[1], Mr. Pierre Delmelle[1]
[1]*UCLouvain, Louvain-la-Neuve, Belgium*

Agriculture is an economic pillar for the less-economically developed countries. When these regions host explosive volcanoes, a serious risk for agriculture arises as exposure of crops to ash fall may have detrimental effects on harvest quality and yield. While ash mass load-production loss relationships have been proposed, these fail in reliably describing crop damage from ash fallout in the low accumulation range (<10 kg m-2). Considering that low ash mass loads typically affect large surface areas after an explosive eruption, inaccurate estimates of crop damage can translate into great uncertainties in the risk analysis. Here we assess the harvest quality and yield loss of potato and corn crops subjected to simulated light ash fall (≤ 5 kg m-2) when at flowering stage. We also evaluate the efficacy of shaking the ash-covered plants manually in limiting yield loss. While the produce quality of potato and corn exposed to ash was not jeopardised by ash, both crops produced significantly less compared to controls when they were exposed to ≥2 kg ash m-2. For potato, we suggest that yield loss reflects lower photosynthesis activity in leaves coated by ash, whereas for corn, incomplete grain filling of ears and stalk lodging due to ash coverage are probably responsible for lower production. Manual shaking of the ash-coated plants did not mitigate the detrimental impact of ash on yield. We emphasise that controlled experiments in near-real field conditions can easily generate ready-to-use impact data for crops. They also provide a powerful approach to constrain impact mechanisms of ash on crops.

659

Sulfide saturation and resorption modulates sulfur and metal availability during basaltic fissure eruptions

Dr Emma Liu[1], Dr Penny Wieser[2], Dr Margaret Hartley[3], Dr Frances Jenner[4], Dr Barbara Kunz[4], Dr Evgenia Ilyinskaya[5], Professor Þorvaldur Þórðarson[6], Professor Marie Edmonds[7]

[1]University College London, London, United Kingdom, [2]UC Berkeley, Berkeley, USA, [3]University of Manchester, Manchester, United Kingdom, [4]Open University, Milton Keynes, United Kingdom, [5]University of Leeds, Leeds, United Kingdom, [6]University of Iceland, Reykjavik, Iceland, [7]University of Cambridge, Cambridge, United Kingdom

Mafic magmas may experience multiple stages of sulfide saturation and resorption during ascent and differentiation, with implications for the availability of sulfur and chalcophile elements. However, evidence documenting sulfide breakdown is commonly overprinted in erupted products. Rapidly-quenched tephra erupted during the 2014-15 Holuhraun eruption preserve abundant evidence for sulfide resorption "caught in the act" before all available sulfide is exhausted, offering a rare opportunity to explore the sulfide life cycle from nucleation through to resorption. By combining textural and geochemical observations of magmatic sulfides, sulfide-hosting minerals and glasses with modelling constraints, we show that sulfides began nucleating as early as ~8 wt% MgO, persisted throughout a prolonged interval of melt crystallisation; and began resorbing heterogeneously in response to shallow sulfur degassing. Sulfides are preserved preferentially in confined geometries within and between crystals suggesting kinetic effects impeded sulfur loss from the melt and maintained local sulfide saturation. We find that the proportion of sulfides exhibiting breakdown textures increases throughout the eruption, coincident with reduced magma effusion rates. Trace element volatility appears positively correlated with sulfide-silicate melt partition coefficients, and relatively independent of vapour-melt partitioning, suggesting that differences in fluid-melt partitioning behaviour cannot explain the observed range of element abundances in aerosol emissions. Outgassing of elements that are highly volatile, highly chalcophile, and have a low natural abundance in silicate melts (e.g., Se, Te) is particularly sensitive to sulfide resorption. Once all available sulfide is exhausted, trace element outgassing will proceed according to fluid-melt partitioning, masking geochemical signatures of sulfide resorption and explaining, at least in part, the contrasting sulfide systematics between Holuhraun melts and other ocean island systems. Rapid, late-stage resorption of sulfide modulates the emission of sulfur and chalcophile elements to the atmosphere and surface environment, with implications for assessing the environmental impacts and societal hazards of basaltic fissure eruptions.

1024

Sedimentary characteristics of the Early Cretaceous volcanic intermittent period in the Songliao Basin, data from ICDP borehole SK2

Dr Haibo Liu[1], Prof. Dr. Pujun Wang[1], Prof. Dr. Youfeng Gao[1]
[1]*Jilin University, Changchun, China*

The Shahezi Formation in the Songliao Basin is a sedimentary cycle between two volcanic cycles, Yingcheng Formation and Huoshiling Formation. It is significant for research on initial basin history restoration, global continental–marine stratigraphic correlation, climate during the age of dinosaurs. As the first set of sedimentary sequence in the basin, it has irreplaceable research significance.

In our research, 6 categories and 12 kinds of lithology were identified from the Shahezi Formation, mainly sedimentary rocks, in accordance with the thickness ratio from high to low are mudstone, grit stones, siltstone, conglomerate, fine sandstone, medium sandstone and lithology containing volcano material, including tuffaceous sandstone, sedimentary breccia tuff, tuffaceous siltstone,sedimentary tuff, tuff and tuffaceous mudstone.

In the Shahezi Formation period, sedimentary process is dominant, sedimentary rocks of fan delta facies are developed, with 3 subfacies: fan delta plain, fan delta front, profane delta, 6 microfacies: braided channel, subaqueous distributary channel, inter subaqueous distributary channel, subaqueous mouth bar, sand sheet, mudstone of still water, showing a fining-upwards sequence.

According to the lithology combination, the Shahezi Formation was divided into 6 cycles which all of them are fining-upwards sequence. However, according to the sediment granularity, the particle size of cycle I with conglomerate mainly developed is maximum, that of cycle III with pebbly grit stone widely developed is second, and that of cycle VI with mudstone and silty mudstone mainly developed is minimum.

788

Vertical vesicularity structure of lava lakes and lava flows – implications for dynamics and emplacement

Professor Ed Llewellin[1], Dr Tim Orr[2], Professor Bruce Houghton[3], Dr Matt Patrick[4], Professor Simon Cox[5], Professor Simon Mathias[1]
[1]Durham University, Durham, UK, [2]Alaska Volcano Observatory, USGS, , USA, [3]University of Hawaii at Manoa, , USA, [4]Hawaiian Volcano Observatory, USGS, , USA, [5]University of Aberystwyth, Aberystwyth, UK

The vesicularity (ϕ) of lava has a profound influence on its physical properties – most notably its density and rheology. These properties, in turn, determine the nature of transport and emplacement processes such as convective overturn and outgassing of lava lakes, and flow velocity and run out length of lava flows. Here, we develop a conceptual and mathematical model for the vesicularity as a function of depth. We solve the hydrostatic equation accounting for the pressure-dependent solubility of H_2O, which is the dominant magmatic volatile species at shallow depths for most mafic magmas. We find that the inclusion of solubility leads to a very sharp transition from a foamy upper layer, to a dense lower layer. We explore the impact of this vertical vesicularity structure for two case-study scenarios at Kīlauea (Hawaii, USA): the summit lava lake that persisted from 2008 – 2018; and a series of perched, channelized lava flows produced by Puʻuʻōʻō in 2007.

For the lava lake, we constrain model parameters against geophysical and textural data and infer that the gas volume fraction of the foam layer decreases gradually from a maximum value of $\phi \simeq 0.95$ at the surface to $\phi \simeq 0.64$ (the lower bound for a foam) at around 80 m depth, then decreases very rapidly to zero over a further 12 m depth. We examine and reinterpret observed lava lake phenomena – spattering, gas pistoning, overturn, and convective surface motion – within the context of this inferred vertical vesicularity structure. For the lava flows, we constrain model parameters against field observations and infer a two-part structure, with a foamy ($\phi > 0.64$) upper layer 1-2 m thick, overlying a much thicker dense lower layer. We explore the implications of this vesicularity structure for the vertical variation of rheology and velocity, and for emplacement processes more generally.

789

Ascent of large bubbles in volcanic conduits: bridging the bubble–slug gap

Dr Valeria Cigala[1], Professor Ed Llewellin[2], Dr Thomas Jones[3], Dr Ulrich Kueppers[1]
[1]LMU Munich, Munich, Germany, [2]Durham University, Durham, UK, [3]University of Liverpool, Liverpool, UK

Basaltic volcanic eruptions commonly involve the ascent and bursting of large, decoupled gas bubbles, often called ‘slugs’. These slugs are understood to be responsible for strombolian activity, and for pulsations in lava fountains; hence, they play an important role in driving and modulating mildly explosive activity at basaltic volcanoes. We present a quantitative physical model for the ascent velocity of gas bubbles in a vertical cylindrical pipe filled with a stagnant viscous liquid. The model is derived from results of analogue experiments scaled to basaltic conduits. The major novelty of the study is that it covers a wide range of dimensionless bubble sizes – i.e., from bubbles that have a diameter that is much smaller than the pipe diameter, to bubbles that fill the pipe cross section (Taylor bubbles).

Our experimental data for the end-member cases of unconfined bubbles (much smaller than the pipe) and Taylor bubbles (pipe-filling) are well described by existing physical models for those cases. The behaviour of bubbles of intermediate size depends on whether the pipe diameter is smaller or larger than the critical bubble size at which the shape of an unconfined bubble transitions from spherical to non-spherical. We capture this intermediate behaviour by using a smooth function that joins the existing end-member models. The model that we develop relates the ascent velocity, bubble equivalent spherical diameter, conduit diameter, magma viscosity, magma density, and gravity. We anticipate that the model will be used to predict bubble ascent velocities, and to invert for magma and conduit properties.

1366

The effect of particle size on the rheology of particle suspensions

Dr Melissa Drignon[1], Professor Ed Llewellin[1], Professor Einat Lev[2], Miss Janine Birnbaum[2]
[1]Durham University, Durham, United Kingdom, [2]Columbia University, New York, United States of America

The rheology of magma and lava is known to be strongly influenced by the concentration and shape of crystals suspended within the melt. Here we present the results of an analogue rheometry study that shows that the absolute size of the particles also has an important influence on rheology: suspensions of smaller particles have a higher apparent viscosity than suspensions of larger particles, at the same concentration. We characterize the rheology of suspensions of spherical glass beads in silicone oil in a concentric cylinder geometry, using roughened sensors to avoid wall slip. Four different particle sets are used, each with a unimodal size distribution, with mean diameters ~60 µm, ~125 µm, ~175 µm, and ~255 µm. All runs use a Newtonian silicone oil with viscosity 46 Pa s at experimental temperature. We collect flow curves over a wide range of strain rates (0.001 – 10 s-1 where possible, truncated if shear heating is detected) at particle concentrations of 5, 10, 15, 20, 25, 30, 35, 40, 45, and 50%. For all particle sets we find that suspensions become more viscous and more strongly shear thinning as particle concentration increases, consistent with previous work. Further, we find that apparent viscosity is systematically higher for suspensions of smaller particles, particularly for the most concentrated suspensions. For instance, the apparent viscosity of suspensions of the smallest particles is approximately twice that of suspensions of the largest particles, at 50% concentration.
Our experiments are scaled to magmatic suspensions, and in all cases fall into the high Peclet number, low particle Reynolds number, low Stokes number regimes. We propose that the increase in apparent viscosity observed for suspensions of smaller particles arises from an increase in the spatial density of contacts among the particles.

1124

Surface temperature of the Cordón Caulle 2011–2012 eruption shown in high resolution captured by thermal IR camera in a drone.

Mr Diego Lobos, PhD Pablo Sanchez, Patrick Phelps, Andie Gomez-Patron, PhD Philipp Ruprecht, PhD Whyjay Zheng, Heather Winslow, Joshua Wiejaczka, Pablo Becerra, PhD Francisco Delgado, PhD Carolina Muñoz, PhD Kevin Reath, PhD Matthew Pritchard, PhD Helge Gonnermann, PhD Thomas Giachetti
[1]*Cornell University, Ithaca, United States*

The 2011-2012 rhyolitic eruption of Cordon Caulle volcano, Chile, produced a ~0.8 km3 laccolith up to 250 m thick and only a few 10’s of m below the surface and provides a rare opportunity to quantify the physical processes and potential hazards from shallow intrusions. To better understand the post-eruptive evolution of the laccolith, we combine very high-resolution thermal imagery (0.2 m/pixel) from an uncrewed aerial vehicle (UAV) collected in 2022 with lower spatial resolution (90 m/pixel) satellite data from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), to identify changes at the laccolith between 2012 and 2022. Satellite and ground-based data show that the laccolith region is still thermally dynamic. To quantify the spatial and temporal temperature fluctuations in the laccolith regions, we used the UAV DJI Mavic 2 Enterprise Advance to collect a total of 6157 infrared images during the predawn hours over several days, covering an area of 4.4 km2. We used DJI Thermal Software Development Kit to convert the radiometric images to temperature before creating a thermal map with the Agisoft Metashape program that highlights cracked and faulted zones with higher temperatures. From the ASTER time series, we find growth in the area of the laccolith with temperatures above background since 2016, including two periods of a sudden increase in size between 11/2017 - 9/2018 and mid-2020. Comparison with a high spatial resolution (~1 m/pixel) satellite Synthetic Aperture Radar and optical data confirms changes to the laccolith over time, including the formation of fractures and explosion craters. We interpret the thermal changes at the laccolith to be related to fractures and craters in the laccolith, exposing the persistent migration of deep rising, hotter fluids in these areas.

906

Rapid mapping by multi-sensor UAV surveying for monitoring volcanic unrest at Vulcano Island

Dr Luigi Lodato[1], Dr Maria Marsella[2], Dr Mauro Coltelli[1], Dr Peppe J. V. D'aranno[2], Dr Matteo Cagnizi[2], Dr Francesco Rossi[2]
[1]I.N.G.V. (Istituto Nazionale di Geofisica e Vulcanologia), Catania, Italy, [2]Università La Sapienza D.I.C.E.A (Dipartimento di Ingegneria Civile, Edile e Ambientale), Roma, Italy

In September 2021, the geophysical and geochemical parameters measured on the Island of Vulcano by the surveillance network and periodic surveys recorded significant changes. Among the additional measures setup by the scientific community and INGV, a number of thermal and ALS surveys were carried out between October 2021 and September 2022 using a DJI Matrice 300 UAV systems. The collected data allowed to extract data and maps directly georeferenced using POS/NAV RTK approach. The Laser Scanner sensors used to extract a Digital Terrain Models are a Genius R-Fans-16 and DJI Zenmuse both coupled with an RGB camera to obtain the orthophoto. The aerial thermal surveys, performed using a Zenmuse XT2 – Ht20 thermal camera, were integrated by ground-based data collected from fixed points of interest to map the fumarole field.

The focus of the surveying activity was on the detection and mapping of the fumarole temperatures and of potential instability on the flanks of the volcano edifice. The surveys in October, November and December 2021, were carried out in the northern area of Vulcano, in particular the summit area, namely 0.357 kmq, of the 'Gran Cratere La Fossa'. Furthermore, a 3D reconstruction of the top of the cone, the area of 'Forgia Vecchia' and the area of the 1988 landslide, was aimed at identifying morphological variations in the most unstable areas. In May 2022, a new event of anomalous degassing occurred in the Eastern Bay, with an increase in the emission of gases and hydrothermal fluids, which produced a phenomenon of whitening of the waters in front of the 'Baia di Levante' of Vulcano. For this event, optical-thermal monitoring was carried out both on land near the port and the 'Faraglione' area and in the sea where different streams of hydrothermal gases were detected.

663

Major and trace element geochemical fingerprints of source volcanoes in the Cook Inlet region, Alaska

Matthew Loewen[1], Kristi Wallace[1], Michelle Coombs[1]
[1]*U.S. Geological Survey, Alaska Volcano Observatory, Anchorage, United States*

The Cook Inlet volcanoes of Alaska—Hayes, Spurr, Redoubt, Iliamna, Augustine, Douglas, and Kaguyak—are some of the most historically and geologically active volcanoes of the Alaska-Aleutian arc and pose the greatest hazard to population centers in Alaska. Detailed characterization of tephra erupted from these volcanoes is used to assess eruption histories (frequency and magnitude) and aid in preparing for the next explosive eruption.

We have defined the major and trace element compositions of glass from proximal tephra erupted from each Cook Inlet volcano. The volcanoes group into two compositional fields using major elements: higher K, lower Ca defines Hayes, Spurr, Redoubt, Iliamna, and Douglas; lower K, higher Ca defines Augustine and Kaguyak. While subtle differences within these two groupings exist in major element compositional space, significant overlap makes positive identification of a source volcano from major element data alone uncertain. With trace element variability we can further distinguish eruptions and source volcanoes. Within the high K group: Hayes has elevated Sr/Y and La/Yb; Douglas has low La/Th; Iliamna has high Ba/Nb. Spurr and Redoubt are not clearly distinguishable apart from broadly lower SiO_2 from Spurr and textural characteristics of the tephra. Kaguyak is distinct from low K Augustine with higher La/Th.

Using these source volcano major and trace element characteristics, we have confidently identified the volcanic source of almost 50 distinct distal tephra layers preserved in a peat bog on the lower Kenai Peninsula (eastern Cook Inlet). We can conclude that the lower Kenai Peninsula is most frequently impacted by eruptions from Augustine and Redoubt volcanoes. These distal deposits preserved in a peat bog offer excellent radiocarbon age control on eruptive history, and when combined with proximal deposits, allow high resolution construction of individual volcano eruptive histories and geochemical evolution through the Holocene.

851

Determining the vertical scale in videos of fissure eruptions from gravitational acceleration of single clasts at their zenith

Miss Ariane Loisel[1], Professor Edward Llewellin[1], Miss Caroline Tisdale[2], Professor Bruce Houghton[2]
[1]*Durham University, Durham, United Kingdom,* [2]*University of Hawaiʻi at Mānoa, Honolulu, United States*

Videography is a popular tool for monitoring and characterising volcanic eruptions. Video records of lava fountains resulting from fissure eruptions allow us to infer eruption parameters such as fountain heights, exit velocities, and pulse durations and frequencies, which may inform us on the subsurface processes that operate within the fissure plumbing system. However, the evolving shape and size of the natural features surrounding eruptive vents make it difficult to convert pixels in an image to meters in reality, due to the lack of fixed reference points with which to compare dimensions. In this poster, we present a new method for determining the vertical scale in videos of lava fountains. We measure the vertical pixel-position of clasts near their zenith, over successive frames, and convert this to an acceleration. By assuming that the only force acting on single clasts near their zenith is gravity, we use the clast motion to determine the scale – mapping pixels to metres. Geometric considerations around the viewing angle and lens distortions are discussed and corrected for, and we consider the conditions under which drag can be neglected. We validate this method with laboratory experiments using water fountains and vertically projected light plastic balls, which act as analogues for lava fountains and single clasts, respectively. An example of field application is then provided from the 2018 fissure eruption at Kīlauea (Hawaii, USA). This approach will be useful to physical volcanologists for monitoring the dynamics of eruptions that produce fountains and/or ballistics from video records, which are becoming increasingly available both from scientific teams and from a wider community of tourists and volcano-enthusiasts.

1157

Large-scale analogue experiments reveal the role of subsurface gas localization in basaltic fissure eruptions

Miss Ariane Loisel[1], Professor Edward Llewellin[1], Doctor Antonio Capponi[2]
[1]Durham University, Durham, United Kingdom, [2]Lancaster University, Lancaster, United Kingdom

Effusive basaltic eruptions produce lava flows that may destroy local infrastructure and emit toxic gas and particles that can adversely impact public health on a regional scale. Predicting the eruptive style and its evolution for basaltic volcanoes is therefore a key goal in volcanology. This requires an understanding of the multiphase flow processes that operate within the sub-volcanic plumbing system and drive these rapid transitions.

We aim to characterize the evolving organisation of gas-driven flow patterns within basaltic feeder dyke systems, with a particular focus on the effects of volcanic outgassing via discrete vents along the fissure. Our laboratory kit was designed to perform scaled analogue experiments reproducing bubbly flows in a 3.0 x 2.0 x 0.03 m glass-walled slot which mimics the geometry of dykes that feed most basaltic eruptions. This apparatus allows us to explore the effects of a slot-like geometry on fluid dynamic processes within the magma, whereas previous experimental studies have usually assumed a cylindrical conduit. We present preliminary results on how this slot-like geometry affects the ascent of gas slugs and the organization of convective flow patterns in bubbly magmas, identifying how patterns emerge 'bottom up'. Our next step is to investigate the role that 'top down' processes play in shaping behaviour. This will be done by occluding parts of the top of the slot to replicate localization of fissure segments. We also consider the role played by flooding of the vent with lava, focussing on long-lived systems that are replicated by a cylindrical conduit and vent geometry. As future work, we will collate the imagery acquired during our analogue experiments with monitoring data from fissure eruptions to improve our understanding of the controls on the eruptive behaviour of basaltic systems.

929

A Study on Magmatic Diversity: Determining the Evolution and Heterogeneity of Plutons in Swales Mountain, NV

Mrs Shasta Longo[1], Philipp Ruprecht[1]
[1]*Department of Geological Sciences and Engineering, University of Nevada-Reno, Reno,, USA*

Many modern volcanic systems change in their eruptive behavior and products over the course of their lifetime. How these changes are recorded in subsurface magmatic records remains poorly understood. By studying magmatic systems that expose the subvolcanic and plutonic levels of old volcanic systems we can reconstruct the spatial and temporal assembly of small to intermediate-sized systems.

Nevada has been affected by the westward convergent plate margin for over 150 million years causing volcanism and arc-style magmatism in the Jurassic, Cretaceous, and Eocene through Miocene. The associated subvolcanic and plutonic plumbing systems have been exhumed and tilted as a result of Basin and Range extension exposing the time-integrated record of magma storage, recharge, and withdrawal. We present emerging results from geologic mapping combined with geochemical analyses from Swales Mountain, NV, which hosts a shallow to mid-crustal Eocene magmatic system. The peraluminous, calc-alkaline intrusions range from 56 to 76 wt% silica. Two texturally and compositionally-distinct plutons each approximately 2 km in width are exposed in different parts of the plumbing system. In between, various dikes, sills, and breccias interact with Paleozoic sedimentary units. Field observations exhibit the dacite cross-cutting rhyolitic deposits. A variety of mixing textures with mafic material have been observed in the plutonic units, indicating contemporaneous heterogeneity in the Swales Mountain system. Results indicate that the oldest preserved episodes of magmatism at Swales Mountain were evolved and felsic, potentially related to more crustally-derived magmas that then transitioned to less evolved, more mafic, mantle-derived compositions. We speculate that this transition to more mafic compositions is related to more direct magma transport from the mantle as slab roll-back progressed. Small systems, like Swales Mountain, may potentially be used to explore how initial crustal magmatism integrates mantle material over time.

1235

Testing links between melt composition, monitoring signals and eruption style at Cumbre Vieja volcano

Professor Marc-Antoine Longpré[1,2], Samantha Tramontano[2,1], Dr. Matthew Pankhurst[3,4], Franco Cortese[2,1], Fátima Rodríguez[3], Dr. Beverley Coldwell[3,4], Alba Martín-Lorenzo[3,4], Dr. Olivia Barbee[3], Dr. Luca D'Auria[3,4]
[1]Queens College, City University of New York, Queens, United States, [2]Graduate Center, City University of New York, New York, United States, [3]Instituto Volcanológico de Canarias, San Cristóbal de La Laguna, Spain, [4]Instituto Tecnológico y de Energías Renovables, Granadilla de Abona, Spain

Melt composition exerts a strong control on the physical properties of erupting magma and the style of volcanic eruptions. For most eruptions, records of melt composition are collected at low temporal resolution, preventing a direct comparison with monitoring data and eruptive parameters. In contrast, the 2021 Tajogaite eruption of Cumbre Vieja volcano (La Palma, Canary Islands) produced sustained Strombolian to violent Strombolian activity that allowed near-continuous sampling of tephra. We report the major element composition of glass from dated, juvenile ash shards, spanning the entirety of the 2021 eruptive sequence, with the goal of testing potential links between melt composition, monitoring signals and eruption parameters at a daily resolution. Overall, glass shows tephritic to phono-tephritic compositions, with 44.2 to 48.2 wt.% SiO2. Three major shifts characterize the temporal-compositional trends: (1) following eruption onset (19 September), Si, Al, Na, K and Cl concentrations sharply increase on 21 September; (2) then steadily decrease from 22 September until 30 November; and (3) finally increase until the eruption end on 13 December. The compatible elements Fe, Mg, and Ca display the opposite behavior. The first inflection point coincides temporally with the effusion of a slowly-advancing and amphibole-bearing lava flow. Interestingly, the tephra glass SiO2 content, in particular, shows patterns that mimic some variations in volcanic tremor amplitude, but does not seem related to the height of the ash plume (as reported by the Toulouse Volcanic Ash Advisory Centre). We postulate that the broad positive correlation between melt SiO2 content and volcanic tremor amplitude reflects a control of melt composition on shallow seismic signals, possibly through subtle changes in viscosity and/or degassing behavior.

888

Insights into Volcanic Activity from Three Years of TROPOMI Satellite SO2 Observations of Alaska Volcanoes

Dr Taryn Lopez[1,2], Dr. Társilo Girona[1,2], Israel Brewster[1,2], Skye Kushner[1,2], Valerie Wasser[1,2], Pablo Saunders-Shultz[1,2]

[1]University of Alaska Fairbanks-Geophysical Institute, Fairbanks, United States, [2]Alaska Volcano Observatory, Fairbanks, United States

Volcanic SO_2 emissions are a key monitoring metric used by volcano observatories to identify and track volcanic unrest. Until recently, monitoring of SO_2 emissions from Alaska's remote volcanoes has been limited to discrete field campaigns providing snap-shot views of volcanic degassing. With the 2017 launch of the ultraviolet TROPOMI satellite sensor, which has a much higher spatial resolution than its predecessors, observations of low quantities of SO_2 (~100-300 t/d) can now be routinely detected from space. Since 2020, TROPOMI imagery have been used operationally by the Alaska Volcano Observatory to detect and quantify volcanic SO_2 emissions. Here we present three years of observations of SO_2 emissions from Alaska volcanoes to provide insights into volcanic activity. Between 2020-2022, we observed degassing on >400 occasions from 11 Alaska volcanoes, from West to East: Semisopochnoi, Gareloi, Great Sitkin, Atka, Cleveland, Makushin, Shishaldin, Pavlof, Veniaminof, Chiginigak, and Iliamna. From these detections, we calculated SO_2 masses ranging from 0.001 to 1.42 kt and emission rates from <50 to >3,000 t/d. While some of these SO_2 observations reflect typical background degassing behavior, the majority reflect discrete periods of elevated degassing associated with volcanic unrest or eruption. Nearly one half of all observations derive from Semisopochnoi, which has been in a persistent state of eruption over the study period. Temporal increasing trends from three volcanoes (Gareloi, Atka, and Cleveland) suggest enhanced degassing, potentially signifying volcanic re-activation; while one volcano (Makushin) shows a decrease in SO_2 detections, potentially suggesting a return to background behavior following 2020 geophysical unrest. Here we compare temporal trends in satellite SO_2 observations to a suite of seismic features, including number of long-period events, real-time seismic amplitude, relative velocity, decorrelation, polarization, etc., to provide insight into volcanic processes and evaluate the utility of quantitative satellite SO_2 observations for volcano monitoring.

1038

Crystal reading into the storage, remobilisation and eruption of mushy magma systems

Dr Charline Lormand[1], Prof Georg Zellmer[2], Dr Naoya Sakamoto[3], Dr Teresa Ubide[4], Dr Geoff Kilgour[5], Prof. Hisayoshi Yurimoto[3], Dr Alan Palmer[2], Prof. Karoly Nemeth[2], Dr Yoshiyuki Iizuka[6], Dr Anja Moebis[2]
[1]Department of Earth Sciences, Durham University, Durham, United Kingdom, [2]Department of Earth Sciences, Massey University, Palmerston North, New Zealand, [3]Isotope Imaging Laboratory, Hokkaido University, Sapporo, Japan, [4]School of Earth and Environmental Sciences, The University of Queensland, Brisbane, Australia, [5]GNS Science, Wairakei Research Centre, Taupo, New Zealand, [6]Institute of Earth Sciences, Academia Sinica, Taipei, Taiwan

Time capsules, thermobarometers, recorders of processes and volatile evolution, windows into magma feeding systems... Volcanic crystals are essential tools as they detain key information to unravel the architecture and time-space evolution of volcanic plumbing systems. This permits to mitigate volcanic hazards and elaborate evacuation strategies in populated areas. The increasing image resolution of analytical instruments allows us to visualise and quantify compositional gradients down to sub-micron scale. Here, we discuss the intracrystalline textures and chemical variations of crystal cargoes at arc settings and how they inform us about magma ascent and transcrustal magmatic processes.

The andesitic tephra suite of the Tongariro Volcanic Centre, New Zealand, is a perfect example to investigate the textural and chemical variations for eruption styles spanning from Strombolian to sub-Plinian. Featureless at first, many microcrysts reveal complex (cryptic) internal structures and textures that reflect local chemical heterogeneities. Fluctuations in cooling rate, inherent during dyke intrusions, are implied by characteristic textures including remnant hopper crystal, phase exsolution at rims and late-stage sector zoning. The occurrence of textures across all eruptions and volcanic vent systems indicates a commonality of processes in time and space in the shallow crust, and an antecrystic origin of the crystal cargoes. We present detailed evidence of sub-aphyric magmas that feed a vertically extended system during repeated ephemeral intrusion episodes, entraining microantecrysts of diverse physico-chemical crystallisation conditions prior to eruption.

441

Non-ideal modelling of volatiles in apatite: application to porphyry systems

Dr Charline Lormand[1], Dr Madeleine C.S Humphreys[1], Dr Jason Coumans[2], Dr Cyril Chelle-Michou[3], Dr Weiran Li[4]

[1]*Department of Earth Sciences, Durham University, Durham, United Kingdom,* [2]*Natural Resources Canada, Ottawa, Canada,* [3]*Institute of Geochemistry and Petrology, ETH Zurich, Zurich, Switzerland,* [4]*Department of Earth Sciences, University of Cambridge, Cambridge, United Kingdom*

To what extent is the volatile evolution of mineralising systems, such as porphyry ore deposits, representative of volcanic plumbing systems? To answer this key question, melt and fluid inclusion compositions are commonly probed to constrain the volatile evolution near the magmatic-hydrothermal transition, as they capture a direct record of the dissolved or exsolved volatile phase. However, fluid inclusions are scarce, challenging to analyse, and melt inclusions may be affected by post-entrapment re-equilibration processes. We propose that in-situ analysis of apatite, which incorporates volatiles in its crystal lattice, may offer a superior alternative to melt and fluid inclusion analysis.

We use apatite as a recorder of the volatile budget of magmas and derive the volatile saturation state of magmatic systems. We model the volatiles in apatite following [1] but with the improvement that we integrate the temperature-dependent exchange coefficients that reflect the non-ideal mixing of F-Cl-OH in apatite [2]. We model the apatite dataset of the Corrocohuayco porphyry-skarn Cu deposit, Peru [3] which comprises early gabbrodiorites, mineralised hornblende(-biotite) porphyries, and later rhyodacite dykes. The modelling determines initial F, Cl and H_2O of each magma and allows us to estimate the timing of volatile saturation relative to crystal fractionation. Further, we are able to retrieve both the melt and fluid compositions (e.g., salinity) at the point of volatile saturation. Our modelling results fall within the range of direct measurements of melt and fluid compositions. This provides a new way to determine whether there are fundamental differences in magma crystallisation and fluid evolution in barren and mineralised systems.

[1] Humphreys et al. (2021, EPSL); [2] Li and Costa (2020, GCA); [3] Chelle-Michou and Chiaradia (2017, Contrib. Mineral. Petrol)

1167

Hephaestus: A low-cost IoT-embedded monitoring geophysical system for volcanic activity

Dr Vinicius Louro[1]
[1]*Universidade De São Paulo, São Paulo, Brazil*

Monitoring volcanic activity is one of the oldest practices in the volcanology field. Many methodologies access on a real-time basis the evolution of the volcanic body using direct and indirect physical properties. New technologies are constantly altering the way of "looking" into the volcanic manifestation, and this is the topic approached in this work. The Hephaestus System is a monitoring system prototype to establish a net of sensors regularly spaced over a given volcanic body. The embedded sensors consist of a triaxial magnetometer, a triaxial accelerometer, a thermometer, and a CO_2 sensor, all connected to a low-cost microprocessor. The actuators (sensors + microprocessors) net establish a connection with gateways using a Low-Power Wide-Area Network (LPWAN) technology, such as LoRAWAN(TM), permitting long-range communication (up to 12 Km in rural areas). The strategically positioned gateways forward the collected data to internet servers using the Internet of Things (IoT) applications. The process consists of each processor reuniting the sensor data and sending them to a secondary gateway. This gateway forwards the message to the main and backup gateway, both connected to the internet using SIM cards. The messages received from all actuators are stacked and uploaded to a server, where they are cataloged, archived, processed, and forwarded to a Graphical User Interface, for near-to-real-time monitoring. The collected data is expected to permit integration with other methodologies, such as seismology and InSAR, to further build Deep Learning models in an effort to contribute to geohazard assessment in volcanic areas.

745

Origin and development of the Commission on Tephrochronology (COT) and its role in advancing global tephra studies

Professor David Lowe[1], Dr Peter Abbott[2], Professor Takehiko Suzuki[3], Associate Professor Britta Jensen[4]
[1]University of Waikato, Hamilton, New Zealand, [2]University of Bern, Bern, Switzerland, [3]Tokyo Metropolitan University, Tokyo, Japan, [4]University of Alberta, Edmonton, Canada

Tephrochronology is a correlational and age-equivalent dating method whereby practitioners characterize, map, and date tephra layers and use them stratigraphically as connecting and dating tools in the geosciences and in studies of past environments and archaeology. Although modern tephra studies began around 100 years ago, the first collective of tephrochronologists with a common purpose and global outlook was formed only on 7 September 1961 in Warsaw, Poland, when the inaugural “Commission on Tephrochronology” (COT) was ratified under the aegis of the International Union for Quaternary Research (INQUA). COT’s formation is attributable largely to the leadership of Kunio Kobayashi of Japan, the commission’s president for its first 12 years.

Tephrochronology continues to grow globally, and studies on cryptotephras, which are fine-grained glass-shard and/or crystal concentrations preserved in sediments or soils but insufficiently numerous to be visible as a layer to the naked eye, have expanded dramatically. We therefore review the role and impacts of COT under the umbrella of INQUA for 53 of the last 60 years or under IAVCEI for seven of the last 60 years, including since 2019. We describe the commission’s development, its leaders, and its activities, which included organizing nine specialist tephra-field meetings in seven different countries, alongside crucially-important advances in geoanalytical and dating techniques and protocols that have enabled the commission to flourish*. Members of the commission have played leading roles in international projects such as INTIMATE and SMART. As well as supporting early-career researchers, the commission, involving 29 elected officers and 15 honorary life members, has generated 10 tephra-themed journal volumes and two books, and continues to break new ground.

*Lowe, D.J. et al. 2022. Global tephra studies: role and importance of the international tephra research group ‘Commission on Tephrochronology’ in its first 60 years. History of Geo- and Space Sciences 13, 93–132. https://doi.org/10.5194/hgss-13-93-2022

743

Using ground-penetrating radar and X-ray computer tomography to survey and characterise distal tephras in lake sediments, Hamilton lowlands, New Zealand

Mr Richard Melchert[1], Professor David Lowe[1], Dr Max Kluger[1], Dr Andrew Lorrey[2], Mr John-Mark Woolley[2], Dr Vicki Moon[1], Dr Tehnuka Ilanko[1], Dr Marcus Vandergoes[3], Mr Nic Ross[4]

[1]University of Waikato, Hamilton, New Zealand, [2]NIWA, Auckland, New Zealand, [3]GNS Science, Lower Hutt, New Zealand, [4]Hamilton Radiology, Hamilton, New Zealand

Numerous distal rhyolitic and andesitic tephra layers are preserved within organic lake sediment (OLS) in shallow (<9 m) riverine-phytogenic lakes formed ~20-kyr ago in the Hamilton lowlands, northern North Island, New Zealand. Cores from 16 lakes show that some tephras contain soft-sediment deformation structures (SSDS) whose characterisation and seismogenic origin form the basis of a companion presentation by Kluger et al. Here we investigated the capacity of ground-penetrating radar (GPR) to enable mapping of individual tephras as continuous layers across lake basins, and to detect evidence of SSDS.

Data were collected along transects on Lake Rotoroa (Hamilton Lake) using a 160-MHz GPR antenna mounted on a flat-bottomed canoe with GPS. GPR measures reflectors of subsurface layers based on their electric conductivity, these being quite different for tephras and OLS. We took six lake sediment cores (adding to cores collected previously), from both deep (~4 m) and shallow (~1.5 m) water, to provide a stratigraphic basis for interpreting the radar profiles. X-ray computer tomography (CT) scanning was performed on the new cores before they were opened and described, to obtain three-dimensional images of tephras (ranging from ~10—50 mm in thickness) and SSDS.

The GPR rapidly provided two-dimensional profiles through up to 4-m-thick OLS with multiple, continuous tephra layers evident in the profiles. The layers draped bathymetric contours, consistent with their subaerial fallout origin; towards lake margins, profiles showed unconformities. Distinct offsets in reflectors (tephra layers) and several metre-wide zones of disturbance were evident. Some of the disturbances may correspond to SSDS evident in the cores. We observed both upward- and downward-directed SSDS, which we interpreted to be the result of paleoearthquakes. Upward-directed SSDS, seen only in shallow-water cores where OLS was ≤2 m thick, were limited to pre-lake alluvium (Hinuera Formation), whereas downward-directed SSDS corresponded to liquefaction in ~15.6-ka Rotorua tephra.

1473

Improving volcano studies and monitoring from NISAR

Professor Zhong Lu[1]
[1]Southern Methodist Univ, Dallas, United States

Interferometric synthetic aperture radar (InSAR) is capable of measuring ground-surface deformation with centimeter-to-subcentimeter precision at a spatial resolution of tens of meters over an area of hundreds to thousands of square kilometers. With its global coverage and all-weather imaging capability, InSAR has become an increasingly important measurement technique for constraining magma dynamics of volcanoes and monitoring volcanic eruptions. The upcoming NASA-ISRO SAR (NISAR) mission will be unique in providing comprehensive, frequent and consistent imaging of nearly all land areas across the global at least twice every 12 days, including ~1400 world's potentially active volcanoes on land, with free and open access to all of the data. Currently scheduled to launch in January 2024, the NISAR mission has been optimized for studying volcanic and other geological hazards and global environmental change. NISAR's tasking and processing systems are also designed to support disaster response with reduced latency product generation after acquisition. In this presentation, I will provide an overview of NISAR imaging parameters, observation plan, products and latency. Then, I will give an overlook how NISAR will improve studies of volcanic processes and volcano monitoring, including but not limited to, 1) monitoring surface deformation at quiescent and active volcanoes worldwide, 2) constraining the nature of deformation sources consistent with surface deformation during the eruption cycle, 3) diagnosing eruption processes such as lava-dome growth and extent of eruptive products from radar backscattering and InSAR coherence imagery, and 4) mapping localized deformation associated with volcanic flows to understand physical property of volcanic flows and help avoid misinterpretations caused by unrecognized deformation sources.

585

Probabilistic source classification of large tephra-producing eruptions in Alaska using supervised machine learning

Dr. Jordan Lubbers, Dr. Matthew Loewen, Dr. Kristi Wallace, Dr. Michelle Coombs
[1]*U.S. Geological Survey Alaska Volcano Observatory, Anchorage, United States*

Alaska contains over 130 volcanoes and volcanic fields that have been active within the last two million years. Of these, roughly 90 have erupted during the Holocene, with many characterized by at least one large, explosive eruption. These large tephra-producing eruptions (LTPEs) generate orders of magnitude more erupted material than a "typical" arc explosive eruption and distribute ash thousands of kilometers from their source. Because LTPEs occur infrequently, and the proximal explosive deposit record in Alaska is generally limited to the Holocene, we require a method that links distal deposits to a source volcano where the correlative proximal deposits from that eruption are no longer preserved.

We present a model that accurately identifies LTPE volcanic sources in the Alaska-Aleutian arc based solely on trace element chemistry. The model is a voting ensemble classifier comprised of six different machine learning algorithms (linear discriminant analysis, logistic regression, k nearest neighbors, support vector machine, gradient boosting, and random forest) trained on proximal tephra deposits that have had their source positively identified. We show that incompatible trace element ratios (e.g., Ba/Nb, Th/La, Zr/Hf, etc.) produce a feature space that contains significantly more variance than one produced by major elements, creating a model that can achieve high accuracy, precision, and recall on predicted volcanic sources, regardless of the data distribution (i.e., bimodal, uniform, normal) or composition (e.g., andesite, trachyte, rhyolite) of that source. Our model is built such that it can facilitate the addition of new data as it becomes available, ultimately allowing more than just LTPEs to be identified. When applied to unidentified distal tephra deposits our model will help further our understanding of explosive volcanism in the Alaska-Aleutian arc, specifically its pre-Holocene spatiotemporal distribution.

1490

Pyroclastic density currents - recent advances in understanding and future challenges

Associate Professor Gert Lube

Pyroclastic density currents (PDCs) are dangerous multiphase flows from volcanoes. Research on PDCs research is highly topical for Aotearoa (New Zealand), where all of our active volcanoes are capable of producing PDCs. New Zealand's most lethal eruption (Mount Tarawera in 1886) as well as its most current volcanic disaster (Whakaari in 2019) generated PDCs. Causing approximately one third of volcanic fatalities globally, the development of robust PDC flow and hazard models is a priority in Volcanology and Natural Hazard Science. However, the wide range and complexity of gas-particle feedback mechanisms inside the currents and their hostile nature make quantitative measurements into PDCs and the validation of hazard models challenging. Over the past approximately 15 years, through combining large-scale experiments, field observations, computational and theoretical modelling, major advances have been made in elucidating the enigmatic internal structure of PDCs; in identifying key processes behind their fluid-like motion; in linking newly recognised processes of mesoscale turbulence and energy cascading in large eddies to the PDC behaviour; and in probing the turbulence structure of PDCs to link its characteristics to the origin and perpetuation of the PDC destructiveness. In this presentation, we take a look at recent progress in PDC research and examine how this closes the gaps towards robust hazard modelling. We provide examples of this through the current international PDC model inter-comparison that runs under the umbrella of the International Association of Volcanology and Chemistry of the Earth's Interior. Finally we highlight critical future research challenges and potential pathways to approach them.

468

The Impact of Ice Caps on the Mechanical Stability of Magmatic Systems

Ms Lilian C. Lucas[1], Dr. John A. Albright[1], Dr. Patricia M. Gregg[1], Dr. Yan Zhan[2]
[1]University Of Illinois at Urbana-Champaign, Urbana, United States, [2]The Chinese University of Hong Kong, Hong Kong, China

Monitoring the activity of subglacial volcanoes along the Aleutian Arc in Alaska is important to the safety of local populations, as well as air traffic flying through the region. However, observations of volcanic unrest are limited by accessibility and resources, particularly at glacier-covered systems, making investigations of their stability challenging. Westdahl Peak, a subglacial volcano located on Unimak Island in the Aleutian Arc has experienced significant unrest and uplift since its most recent VEI 3 eruption in 1991-1992. Given the magnitude of observed uplift, previous investigations suggested the potential for eruption by 2010 (e.g., Lu et al. 2004), but no such event has occurred. In this study, thermomechanical finite element models are used to evaluate how magma system stability of a glaciated volcano is impacted by variations in ice cap thickness, magma chamber depth, geometry, magma flux rate, and seasonal changes in ice cover thickness. The generic ice cap model is then applied to investigate the current unrest and stability of the Westdahl system. Our numerical experiments indicate that presence of an ice cap (1-3 km thick) increases the average repose interval for a magma system. The greatest increases in repose interval are observed in prolate systems where the increase is up to 57% for a chamber located at 5 km-depth. Additionally, the percentage increase in repose interval is not impacted by variations in magma flux rate for a given ice cap thickness and magma chamber geometry. Our numerical estimates further suggest that the ice capon Westdahl Peak, which is ~ 1 km-thick, may slightly increase the stability of the magma system and repose interval by ~7 years. This increase is small on a geologic scale, but significant on human time scales and the impact of glaciers must be considered in future forecasting efforts.

262

Unrest Dynamics of Domuyo Volcano, Argentina: Multiphysics Models Constrained by InSAR and Thermal Time Series

Dr Paul Lundgren[1], Dr Yan Zhan[2], Dr Társilo Girona[3], Dr M. Grace Bato[1], Dr Carlos Cardona[4]
[1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, United States, [2]Earth System Science Programme, Chinese University of Hong Kong, Hong Kong, China, [3]Geophysical Institute, University of Alaska Fairbanks, Fairbanks, United States, [4]Observatorio Vulcanológico de los Andes del Sur, Servicio Nacional de Geología y Minería, Temuco, Chile

Domuyo volcano is a large silicic system that has experienced a cycle lasting more than a decade of deflation-inflation-deflation, with a low-temperature thermal anomaly showing a similar but lagged cooling-warming time series. In this update to our recent work on this system we present, for the first time, a fluid-mechanical magma reservoir coupled with Darcy flow of volatiles through the crust to model the observed geodetic and thermal time series. While our focus is Domuyo, the model is general and should be relevant to other volcanic systems where gentle deflation-rapid inflation time series are observed. Domuyo volcano is a large (4700 m high) system with the second largest hydrothermal system in the world, despite its most recent effusive eruption dating to ~100,000 years before present. InSAR time series from several satellites (ALOS, RADARSAT-2, ALOS-2, and Sentinel-1) shows deflation (2008-2013), pause (2013-2014.5), then rapid inflation, up to ~70 cm in the radar line-of-sight (LOS) through 2020, that is now deflating. During the period of rapid inflation, seismicity also showed a commensurate increase. Low-temperature thermal anomaly time series from MODIS data through 2021 appears lagged with respect to the InSAR time series, suggesting a bottom-up model driven by magma influx. To test this conceptual model, we have developed a preliminary thermo-fluid-mechanical model using COMSOL Multiphysics software. This model couples magma influx into a geodetically constrained flat ellipsoidal source centered at 6.5 km depth with Darcy flow of magmatic steam diffusing through the crust, from the magma source to the surface. The amplitudes and lag times of inflation-deflation and temperature time series are roughly fit by this model. As we continue to extend the time series and refine the models, understanding Domuyo has important implications for the behavior of large silicic, non-erupting systems such as Laguna del Maule and other calderas.

1213

SuPreMeChiF - A New Approach to Detect Subtle Changes in Continuous Monitoring Data

Miss Yizhou Luo[1,2], Dr Benoit Taisne[1,2]
[1]*Earth Observatory of Singapore, Nanyang Technological University, Singapore, Singapore,* [2]*Asian School of the Environment, Nanyang Technological University, Singapore, Singapore*

When looking at global volcano monitoring data, one could note that some eruptions show little to no signs of precursory activity while some have clear indications. Since volcanic activity is the result of perturbations in the system, then why some activities seemed to occur without any precursor? We believe that the inability to detect those changes could be due to the analysis performed or the locations or the type of instruments used, which failed to capture them. To test the effect of the analysis, we are developing a new technique that aims to detect subtle changes in continuous monitoring data that may be overlooked by usual analysis. This new method, named "Subtle Precursor Measurement of Change in Frequency (SuPreMeChiF)", combines statistics with continuous data analysis. It uses Kolmogorov-Smirnov test to calculate the cumulative distribution difference between monitoring features in given reference and sample windows and quantify the amount of change. We first tested SuPreMeChiF on seismic and infrasound data to confirm its detection capability of changes induced by mobility shift during Singapore COVID-19 lock-down period. This case study was chosen because we have a known timeline of changes due to anthropogenic activity to compare our results with. The results are consistent with the COVID-19 timeline and revealed details of the changes that were not indicated in conventional spectral analysis. Not only were the timing of the changes obtained in the analysis, but also the frequency range where changes took place, indicating the potential to retrieve the source physical processes. We then applied the method on monitoring data from Marapi volcano in Sumatra, Indonesia. Our results reassured the capability of detecting subtle abnormality in a system by revealing changes in seismicity before the 2018 phreatic explosions. This quantitative approach also provides insight for future application in automated detections during real-time monitoring.

1233

Basement fault-parallel dual feeder conduits beneath Rangitoto monogenetic volcano, inferred from gravity and magnetic modelling

Mr Alutsyah Luthfian[1], Dr Jennifer Dawn Eccles[1], Dr Craig Miller[2]
[1]*School of Environment, The University Of Auckland, Auckland, New Zealand,* [2]*GNS Science, Taupo, New Zealand*

Rangitoto is the largest and youngest volcano within the monogenetic Auckland Volcanic Field (AVF), New Zealand. Monogenetic volcanoes are typically thought to have a single conduit, feeding a single eruptive episode. However, at Rangitoto, there is geochemical and chronostratigraphic evidence of two eruptive episodes, which has also happened elsewhere in the AVF (e.g. the spatially and temporally close Purchas Hill and Mt. Wellington, also Otara Hill and Hampton Park). As Rangitoto summit stands just 3.5 km from a basement normal fault (the Islington Bay fault), the question arises as to the role of faults in localising the final ascent of magma toward the surface. New 2.5D and 3D models from pre-existing aeromagnetic data and new gravity data potentially image a dual feeder conduit extending to >250 m below sea level, associated with the Rangitoto North and South cones. The north-south alignment of the Rangitoto dual feeder conduit is parallel with the steeply-dipping Islington Bay fault. We propose that the crustal weakness of the Islington Bay Fault may have acted as a primary crustal pathway for magma batches that drove two temporally distinct eruptions, with magma departing from this fault when open vertical hanging wall fractures diverted the magma upwards. Our study suggests that major basement faults within the AVF may play a role in guiding the initial ascent of magma, however the final eruption location may be some kilometres from the fault plane. The implication is that if seismic monitoring is used for tracking magma ascent, deviation from an initial ascent trajectory may occur within the final few kilometres, complicating hazard mitigation measures.

341

Magma storage and transport histories preceding Mauna Loa's 1852 eruption recorded by olivine crystals

Dr Kendra Lynn[1], Frank Trusdell[1]
[1]*USGS Hawaiian Volcano Observatory, Hilo, United States*

Mauna Loa volcano has produced 33 eruptions since 1843, yet the pre-eruptive magma storage and transport histories for these eruptions remain under-constrained. Here we leverage compositions and zoning patterns of olivine from the 1852 eruption to characterize timescales of magma mobilization prior to eruption. Whole-rock and glass chemistry suggest these picrites are the result of olivine accumulation in lower-MgO melts, and olivine was likely sourced from deeper parts of a stratified reservoir [1]. Olivine crystals 0.5-3 mm were carefully oriented down either the a- or b- crystallographic axes and sectioned through their cores [2] and analyzed yielding an exceptional olivine compositional dataset. BSE images (n=119) indicate that 59% of crystals have Fe-Mg zoning that is normal (Focore>Forim), 33% are complexly zoned (recording more than one diffusion event), 6% are reversely zoned (Focore<Forim), and 2% are non-zoned. Preliminary analyses on 1-2 mm crystals (n=56) show that core compositions generally range from Fo82-90 with most Fo87-90, well above typical "reservoir lavas" that would yield Fo77-82 olivine [1]. Most crystals (69%) have Fo87-89 cores normally zoned to Fo85 rims over 50-100 µm. Preliminary diffusion modeling (n=10) yields remarkably consistent Fe-Mg timescales of 15-53 days, indicating that deep-seated high-Fo olivine rose to shallow levels weeks prior to eruption. The host high-Fo magmas originated from deeper in the column and migrated laterally to their vent sites on the NERZ, bypassing the shallowest portions of the reservoir system (consistent with [1]). Complexly zoned crystals have Fo82-85 cores reversely zoned to Fo84-86 shoulders and an outer normal zone with Fo83-84 rims. Shoulder zoning yields more diverse timescales (n=8) that range from weeks to months indicating that magmas may have been mobilizing in a vertically stratified reservoir system over these longer timescales.

[1] Rhodes 1995. AGU Mono 92.
[2] Lynn and DeSmither, in revision. USGS Pubs.

376

Creating oriented and well-sectioned mineral mounts for in situ chemical analyses: An example using olivine for diffusion modeling

Dr Kendra Lynn[1], Liliana DeSmither[2]
[1]*USGS Hawaiian Volcano Observatory, Hilo, United States,* [2]*Research Corporation of the University of Hawai'i, Hilo, USA*

Diffusion chronometry is now a widely applied methodology for determining the rates and timescales of geologic processes from chemical zoning in minerals. Despite its popularity, several challenges still remain during application including: 1) the random sectioning of minerals either in thin sections or grain mounts, where both off-center and oblique sections contribute significant uncertainty to modeled timescales and 2) the incorporation of diffusion anisotropy in models, which requires determining the orientation of crystallographic axes using electron backscatter diffraction (EBSD), a technique that is both challenging and limiting because few scanning electron microscopes have an electron backscatter detector. To overcome these issues, we present a step-by-step methodology for 1) orientation and sectioning of individual crystals or crystal clusters prior to mounting, and 2) orientation of similarly sized crystals or clusters during mounting and subsequent whole-mount sectioning. We utilize olivine crystals from Hawaiian tholeiites oriented down either the a- or b- axes (c-axis in the plane of the section) and prepared using both methods. Crystals were analyzed and modeled for Fe-Mg interdiffusion using assumptions of ideal (i.e., perfect) sections and using EBSD confirmed orientations to correct for anisotropy. Oriented crystals almost always have the c-axis plunging ≤10° from the sectioning plane, resulting in <5% relative uncertainty in calculated diffusion timescale between ideal (e.g., assumed orientation) and EBSD confirmed (e.g., measured) models, dwarfed by the uncertainty from other model inputs (T, P, fO2). Method efficacy is high for euhedral to subhedral crystal morphologies, simple to complex crystals or crystal clusters (including buds and twins), and a range of textures including skeletal and abraded/broken grains. Using this technique, scientists can significantly reduce the uncertainties associated with off-center sections and minimize or completely remove the need for determining crystallographic orientation via EBSD analyses.

503

Crystal Archives of Magmatic Processes Leading to the 2021 Paroxysms at Mt. Etna

Alice Macdonald[1], Teresa Ubide[1], Silvio Mollo[2,3], Jacopo Taddeucci[3]
[1]School Of Earth And Environment Sciences, The University Of Queensland, Brisbane, Australia, [2]Sapienza University of Rome, , Italy, [3]Istituto Nazionale di Geofisica e Vulcanologia, , Italy

Since 1986, there have been over 240 short, explosive, paroxysmal events at the summit of Mt. Etna, Italy. These events are characterised by Strombolian activity, followed by lava fountaining that can last up to hours, and can pose heightened hazards compared to other styles of activity at Etna.

To reconstruct magmatic processes leading to recent paroxysms, we present high resolution major and trace element data of clinopyroxene and plagioclase crystals from lava flows, bombs, lapilli and ash erupted during the February – March 2021 paroxysmal events. We apply a high resolution analytical approach, including FE-SEM, EPMA, XFM and LA ICP-MS analyses across our sample set.

Clinopyroxene can record a protracted history of magmatic processes throughout Etna's vertically extended plumbing system. Major, minor, and trace element data demonstrate that mafic magma injections remobilised deep mush portions in the lead up to volcanism, similar to other eruptive styles at Etna. Importantly, the composition of Cr-rich recharge bands, and resorption of Na-Fe-rich cores, vary between crystals across all sample types, preserving the dynamics of mush disaggregation and convection upon mafic invasion and mixing. In addition, the occurrence of sector-zoning at the rims, and occasionally cores of crystals further track dynamic crystallisation conditions at low degrees of undercooling.

Plagioclase crystallises in the upper portions of the plumbing system as the magma begins to degas. Our samples contain plagioclase with disequilibrium textures, including strong sieve textures, recording the combined effect of mafic recharge and gas flushing prior to eruption.

Overall, when compared to non-paroxysmal activity, crystal textures and compositions are similar, except for disequilibrium plagioclase textures, suggesting key differences in shallow pre-eruptive processes in the lead up to paroxysms.

226

Post-eruption seafloor mapping around Hunga Tonga-Hunga Ha'apai

Mr Kevin Mackay[1], Dr Sarah Seabrook[1], Dr Malcolm Clark[1], Dr Richard Wysoczanski[1], Dr Emily Lane[1], Dr Sally Watson[1]
[1]NIWA, Wellington, New Zealand

Hunga Tonga - Hunga Ha'apai (HTHH), one of 22 volcanoes in the waters around the Kingdom of Tonga, erupted violently on 15th January 2022. This eruption triggered shock waves through the atmosphere and generated a tsunami across the Pacific Ocean. No part of the caldera of the volcano remains above water following the eruption, and the islands of Hunga Tonga and Hunga Ha'apai were vastly reduced in size. During an oceanographic survey 3-months after the eruption, we assessed the impacts of this eruption on the surrounding ocean environment, from underwater topography to ecosystem structure and function. While the HTHH edifice was largely intact, erosional channels were identified radiating out from the summit caldera indicating turbulent pyroclastic density flows which are supported with our modelling. At least 6 km3 of material was deposited on the seafloor in areas downstream of these pyroclastic flows, and >50cm of fine ash deposition was observed on the seafloor in some areas. Mid-water volcanic ash layers north of the HTHH caldera were identified which indicate on-going venting from the volcano. Significant seafloor ecosystem impacts were found throughout much of the region, with little signs of life remaining on the flank of the volcano and along the deeper slope. However, diverse and abundant invertebrate and fish communities were seen on the summits of several of the adjacent seamounts. This study is a rare account of the initial impact of a large-scale eruption which can be used to better understand volcanic risks to the ocean environment in the future.

1013

Tracking the evolution of porosity in mushy gabbroic nodules from the Bárðarbunga volcanic system, Iceland

Xenia Boyes[1], Professor John Maclennan[1], Euan Mutch[2]
[1]*University Of Cambridge, Cambridge, UK,* [2]*Lamont-Doherty Earth Observatory, Columbia University, New York, USA*

Mushes are thought to play an important role in magmatic systems. The processes that control the evolution of porosity and transform mushes into solid rocks are not well understood. A suite of partially-glassy gabbroic nodules from the Bárðarbunga volcanic system in Iceland present an excellent opportunity to provide petrological constraints on the length-scales and time-scales of processes that occur in mushy systems. Thin-section-scale chemical and phase maps were obtained with a QEMSCAN system for 10 mushy nodules. The nodules preserve a solid interconnected framework of primitive crystals (Fo84-86 olivine, An88-90 plagioclase and, more rarely, Mg#~86 clinopyroxene) which are equant, 1-3 mm in size and occupy 60-70% of the sections. The interstitial spaces between these primitive crystals contain basaltic glass, microphenocrysts and overgrowth rims. The rims and microphenocrysts have similar compositions (Fo~75 olivine, An~75 plagioclase, Mg#~78 clinopyroxene) and are close to chemical equilibrium with the glass. If the mush had remained a closed chemical system during crystallisation of the rims and microphenocrysts then the overall composition of the interstitial material between the primitive crystals would be equivalent to that of a mush liquid in equilibrium with those crystals. This overall composition was estimated from the QEMSCAN maps and was found to be significantly out of expected equilibrium with the primitive crystals. Therefore, the infilling of the porosity in the mush by crystallisation was accompanied by chemical exchange with the liquid outside the nodule. Diffusion chronometry indicates that this exchange occurred several months prior to eruption of the mushy nodules and provides novel constraints on the timescales of processes in magmatic mushes.

1017

Deep magma mobilisation years before the 2021 Fagradalsfjall eruption, Iceland

Maren Kahl[2], Euan Mutch[3], Professor John Maclennan[1], Daniel Morgan[4], Fiona Couperthwaite[5], Enikő Bali[6,7], Thor Thordarson[7], Guðmundur Guðfinnsson[6], Richard Walshaw[4], Iris Buisman[1], Stephan Buhre[8], Quinten van der Meer[6], Alberto Caracciolo[6], Edward Marshall[6], Maja Rasmussen[6], Catherine Gallagher[6], William Moreland[9], Ármann Höskuldsson[9], Robert Askew[10]

[1]University of Cambridge, Cambridge, UK, [2]Universität Heidelberg, Heidelberg, Germany, [3]Lamont-Doherty Earth Observatory, Columbia University, New York, USA, [4]University of Leeds, Leeds, UK, [5]Oregon State University, Corvallis, USA, [6]Nordic Volcanological Centre, Institute of Earth Sciences, University of Iceland, Reykjavik, Iceland, [7]Faculty of Earth Sciences, University of Iceland, Reykjavik, Iceland, [8]Johannes Gutenberg Universität Mainz, Mainz, Germany, [9]Institute of Earth Sciences, University of Iceland, Reykjavik, Iceland, [10]Icelandic Institute of Natural History, Garðabær, Iceland

The deep roots of magmatic systems play a key role in the priming, initiation and endurance of volcanic eruptions. Causative links between initial magmatic unrest at depth, and later eruption triggering remain poorly constrained. The 2021 eruption at Fagradalsfjall in SW Iceland, the first deep-sourced eruption on a spreading ridge system monitored with modern instrumentation, presents an ideal opportunity to compare geophysical and petrological datasets to explore processes of deep magma mobilisation. Here we use diffusion chronometry to show that deep magmatic unrest in the roots of volcanic systems can precede apparent geophysical eruption precursors by a few years. Early phases of magma accumulation and reorganisation in the near-Moho plumbing system, part of the priming for eruption, can occur in the absence of significant increases in shallow seismicity (<7 km depth) or rapid geodetic changes. In contrast, geophysical signals of unrest and crystal records of changing magmatic conditions both show significant increases in intensity over the months and days prior to eruption. This correlation may signal a rapid transition from a state of priming to full scale mobilisation in which magma begins to traverse the upper/brittle crust. Our findings provide new insights into the dynamics of near-Moho magma storage and mobilisation. Monitoring approaches optimized to detect early phases of magmatic unrest in the lower crust, such as careful identification and location of deep seismicity, could potentially improve our response to future eruptive crises.

613

Subsurface structure and recent activity of Mt. Ontake, central Japan

Dr Yuta Maeda[1], Dr Toshiki Watanabe[1], Dr Toshiko Terakawa[1], Dr Yoshiko Yamanaka[1], Mr Shinichiro Horikawa[1]
[1]*Nagoya University, Nagoya, Japan*

Mt. Ontake is an active volcano that has repeated phreatic eruptions. We investigated the subsurface structure and recent activity of this volcano to better understand its shallow hydrothermal system.
We estimated a typical P-wave velocity in the summit region using vertical propagation of intermediate-depth (~250 km) earthquakes (IDEs) from the Pacific plate. Using the result (~2600 m/s) as the starting model, we investigated a layered model using P- and S-wave arrivals of shallow volcano-tectonic (VT) earthquakes. We also investigated reflection profiles by autocorrelating the IDE waveforms. The results suggest a three-layer model composed of new (< 0.1 Ma) and old (> 0.4 Ma) lavas and the basement, with boundaries at ~1800 and ~800 m above sea level. A comparison of the results with several other studies (Asai et al., 2006; Maeda et al., 2017) suggests that the old lava works as a barrier for fluid migration.
The VT seismicity has gradually decreased since the 2014 eruption, which turned into a sudden increase from late February to early March 2022. Most events during this period were located in the basement layer. Waveform inversion of very long period signals that accompanied some of these events suggested inflation of 10^{14}-10^{15} N m, which were by 1-2 orders of magnitude smaller than that of the 2014 eruption. The results suggest a moderate fluid migration not enough to break the barrier to move upward, unlike the 2014 eruption (Maeda et al., 2017).

We used the hypocenters located by Junko Sumida and Eri Hibino. We used seismic records from the Japan Meteorological Agency, Nagano and Gifu prefectures, and the National Research Institute for Earth Science and Disaster Resilience. This work was supported by JSPS KAKENHI Grant Number JP19K04016, the Second Earthquake and Volcano Hazards Observation and Research Program, and ERI JURP 2022-F2-02.

496

Seawater-magma interactions sustained the high water-rich column during the 2021 Fukutoku-Oka-no-Ba eruption, Ogasawara, Japan

Dr Fukashi Maeno[1], Dr Takayuki Kaneko[1], Dr. Mie Ichihara[1], Dr. Yujiro Suzuki[1], Dr. Atsushi Yasuda[1], Dr. Kiwamu Nishida[1], Professor Takao Ohminato[1]
[1]Earthquake Research Institute, University Of Tokyo, Tokyo, Japan

Phreatomagmatic eruptions are among the most hazardous types of volcanic eruptions on Earth. Direct observational data from substantial phreatomagmatic eruptions are, unfortunately, limited. How magma interacts with seawater in the shallow water environment, the relationship between mass discharge rate and plume height in such conditions, and their transition in real space and time are most poorly constrained. In this presentation, we show how rapidly ascended magma interacted with seawater in a shallow sea environment based on a high-resolution timeseries record of a sizeable phreatomagmatic eruption at the Fukutoku-Oka-no-Ba volcano (FOB), Ogasawara, on 13 August 2021. We analyse the surface phenomena and their transitions during this eruption using satellite imagery, aerial photos, infrasound data, plume modelling, and geochemistry and discuss the interaction between magma and ambient seawater. The eruption started on the seafloor at a depth of <70 m and breached the sea surface to produce a 16-km-high, water-rich sustained eruption column. The magma volume, ~0.1 km³, including the tuff cone and the pumice raft, is consistent with SO_2 emissions estimated from satellite observations and geochemistry. Chemical analyses of the pumice clasts indicate that the eruption consisted of trachytic magma with glass compositions reaching 68 wt.% SiO_2. Most eruption and deposit observations can be explained by the effective near-vent accumulation of pyroclasts emitted during jet-seawater interactions fed by magma discharging at a rate of 3–6 ×10^5 kg/s. Our key finding is that even if the major portion of the pyroclastic materials ejected from the submarine vent is not released into the atmosphere, it can cause the eruption plume to grow very large when the magmatic heat is efficiently consumed to vapourise the seawater. Therefore, the relationship between the erupted mass and the plume height in explosive submarine eruptions is not as straightforward as proposed for on-land eruptions.

1196

RiskScape® for multi-hazard multi-phase volcanic risk assessment

Dr Christina Magill[1], Dr Alana Weir, Dr Josh Hayes, Dr James Williams, Dr Nick Horspool, Dr Heather Craig, Dr Victoria Miller, Nick Griffith, Tim Beale
[1]*GNS Science, Lower Hutt, New Zealand*

RiskScape® is open-source software to deploy deterministic, stochastic or probabilistic, single- or multi-hazard risk assessment models. A key feature of RiskScape® is its geospatial capabilities that allow geoprocessing and spatial sampling, and for hazard and exposure information to be geographically combined. Risk functions (fragility or vulnerability) are called within workflows or 'pipelines' to allow quantification of impact and risk.

The flexibility of RiskScape® makes it an ideal solution for the complexity of volcanic risk assessment. Development of pipelines means that impacts from multi-phase or long-duration eruptions can be calculated; impacts from different hazard types (e.g., ash-fall followed by lahar) can be cumulated; physical impacts to buildings and linear infrastructure can be assessed alongside agricultural, health and societal outcomes. We will present examples of how RiskScape® has been used for probabilistic tephra hazard and risk assessment (Aotearoa New Zealand and Japan), to prepare for future eruption scenarios (Taranaki and Ruapehu, Aotearoa New Zealand), and to respond to volcanic crises (2022 Hunga eruption, Tonga).

1193

A volcanic hazard and impact assessment for Mount Erebus, Antarctica

Dr Christina Magill[1], Dr Josh Hayes, Dr Marwin Katurji, Dr Adam Martin, Ceisha Poirot, Dr Dongqi Lin, Dr Rebecca Fitzgerald, Dr Craig Miller, Professor Thomas Wilson, Dr Sarah Inglis, Dr Graham Leonard
[1]*GNS Science, Lower Hutt, New Zealand*

Mount Erebus, located 36 km to the south of Scott Base, presents a volcanic hazard to National Antarctic Programmes operating in the Ross Sea region. A review of the potential exposure of people and infrastructure at Scott Base to volcanic hazards and their impacts was conducted, including a volcanic hazard likelihood assessment, ash-fall modelling for Mount Erebus volcano, an impact assessment and consideration of monitoring options.

Probabilistic modelling using Tephra2 found that ash thicknesses exceeding 0.5 mm occurred at Scott Base, on average, less than every 1000 years; a lighter dusting of ash (~0.1 mm) is expected on average every 100 years. Deterministic modelling using Ash3D demonstrated that a large eruption (VEI 5) may result in 0–24 mm of ash deposition at Scott Base, depending on the wind conditions at the time. Ash concentrations over Scott Base may rapidly rise and remain very high for several hours.

Damage to facilities and disruption of services may occur under future ash-fall events, but the likelihood and severity will depend largely on the amount of ash-fall accumulation. Many of the impacts could be mitigated by ash fall management plans. The hazard and impact analyses highlighted still unknown aspects of the eruptive history and current magmatic system of Mount Erebus.

1279

Volcanic debris avalanche propagation mechanisms and dynamics: field evidence and analogue experiments

Mr Symeon Makris[1], Dr Irene Manzella[1,2], Dr Matteo Roverato[3], Dr Paul Cole[1], Dr Alejandro Lomoschitz[4], Dr Alessandro Sgarabotto[1]

[1]University Of Plymouth, Plymouth, United Kingdom, [2]Department of Applied Earth Sciences (AES), Faculty of Geo-Information Science and Earth Observation (ITC), University of Twente, Enschede, The Netherlands, [3]Department of Earth Sciences, University of Geneva, Geneva, Switzerland, [4]Instituto de Oceanografía y Cambio Global, Universidad de Las Palmas de Gran Canaria, Las Palmas de Gran Canaria, Spain

Volcanic debris avalanches (VDAs) initially propagate as slides and usually evolve into flows. Their long runouts and destructive potential pose a great hazard. However, the mechanisms enabling their extreme mobility remain poorly constrained due to the difficulty of theoretical models to interpret and represent field observations. In this study, findings from field studies combined with analogue experiments provide insights into their propagation mechanisms and dynamics.

Two deposits in the Canary Islands with distinct characteristics are examined: Tenteniguada (Gran Canaria), and Abona (Tenerife). The field study examines their facies distribution and sedimentology. 3D models of outcrops and sample windows were generated using structure-from-motion photogrammetry to quantify sedimentological properties. Evaluating this data allows the generation of conceptual models for their propagation dynamics. Tenteniguada is principally composed of competent lava lithologies. Disaggregation is low, with widespread preservation of the original structure, although displaced by brittle deformation. The deposit represents propagation by normal fault-accommodated spreading. In contrast, the majority of Abona is composed of weak pyroclastic products. It exhibits high disaggregation and microfracturing, constituting the mass granular and enabling fluidised spreading with distributed shear. Propagation dynamics and stress distribution in the two events were different, owing to material properties.

The study of Abona supports the theory that VDAs can behave as granular flows with interacting particles exchanging and dissipating energy. In addition to field evidence, small-scale granular flow analogue experiments are employed to evaluate particle interactions and energy exchange processes.

The findings suggest that VDA mobility does not require auxiliary friction-reducing mechanisms. It is suggested that purely gravity-driven avalanches can evolve into flows due to increasing momentum and kinetic energy from their initial potential energy. However, other mechanisms can also enable long runouts according to material properties. The study highlights the effectiveness of coupling field examinations and physical experiments in understanding VDA dynamics.

1027

The impact of tephra on agriculture: systemic analysis of farms' structure and functioning reveals contrasting vulnerability

Ms Sophie Malherbe[1], Ms Marine Donfut[1], Ms Noa Ligot[1], Dr Fabien Stark[3], Mrs Suyin Jamoralin[4,5], Mrs Jhana Tejome[4], Mrs Karlenma Mendoza[2], Mrs Virginia Talens[2], Professor Pierre Delmelle[1]
[1]Université Catholique De Louvain, Louvain-La-Neuve, Belgium, [2]Climate Change Network for Community-based Initiatives (CCNCI), Quezon City, Philippines, [3]Institut national de recherche pour l'agriculture, l'alimentation et l'environnement (INRAE), Montpellier, France, [4]Viva Salud, Bruxelles, Belgium, [5]Solidagro, Saint-Nicolas, Belgium

Young volcanic soils developed on tephra deposits have an outstanding agronomical potential and, as such, attract a large and dense population that draws its livelihood from their use. Ironically, being often collocated with Holocene volcanoes, agriculture on these soils is threatened by tephra fall during explosive eruptions. Most studies dealing with agriculture vulnerability to tephra focus on crops and attempt to describe their susceptibility to tephra damage using a "dose-response" model where the expected yield loss relates to tephra thickness. However, agriculture cannot be reduced to crops only as it is comprised of farming systems, themselves consisting of combinations of cropping and livestock activities and the resources available to the farmers to raise them for their production purposes. Here we aim to assess the potential vulnerability to tephra fall of farms that diverge in their structure and functioning. Our study took place in the rural region near Taal volcano, Philippines. We conducted semi-structured interviews in seven farms. The data collected allowed us to generate a quantitative description of the farming system's components, inputs and outputs and production fluxes. Visualisation of the results with a System Network Analysis revealed contrasting farm structures, ranging from a pineapple monoculture to a complex system with various field crops, fruit trees and livestock, all interacting with one another. We then assessed the farms' vulnerability to tephra fall by considering two fictitious scenarios of tephra accumulation on the ground and their potential impacts on each component of the farm. We used the holdings' gross revenue as a metric of impact intensity. The findings suggest complex patterns of vulnerability depending on the level of interactions between the farm's components. Financially, the biggest losses may originate from the cattle's vulnerability. We argue for the use of a systemic approach for assessing volcanic risk to agriculture.

650

Trace element transport in volcanic gases at Vulcano, Italy

Dr Celine Mandon[1], Dr Andri Stefansson[1], Dr Franco Tassi[2]
[1]University Of Iceland, Reykjavík, Iceland, [2]University of Florence, Florence, Italy

Metals and magmatic systems are closely associated. Many of the exploited ore deposits formed within magmatic-hydrothermal systems, while metal-rich toxic plumes are emitted at degassing volcanoes. Understanding the volatile transport of these elements is therefore important. Our study focuses on trace element transport at Vulcano in the mid-temperature fumaroles of 2008-2012 and during the recent unrest in early 2022. Major gas composition shows the previously described magmatic and hydrothermal contributions, varying in space and time, and a sharp decrease in HCl content in 2022. Two samples with typical magmatic composition were chosen for thermochemical calculations, with low and high HCl contents respectively. For trace element composition, we used an average value from 35 fumarolic condensates. We distinguish elements depending on their gaseous transporting ligand and the type of sublimates they form as temperature decreases. Only few elements (Au, Se, Te, As) are systematically transported as sulfur compounds at high-T, while the role of S increases in low-Cl gases for Pb, Bi and Sn. Chlorine is the major ligand for transition metals from column 7 to 12, with increasing elemental transport or hydroxide complexing at low-Cl content for Zn, Ag, Cd and Fe, Co, Ni respectively. Transition metals from the first three columns show the influence of both halogens (Cl, F) and water (O, OH) as ligands. Chemical reactions are associated with deposition, with most of the sublimates predicted to form of different nature than the gaseous compounds. However, despite equilibrium thermodynamics predicting deposition of most trace elements with decreasing temperature, samples from mid-temperature fumaroles show that only a small mass is actually lost to solids. Our results therefore reveal the importance of kinetics, and by extent gas flux in the subsurface, and the role of ligand availability rather than temperature on volatile transport.

646

Controls on plagioclase shape during interface-limited growth in rhyodacitic and basaltic melts

Dr Martin Mangler[1], Dr Madeleine C.S. Humphreys[1], Eshbal Geifman[1,2], Dr Alexander A. Iveson[1], Dr Fabian B. Wadsworth[1], Dr Richard Brooker[3], Keiji Hammond[4]

[1]Durham University, Durham, United Kingdom, [2]Trinity College, Dublin, Ireland, [3]University of Bristol, Bristol, United Kingdom, [4]American Museum of Natural History, New York,, USA

Crystal shape is the product of a competition between its thermodynamic equilibrium shape and the kinetics of crystal growth. Specifically, euhedral crystal shapes are often considered to reflect thermodynamic equilibrium attained during interface-controlled growth at low undercoolings, whereas kinetic controls over crystal shape are only invoked for diffusion-limited growth at high undercoolings. The established paradigm associated with this view is that crystals shapes reflect undercooling, with higher undercoolings producing more elongated crystal shapes. However, euhedral microlite shapes in natural volcanic rocks have recently been shown to systematically change from prismatic to tabular during growth, questioning the concept of a straightforward relationship between undercooling and shape.

Here, we conducted interface-controlled crystallisation experiments in a basaltic and a hydrous, silicic melt to trace plagioclase shape evolution during post-nucleation growth and explore potential kinetic effects on euhedral crystal shapes. No clear relationship between crystal shape and undercooling is observed; instead, we find that plagioclase shape depends on nucleation density and the relative rates of diffusion and interfacial reaction. As with natural rocks, this results in a systematic variation in crystal shape from prismatic to tabular with increasing size. Crystallisation from the basaltic melt produced generally higher plagioclase aspect ratios, with relative growth rates along the 3D short and intermediate crystal dimensions varying from 1:6–1:20 in the basaltic melt and from 1:2.5–1:8 in the rhyodacitic melts. The discrepancy in relative growth rates between basaltic and silicic melts scales with differences in melt viscosity, suggesting a significant role for diffusivity in controlling crystal shape even outside a diffusion-limited growth regime. The findings of this experimental study illustrate the fundamental controls on plagioclase crystal shape across a wide range of igneous rock types, and highlight the importance of considering crystal shape variations in quantitative textural studies of volcanic rocks and their experimental analogues.

1380

A unified approach for improving global preparedness for large magnitude volcanic eruptions

Dr Lara Mani[1], Dr Pablo Suarez[1,2], Dr Mike Cassidy[3]
[1]Centre for the Study of Existential Risk, University Of Cambridge, Cambridge, United Kingdom, [2]Red Cross and Red Crescent Climate Centre, The Hague, Netherlands, [3]School of Geography, Earth an Environmental Sciences, University of Birmingham, Edgbaston, United Kingdom

The eruption of the Hunga Tonga Hunga Ha'api volcano in the South Pacific in early 2022 provided us with a unique opportunity to assess our global preparedness for a potential future large magnitude volcanic eruption. The eruption, despite its short duration (just a few hours), was one of the highest intensity eruptions recorded with modern instruments. It sent a shockwave around the world, triggered tsunamis in two oceans, and caused severe disruption and damage to the Kingdom of Tonga. In the immediate aftermath of the eruption, the severing of submarine cables and damage to critical infrastructure left Tonga shut off from the outside world. As the eruption unfolded disaster risk managers and humanitarians scrabbled to understand the severity of the crisis, uncertain of where to seek information vital to help coordinate their emergency response. With the risk of large magnitude eruptions estimated at 1 in 6 per century, more must be done to increase our preparedness for such events.

In order to address this, in September 2022 we convened a workshop bringing together a group of interdisciplinary researchers from volcanology, climate science, and food security along with disaster risk managers, humanitarians, policy makers, journalists, and artists. Through a range of interactive discussions and activities, participants were challenged to consider how we can best prepare for large magnitude eruptions and develop actionable recommendations for increasing our resilience. Here, we will discuss the outcome of the workshop and what actions might be most effective for mitigating the impacts going forward. Some recommended actions included the need for a coordinated organisation responsible for collating information to support rapid response campaigns during volcanic eruptions, including the provision of satellite imagery and pinpointing the risk localities, as well as increasing and improving volcano monitoring, and pre-eruptive preparedness.

227

TWiCE: A New Tephra Fall Simulation Code Based on Advection–Diffusion Model Running on GPU

Dr Kazutaka Mannen[1]
[1]Hot Springs Research Institute Of Kanagawa Prefecture, Odawara, Japan

Quantitative reconstruction of eruption parameters such as erupted volume and total grain size distribution is one of the major goals of volcano geology. Recent development of tephra simulation codes allows such reconstructions using inversion approach. However, since inversion calculation requires many calculations, the simulation code must be very fast. This is especially true for isopach reconstruction because drawing isopach requires numerous mass loading calculation on the points aligned in a grid. I thus decided to use GPU (Graphics Processing Unit) for the calculations to deduce computation time significantly and developed a new code from scratch.

The new code named TWiCE (Tephra simulation code for Windy Conditioned Eruption) is based on an advection-diffusion model and its prototype is WT, which is a modified version of Tephra2 to simulate tephra fall from eruption plumes bent by wind. Tephra2 and WT were written in C language and use structures to store data such as calculation points and plume trajectory. However, these data are stored as array of structures (AoS), which is not advantageous for data transfer to the GPU. This was the principal reason for the complete rewrite.

TWiCE was developed in CUDA C, NVIDIA's development environment for GPUs, and has two versions: one that uses the GPU and one that uses only the CPU. The CPU version of TWiCE is about 20% slower in computation than WT, but the GPU version of TWiCE runs on NVIDIA GeForce 3060 is up to 30 times faster than the CPU version on Ryzen 9 5900X. The next step of this project will be further speedups by omitting calculations that hardly affect the final calculation results, or by hiding memory latency by using streams.

1291

Tracking magma pathways in the Southwest Rift Zone and the Koaʻe fault zone (Kīlauea volcano) using structural observations and photogrammetry

Mr Stefano Mannini[1], Dr Joël Ruch[1], Dr Carolyn Parcheta[2], Dr Richard Hazlett[3], Dr Drew Downs[2]
[1]University Of Geneva, Geneva, Switzerland, [2]USGS Geological Survey - Hawaiian Volcano Observatory, Hilo, United States of America, [3]University of Hilo, Hilo, United States of America

Normal faults, monoclines and graben structures are key surface features for tracking the magma pathways at depth beneath basaltic volcanoes and at divergent plate boundaries. However, the relation between magma propagation and faulting at the surface is still not well understood. Kīlauea volcano is characterized by a central caldera bordered by two rift zones (East and Southwest Rift Zones) and is prone to recurrent flank instability. The Southwest Rift Zone and the connecting Koaʻe fault zone are major structures controlling the magma propagation. This rift zone was affected by dozens magmatic intrusions in the last few centuries. The connection between surface faulting and magma intrusion is poorly studied, despite the faults' importance in controlling the magma pathways.

In March 2022, we completed five surveys over the south flank area acquiring high-resolution images (~ 4-5 cm ground resolution). We used a photogrammetry platform fixed beneath the aircraft with a high-resolution camera connected to an onboard Global Navigation Satellite System (GNSS). Approximately 9300 images were acquired that cover 72 km2 over Koaʻe fault system and Kaʻū desert. From this imagery, using Photoscan Metashape, we generated high-resolution DEM (~8 cm) and orthomosaics (~4 cm). First results of a detailed structural map show small nested grabens, monoclines, and en-echelon fractures. We infer that these structures are the surface expressions of past magma intrusions, with direct implication for understanding the location of future eruptions.

1293

Volcano flank motion imaged by historical air photo correlation during the M7.7 Kalapana earthquake (1975), Big Island, Hawaii

Mr Stefano Mannini[1], Dr Joël Ruch[1], Dr James Hollingsworth[2], Dr Donald A. Swanson[3], Dr Ingrid Johanson[3]
[1]University of Geneva, Geneva, Switzerland, [2]ISTerre University of Grenoble, Grenoble , France, [3]U.S. Geological Survey - Hawaii Volcano Observatory, Hilo, United States of America

Volcanic islands are often subject to flank instability, resulting from a combination of magma intrusions along rift zones, gravitational spreading and extensional faulting observed at the surface. The Kīlauea is one of the most active volcanoes on Earth and its south flank shows recurrent flank acceleration related to large earthquakes and magmatic intrusions.

We focus on the 1975 Kalapana earthquake (M 7.7) that caused ground displacement of several meters over the entire south flank of the Kīlauea volcano. The identification and quantification of the co-seismic rupture aim to better understand the processes of the overall flank destabilisation and its possible connection to key structural components, such as the deep basal detachment where large earthquakes episodically nucleate. We used 26 and 22 historical air photos as pre-event (October 1974 and July 1975, respectively) and 7 and 44 for the post-event time period (December 1976 and March 1977, respectively) to quantify the ground displacement of the volcano's south flank. The resulting displacement maps show metrical horizontal and vertical displacement along a 25 km long East-West sector of the Kīlauea south flank. We show that the ground rupture is continuous with most portions of faults that have been reactivated in agreement with EDM and levelling measurements. Several fault segments have been activated close to the seashore and their extension were previously unnoticed. The deformation turns out to be higher where the faults are oriented NE-SW (western sector) compared to E-W oriented structures. This suggest that the flank is likely strongly influenced by gravitational effect, typical from large landslide processes. Episodic flank motions on volcanic islands are rare events and this work contributes to the overall comprehension of volcano flank instability elsewhere.

1081

An integrated approach to understand tsunamigenic flows in volcanic environments, the case of Stromboli volcano (Italy)

Dr Irene Manzella[1,2], Symeon Makris[2], Dr Federico Di Traglia[3], Dr Paul Cole[2], Dr Daniele Casalbore[4], Dr Karim Kelfoun[5]

[1]Faculty of Geo-Information Science and Earth Observation, University of Twente, Enschede, Netherlands, [2]School of Geography, Earth and Environmental Science, University of Plymouth, , UK, [3]Osservatorio Vesuviano, Istituto Nazionale di Geofisica e Vulcanologia, Napoli, , Italy, [4]Dipartimento di Scienze della Terra, Università Sapienza di Roma, , Italy, [5]Laboratoire Magmas et Volcans, Université Clermont Auvergne, Clermont-Ferrand, , France

Tsunamis generated by landslides and pyroclastic density currents are complex, cascading phenomena. The higher magnitude events, which are usually the most disruptive, have a relatively low frequency and as a consequence, there is a general scarcity of data, understanding and awareness of these processes.
In this framework, the analysis of past events becomes important for improving the modelling of these tsunamigenic flows in an hazard predictive perspective.

In the present research, we have analysed both low-magnitude / high-frequency tsunamigenic events and high-magnitude/low-frequency ones in Stromboli Volcano, Italy. In this endeavour we have combined remote sensing, marine survey, fieldwork and literature data to constrain the material involved, the type of flows and the pathway along which they have travelled. We also back-analysed these events with the two fluids version of VolcFlow, a continuum mechanics model developed by the Laboratoire Magmas et Volcans (France), to assess the rheology and the behaviour of the flows.

Once the Constant Retaining Stress rheology has been identified as the best fitting one, we undertook parametrical studies to determine sensitivity to different factors of these phenomena and significant thresholds of volume and discharge of mass flows which could trigger significant tsunami waves.

The present study shows that a comprehensive approach is key to accurately constraining events of this type and that back analysis of previous events is critical to better assess and understand the hazard associated with such complex cascading phenomena.

1356

The Centre for Disaster Resilience (CDR): technology and society for risk reduction

Dr Irene Manzella[1], Dr Dinand Alkema[1], Dr Ling Chang[1], Dr Heather Handley[1], Stephanie Hessing[2], Prof Andy Nelson[1], Dr Frank Ostermann[1], Prof RIchard Sliuzas[1], Prof Freek van der Meer[1], Prof Mark van der Meijde[1], Prof Daphne van der Wal[1], Prof Cees van Westen[1]
[1]Faculty of Geo-Information Science and Earth Observation, ITC, University of Twente, Enschede, Netherlands, [2]MD 4TU Resilience Engineering and MT Digital Society Institute, University of Twente, , Netherlands

Our growing population is increasingly affected by the occurrence and impacts of disasters calling for more effective approaches to build resilience. This requires innovative and effective tools to monitor disasters, assess damages, manage and mitigate risk and in community-based, participatory co-production and implementation.

The recently founded Centre for Disaster Resilience (CDR: https://www.itc.nl/cdr), at the Faculty ITC of the University of Twente, aims at reaching a tangible impact by developing tools and approaches that embody geo-information technologies. This will be achieved through synergetic collaborations with groups and institutions working on disaster resilience nationally and internationally, in academia, policy and practice. By following open science principles, the products of our work will be open and accessible for communities, scientists and practitioners. Examples of such outputs include real-time monitoring systems for natural, complex, and cascading hazards using spaceborne and airborne observations, tools to improve climate risk and forecast-based financing solutions, 4D modelling of multi-hazard processes and risk, and collaborative decision support systems for risk reduction.

Because of the intrinsic interdisciplinarity of disaster management and resilience, the development of new communication strategies and the implementation of a collaborative and transdisciplinary approach will be at the core of our Centre and we will work to fuse academic cultures in geoscience, engineering, data science, social science, health, humanities, media, and the creative arts while engaging with non-scientific stakeholder communities.

Ultimately, together with our partners we will develop, support, and implement strategies and activities with the overarching aim of increasing the well-being of communities worldwide, enhancing sustainability and resilience by significantly decreasing disaster risk.

364

The giant Parathetys Mn deposits and the role of 33.4 Ma Rhodope supereruption: inferences from Obrochishte and Binkilic deposits

Professor Peter Marchev[1], Dr. Brian Jicha, Dr Raya Raicheva, Professor Aral Okay, Professor Irena Peytcheva
[1]*Geological Institute of Bulgarian Academy Of Sciences, Sofia, Bulgaria*

A number of giant Mn deposits formed in the Paratethys region during the Early Oligocene (Rupelian). Examples include large Obrochishte (Bulgaria), Chiatura (Georgia), Nikopol (Ukraine), Binkilic deposits (Turkey) and smaller deposits in Hungary and Slovakia. Combined, these deposits contain ~ 600 × 106 metric tons of Mn reserves, which makes the region the second largest accumulation of Mn in the world, after Kalahari Manganese Field.

The origin and source of metals of the deposits are a matter of long-standing debate. Despite convincing evidence for the existence of volcanic ash and its alteration products, the volcanogenic origin of the deposits has not been discussed. Here, we present high-precision sanidine 40Ar/39Ar and zircon U-Pb LA-ICPMS ages for the Obrochishte (Bulgaria) and Binkilic (Turkey) Mn deposits. We propose a new conceptual model for the formation of these deposits based on their contemporaneity with the 33.38 Ma Rhodope Massif Duzhdovnitsa supereruption, Bulgaria.

The eruption expelled enormous amount of ash and gases (H2O, CO2, S, Cl and F), their acids (H2SO4, HCl and HF), and volatile metals that affected the stratospheric chemistry and reacted with water to form acids and metal salts. These adsorbed on the ash surface to form aerosols particles, which settled on the sea surface and sank through the water column. The absorbed acid salts dissolved instantaneously and released high amounts of Mn, Fe, Si and P, whereas the dissolution of volcanic gases created anoxic-exilic conditions, a prerequisite for Mn deposition. The concentration of the dissolved metals depends on the metal supply and the volume of water. Although the supply of ash to shallow and deeper seas was likely similar, Mn deposits formed only in the shallow sea and lagoon basins where reaction of abundant Mn2+ and Ca2+ ions with volcanic and dissolved CO2 precipitated Mn-Ca and pure Ca carbonate minerals.

1470

Reconstruction of the recent effusive activity of the Stromboli volcano as a contribution to the evaluation of future scenarios

Professor Maria Marsella[1], dr mauro coltelli, dr jose palenzuela
[1]Sapienza University, Rome, roma, Italia

The morphological evolution of the Sciara del Fuoco, Stromboli, is described from a time series dataset formed by Digital Elevation Models and orthophotos derived from historical contour maps and maps and observations from aerial and satellite surveys carried out between 1954 and 2022. These analyses led to the quantitative reconstruction of the lava flows emplaced on the Sciara del Fuoco slope whose volumes were estimated also considering erosion rates and the volumes that presumably developing along the submarine portion of the slope. The results of this analysis constrain the interpretation of the evolution and the magnitude of the recent effusive activity at the Stromboli volcano and contribute to understanding the recent effusive eruptive styles at Stromboli volcano that is a crucial aspect for the assessment of future scenarios.

610

Utilizing a Portable ROV for Measuring Submarine Volcanic Emissions

Alexander James Marshall[1], Dr C. Ian Schipper[1], Dr Cynthia Werner[1], Mr Marco Rebecchi[1], Ms Cassandra Trinh-Le[1]
[1]*Victoria University Of Wellington, Mt. Victoria, New Zealand*

Submarine volcanoes are infrequently studied, and little is known about their eruption dynamics and warning signs. Recent and historical eruptions have proven that they can be extremely destructive, and often display very few observable precursors. The goal of our study is to utilize the Boxfish® submersible ROV (Remotely Operated Vehicle) to create detailed emission profiles for active volcanic and hydrothermal vents below Aotearoa (New Zealand) lakes and offshore volcanoes, with the goal of extending our research out to the Vanuatu volcanic arc.

The Boxfish ROV is an innovative technology that we are utilizing to improve methods for monitoring submarine volcanoes and create new pathways for marine education. The ROV has native 4K videography capabilities, and is navigable to 300 metres below sea level, with high-precision positioning by linked GPS/Ultra Short Baseline (USBL) telemetry. Multiple sensors, including coupled CTD and pCO_2 IR sensors have also been added for measuring temperature, pH, conductivity, and partial pressure of CO2 in water columns. This technology will be used to view and monitor chemical and physical changes at submarine volcanic vents to document their activity and behaviour.

We utilize the high-resolution information from 4K video and precise positioning to achieve 3D photogrammetry to study the morphology of submarine vents and assess changes in time. Elaborate navigation and underwater coordinate collection combined with simultaneous gas and temperature measurements, allows for comprehensive vertical profiles to be created and updated for monitoring of vent conditions.

Additionally, we are creating a virtual reality experience to be used in partnership with Wellington University Coastal Ecology Laboratory (WUCEL) for the use of outreach and education on the region's submarine environments.

Here, we present a first-look at ongoing technological developments and ROV deployments, that will assist in demystifying the volcanic emissions from hidden, subaqueous, volcanic vents.

823

Petrogenetic models for the evolution of alkalic magmas in the Erebus volcanic province, southern Victoria Land, Antarctica

Dr Adam Martin[1], Prof Alan Cooper[2], Prof Richard Price[3], Prof Phil Kyle[4], Prof John Gamble[5]
[1]GNS Science, Dunedin, New Zealand, [2]University of Otago, Dunedin, New Zealand, [3]University of Waikato, Hamilton, New Zealand, [4]New Mexico Institute of Mining and Technology, Socorro, USA, [5]Victoria University of Wellington, Wellington, New Zealand

The Erebus volcanic province (EVP) is a Cenozoic, alkaline intraplate province on the edge of the West Antarctic rift system. Based on field and source characteristics and geographic locations, the EVP is newly subdivided into five volcanic fields. The EVP rocks are mainly nepheline normative, with rare, quartz normative compositions attributed to wall-rock assimilation. Eruption commenced by at least 18.7 Ma, but by correlation with distal tephra, may have started as early as 25 Ma. Volcanic activity is ongoing today at Mount Erebus, and several other volcanic centres in the region are considered dormant. Several petrological lineages that record crystal fractionation history have been identified in the EVP, with modelling showing olivine + clinopyroxene + ilmenite/magnetite + titanite ± kaersutite ± feldspar to be important fractionating phases. Modelling and geobarometry show depths of melting are greatest beneath Ross Island and the Transantarctic Mountains, relative to Mount Morning and Mount Discovery volcanic fields which lie between these two localities. The generation of relatively undifferentiated magmas in the province can be modelled by < 10 % partial melting of mixed spinel and garnet lherzolite mantle sources. Variable lines of evidence also point to a role for amphibole, enriched mantle-like and carbonatite-like components in the source. Equilibration of radiogenic Sr, Nd, Pb and Hf isotopic systems in relatively undifferentiated rocks are best explained in terms of a high time integrated HIMU 'sensu stricto' component in the mantle source, at least beneath Ross Island. The HIMU signature is likely to be older than 0.5 Ga and is thus unrelated to subduction of the palaeo-Pacific plate beneath East Antarctica at c. 0.5 Ga. Relatively undifferentiated whole rock chemistry from the province can also be modelled to show an eclogite component in the source, with increasing involvement of an eclogitic, oceanic crustal component eastwards.

820

Dunedin Volcanics: new mapping of Cenozoic volcanic rocks to better understand volcanic evolution and related hazards in an urban setting

Dr Adam Martin[1], Dr Dougal Townsend[2], Prof James White[3], Dr Graham Leonard[2], Mr David Barrell[1]
[1]*GNS Science, Dunedin, New Zealand,* [2]*GNS Science, Wellington, New Zealand,* [3]*University of Otago, Dunedin, New Zealand*

The city of Dunedin, New Zealand, is situated on the eroded remnants of an intraplate volcano. The Dunedin volcanic rocks are part of the Waipiata Volcanic Field, which at 25 Ma began as small (≤ one km^3) volcanoes widely spaced through the region. Sixteen million years ago, for reasons yet unknown, a much larger (> 100 km^3), more explosive concentration of volcanism initiated in shallow seas at the site of Dunedin.

A new collaborative research effort is being undertaken to identify the foreshadowing conditions of intraplate volcanism, understand palaeonvironmental conditions, the eruption sequence and magmatic evolution of the region and, to better constrain hazards from faulting and landslides through a better constrained volcano-stratigraphy. This will be the first updated regional approach to mapping the Dunedin volcanic stratigraphy since the classic work of Benson in the mid-20th century.

The mapping is integrating new high precision LiDAR data, geomorphology, modern physical volcanology interpretations, onshore airborne geophysics, offshore seismic and magnetic surveys into a GIS supported by GeoSciML. The mapping is being supported by petrology, new high-precision Ar-Ar geochronology, whole rock and mineral isotopic and geochemical analysis and palaeomagnetic studies. These efforts build upon the detailed and significant work already undertaken by researchers and students. Combined, these data will provide the most complete picture of Dunedin volcanism so far. The project, which is currently underway, will produce a map sheet and accompanying monograph, as well as being available as a downloadable GIS package. Numerous supporting journal articles and student theses are also anticipated.

The research will be applicable to sea-rise studies, hazard modelling for faults and landslides, understanding the causes for intraplate volcanism away from subduction or rifting at plate boundaries, or mantle plumes and what drives highly variable rates of magma generation in these settings.

628

Evolving Pyroclastic Density during the 2018 Eruption on Kīlauea Volcano

Alice Martin[1], Dr. Carolyn Parcheta[2]
[1]University Of Minnesota, St. Paul, United States, [2]USGS Hawaiian Volcano Observatory, Hilo, United States

Basaltic fissure eruptions with low fountains typically produce spatter bombs, scoria, lapilli, and pele's hair. On rare occasions where the fountain is over 300 m in height, reticulite is produced. Fissure fountain heights typically increase over a week or two as the fissure narrows down to a single vent that sustains prolonged eruptions. Interestingly, the 2018 Kīlauea eruption took a month to focus into a single vent, and had a maximum fountain height of 80 m, but produced the entire spectrum of basaltic pyroclastic products during this first month. The initial 15 fissures (May 3–9) produced textures consistent with scoria and vesicularity modes of 40–65% through an eruption style akin to "sustained strombolian". Another nine fissures opened May 12–24 with classical hawaiian fissure fountain activity and producing increasingly higher modal vesicularities moving from 50% towards 80% with each new fissure. This shift in vesicularity reached the pumice range before the main effusive phase began. On May 27, fissure 8 became the dominate vent with a trio of 80 m-tall lava fountains that produced basaltic pumice that floats and a vesicularity of 93% - nearly reticulite (>=95% vesicularity)! The early fissure 8 basaltic pumice correlates to record high Kīlauea gas emissions of >100 kT SO_2 per day. Minimal tephra was produced in July and pyroclastic material was not produced for most of August before the eruption ended Sep 5th, 2018. The unusually prolonged opening of the 2018 fissure system and low fountain heights combined with observations on viscosity, chemistry, and temperature (Ganseki et al., 2019), provide insight on the density evolution of basaltic fissure tephra. This eruption demonstrates that the range of pyroclasts for low fissure fountains is not limited to just spatter and scoria.

436

Risk communication and local languages: Case studies on Philippine volcanoes

Dr Ma. Mylene Martinez-Villegas[1], Joan Cruz-Salcedo[1], Lucille Rose Sanico[1], Abigail Pidlaoan[1]
[1]Phil. Institute Of Volcanology And Seismology (DOST-PHIVOLCS), Quezon City, Philippines

Volcanic risk communication is crucial in raising public awareness, developing social preparedness, and managing actual crisis responsiveness. We present case examples of experiences in implementing volcano information education programs for preparedness, and communicating risks before and during volcanic crises (i.e. Mayon, Kanlaon, and Taal volcanoes). We focus on identifying the challenges and opportunities related to ensuring efficient and effective risk communication. Several factors affect science-based hazards and risk communication in the country: 1) Filipinos are geographically separated owing to the country's archipelagic setting, 2) language diversity with the existence of several local languages in one volcanic area, not necessarily Filipino which is the national language, 3) bilingual policy, which utilizes English as the language of communication in official government documents and higher education institutions, 4) need for a science culture among Filipinos but building upon valuable local experiential and indigenous knowledge on disaster risk reduction, and 5) delivery of information and global thrusts in digital transformation.

710

A complete volcanic hazard/risk model requires a proper handling of all kinds of uncertainty

Professor Warner Marzocchi[1], Professor Thomas H. Jordan[2], Dr Jacopo Selva[3]
[1]University Of Naples Federico Ii, Naples, Italy, [2]University of Southern California, Los Angeles, USA, [3]Istituto Nazionale di Geofisica e Vulcanologia, Bologna, Italy

Volcanic hazard and risk are rooted in the quantification of the known uncertainties about the volcanic processes and the impact of eruptions on society. They are usually quantified through one statistical distribution of the parameter of interest, which may be, for example, the ash fall thickness, the magnitude of the eruptions, the economic losses, etc. However, we argue that one single statistical distribution can barely describe uncertainties of different kind, hence it may not provide a full description of the volcanic hazard and risk.

Despite the existence of uncertainties of different kind is well accepted by many scientists, their unambiguous definition is challenging and the classical frequentist and Bayesian frameworks are not suitable to describe them simultaneously. Here we discuss a unified probabilistic approach which overcomes these obstacles introducing an unambiguous hierarchy of uncertainties (aleatory variability, epistemic uncertainty and ontological error). Within this framework, a volcanic hazard/risk model is said to be complete only if (a) it fully characterizes the epistemic uncertainties in the model's representation of aleatory variability and (b) can be unconditionally tested (in principle) against observations to identify ontological errors.

Despite the merit of allowing unconditional testing of the model, which is the cornerstone of the scientific progress, the unified framework provides a more complete description to the decision-makers about what we do and do not know about volcanic hazard and risk.

We illustrate the application of this unified probabilistic framework in the real case of forecasting the tephra fall and the associated risk at Campi Flegrei.

1411

Probabilistic gas dispersion modelling at Nisyros island (Greece)

Dr Silvia Massaro[1,2], Dr Fabio Dioguardi[1,3], Dr Manuel Stocchi[1,2], Dr Antonio Costa[2], Prof Roberto Sulpizio[1,2], Dr Laura Sandri[2], Dr Jacopo Selva[2], Dr Giovanni Chiodini[2], Dr Giulio Bini[2], Dr Georges Vougioukalakis[4]
[1]Dipartimento Di Scienze Della Terra e Geoambientali, Aldo Moro University , Bari, , [2]Istituto Nazionale di Geofisica e Vulcanologia, Bologna, , [3]British Geological Survey, The Lyell Centre, Edinburgh,, , [4]Hellenic Survey of Geology and Mineral Exploration – HSGME, Athene,

Gas emissions from persistent passive volcanic degassing can produce significant long-term (years to decades) effects at local and regional scales, both on humans and the environment. For this reason, quantitative probabilistic volcanic hazard assessment (PVHA) of gas dispersion represents a critical tool for supporting risk and mitigation actions in active volcanic areas. In this framework, standard probabilistic methodologies are based on running physical models of gas dispersal which explore the full range of uncertainty in the input parameters and boundary conditions. This allows for an aware application of simulation tools for quantifying the volcanic hazard.

In this work, we simulate CO2 concentration at Nisyros volcano (Greece) which is affected by a widespread fumarolic activity in the southern part of the Lakki plain and the Lofos dome. Even though the present-day total CO2 emission is not particularly high, the hydrothermal system shows a large flux of energy which could potentially increase during future unrests triggering even hydrothermal explosions, as happened in historical times (last events in 1871– 1873 and 1887).

By using VIGIL-1.3 (VolcanIc Gas dispersIon modeLling), an open-source Python tool designed for automating the process to get probabilistic applications of dispersion modelling, we provide the first CO2 concentration maps running two passive dispersion scenarios based on the 1991-2001 and 2018 datasets of diffusive and fumarolic flux measurements, and considering as meteorological variability the last 30 years of wind fields taken from the Copernicus ERA5 reanalysis dataset. Our results show that the concentrations provided by the model do not exceed the gas hazardous threshold limits in the Lakki plain area, which is actively visited by tourists throughout the most part of the year, even for a hypothetical worse-scenario.

756

Identification of Hydrothermally altered volcanic rock types using borehole images at the Wairakei Geothermal Field and submarine Brothers volcano

Dr Cecile Massiot[1], Sarah D Milicich[1], Iona McIntosh[2], Cornel de Ronde[1], Jeremy Deans[3], Fabio Caratori Tontini[4]

[1]GNS Science, Lower Hutt, New Zealand, [2]JAMSTEC, Yokosuka, Japan, [3]University of Southern Mississippi, Hattiesburg, USA, [4]University of Genova, Genova, Italy

Identifying volcanic rock types and facies are important to understand volcanic and hydrothermal processes. Drill cores are ideal for volcanic facies identification but are sparse due to limited recovery and costs. Borehole images provide in-situ, continuous images down boreholes, albeit at a lower resolution than cores. Characteristics of volcanic rocks in borehole images are now emerging but remain rare, especially in hydrothermally altered silicic systems. We present image facies analysis of micro-resistivity images from two silicic systems: 1) well WK271, Wairakei Geothermal Field, Aotearoa New Zealand and 2) Hole U1530A in the active submarine Brothers volcano, Kermadec arc, collected during IODP Expedition 376. With an absence of cores in well WK271, the high-quality images were linked to core from nearby wells or outcrop analogues. At Brothers volcano, images were linked to observations on sporadically and partially (18%) recovered core and other rock property measurements.

At both sites, lavas show a high background resistivity and clear honeycomb fracture pattern. Ignimbrites show heterogeneous aspect with distinct features interpreted as clasts and pumice. In WK271, individual flow units separated by texturally characteristic intervals of airfall tephra are recognised within the Whakamaru Group ignimbrite. Additionally, textures inferred to represent volcaniclastic and sedimentary deposition, and breccia are recognised. In the deeper part of Hole U1530A at Brothers volcano, cores presented apparent volcaniclastic textures but were too hydrothermally altered to assess they primary rock type, and borehole image appearance is consistent with ignimbrites. Using additional petrophysical evidence, we propose that rocks in this interval are dominantly lava flows with apparent volcaniclastic textures.

The revised and detailed stratigraphy based on borehole images at both sites will support further understanding of aerial and submarine volcanic processes. Borehole image facies documented at the Wairakei Geothermal Field and Brothers volcano will support image facies interpretation at other volcanoes.

755

CALDERA: a scientific drilling idea to unravel Connections Among Life, geo-Dynamics and Eruptions in a Rifting Arc caldera

Dr Cecile Massiot[1], Craig Cary[2], Craig Miller[1], Pilar Villamor[1], Hiroshi Asanuma[3], Eric Boyd[4], Matthew Stott[5], Matteo Lelli[6], Karen Lloyd[7], David D. McNamara[8], Santanu Misra[9], Doug R. Schmitt[10], Guido Ventura[11], Pujun Wang[12], Ludmila Adam[13], Ery Hughes[1], Geoff Kilgour[1], Sarah D. Milicich[1], Alex Nichols[5], Shane Rooyakkers[1], Agnes Mazot[1], Sadiq Zarrouk[13]

[1]GNS Science, Lower Hutt, New Zealand, [2]University of Waikato, Hamilton, New Zealand, [3]AIST, Koriyama, Japan, [4]Montana State University, , USA, [5]University of Canterbury, , New Zealand, [6]National Research Council (CNR), Institute of Geosciences and Earth Resources (IGG), , Italy, [7]University of Tennessee, Knoxville, USA, [8]University of Liverpool, , UK, [9]Indian Institute of Technology, Kanpur , India, [10]Purdue University, , USA, [11]INGV, Roma, Italy, [12]Jilin University, , China, [13]University of Auckland, , New Zealand

Caldera volcanoes produce Earth's largest explosive eruptions, generate seismicity both independent and associated with unrest and eruptive periods, host mineral and geothermal resources that interact with groundwater, and support a largely unexplored biosphere. Volcanic, tectonic, hydrologic and biologic processes in calderas are intimately connected, yet poorly understood, and require subsurface observations. The project "Connections Among Life, geo-Dynamics and Eruptions in a Rifting Arc caldera (CALDERA)" aims to obtain drill cores, downhole measurements and monitoring data from the Okataina Volcanic Centre (OVC), one of two giant active silicic calderas in the actively rifting Taupō Volcanic Zone, Aotearoa New Zealand.

CALDERA is ideally suited to address fundamental questions on caldera processes that include: 1) How do caldera magmatic plumbing systems and their eruptive behaviour mature and evolve? 2) How do complex crustal stresses vary in caldera regions and affect geo-hydro-bio-processes? 3) What controls fluid flow and chemistry in calderas? 4) What are the physicochemical conditions that drive subsurface microbial community structure, function and activity? 5) How to predict the onset and style of caldera unrest and eruptions?

We invite scientists to contribute to the design of this project in the exceptional OVC settings and strengthen linkages with other ongoing research and scientific drilling programmes. The outcomes of an international workshop supported by the International Continental Scientific Drilling Program (ICDP) will be presented. The significant scientific discoveries will underpin 1) resilience to volcanic and seismic hazards; 2) sustainable management of groundwater and geothermal resources, and 3) understanding of subsurface microbial diversity, function and geobiological interactions. These topics are all potent for compelling education and outreach efforts, at Okataina and globally.

1297

High surface fluoride content on ash from the 2021 Tajogaite eruption, Cumbre Vieja, Canary Islands

Elena Maters[1], Arnaud Denis[2], Matthew Pankhurst[3,4], Pierre Eloy[2], Olivia Barbee[5], Pierre Delmelle[2]
[1]University of Cambridge, Cambridge, United Kingdom, [2]UCLouvain, Louvain-la-Neuve, Belgium, [3]Instituto Tecnológico y de Energías Renovables, Santa Cruz de Tenerife, Spain, [4]Instituto Volcanológico de Canarias, Santa Cruz de Tenerife, Spain, [5]Whitman College, Walla Walla, USA

Explosive activity of Cumbre Vieja volcano led to recurrent ash fall on La Palma, Canary Islands, for almost three months in autumn 2021. A multi-day time series of ash samples were collected throughout the eruption in stations set up by the Instituto Volcanológico de Canarias at distances of 2–10 km from the vent complex. We examined the water leachate composition of 36 ash samples and the surface composition of seven ash samples erupted from 19 September–16 November. Water leachates filtered after 1 h of ash-water contact (1:100) were analysed for Si, Mg, Ca, Na and K by inductively coupled plasma atomic emission spectroscopy and SO_4^{2-}, Cl- and F- by ion chromatography. Ash surfaces (topmost 2–10 nm), both fresh and water-leached, were analysed for Si, Al, Fe, Mg, Ca, Na, K, Ti, S, Cl and F by X-ray photoelectron spectroscopy.

Water leachate F- concentrations ranged from 13–683 (mean 288 ± 177) mg kg^{-1} with pH values from 5.3–5.8 (mean 5.6 ± 0.1). Surface F concentrations on fresh ash ranged from 8.3–52.4 (mean 23.4 ± 11.6) at.% (excluding C and O, normalised to 100%); reaching higher values than any reported F content on volcanic ash to date. These surface F concentrations were greatly reduced (by 67–91%) on all except one of the water-leached ash samples analysed, suggesting that most of the surface F is water-soluble. Comparison of F- concentrations in water leachates and 0.1 M HCl leachates supports this, although for several samples a large fraction of F- only dissolved in acid. Salts such as Na_2SiF_6 and NaF formed by ash-HF reactions may be the source of soluble F-, while less-soluble F may occur in other salts (e.g., CaF_2), minerals (e.g., $Ca_5(PO_4)_3F$) or the glass. Potential implications around toxic and nutrient element release from the ash in the environment will be discussed.

889

Analogs for Explosive Volcanism on Mars – Alteration Minerals at the Valley of Ten Thousand Smokes, Alaska

Dr Alexandra Matiella Novak[1], Dr Patrick Whelley[2,3], Dr Jacob Richardson[3], Dr David Hollibaugh Baker[3]
[1]Johns Hopkins University Applied Physics Lab, Laurel, United States, [2]University of Maryland, College Park, United States, [3]NASA Goddard Space Flight Center, Greenbelt, United States

The Valley of Ten Thousand Smokes (VTTS) in Katmai National Park, Alaska has been studied as an analog for understanding alteration minerals associated with explosive volcanism on Mars. The 1912 eruption at Novarupta in the VTTS produced 11 km3 of ignimbrites and 17 km3 of fall deposits that filled the valley and provides a unique opportunity to observe the presence, variety, and distribution of clay minerals forming near source and near fumaroles as well as those forming distally and away from fumaroles. These observations provide context for regional clay species trends observed downwind from Martian ash sources within Arabia Terra that have been suggested, based on geomorphology, to be explosive calderas. Sample sites were selected through remote sensing images, focusing on areas that showed alteration of ash at the surface (orange, yellow and red colors visible at the surface). Minerals of interest included alteration minerals known to be associated with volcanic explosive material such as phyllosilicate clay minerals (e.g. smectites) and hydrated sulfates (e.g. jarosite). Field sampling at these locations included digging trenches to expose several layers of altered mineral species, taking spectra in the field with a handheld Halo spectrometer, and collecting samples to take back to the APL Planetary Exploration Research Lab for analysis using a spectrometer with a Hyperion microscope. Preliminary results show that the very same minerals identified on Mars in Arabia Terra and presented as evidence for ancient explosive volcanism were found in VTTS. Comparisons of these field samples with remotely sensed spectral data will aid in interpreting data from Mars and other terrestrial planets.

294

Seismo-acoustic source mechanism of high-rate very-long-period seismicity at Yasur volcano, Vanuatu

Professor Robin Matoza[1], Bernard Chouet[2], Arthur D. Jolly[3], Phillip B. Dawson[4], Rebecca H. Fitzgerald[5,6], Ben M. Kennedy[6], David Fee[7], Alexandra M. Iezzi[1,8], Geoff N. Kilgour[9], Sandrine Cevuard[10]
[1]Department of Earth Science and Earth Research Institute, University Of California, Santa Barbara, Santa Barbara, United States, [2]Arzier-Le Muids, , Switzerland, [3]U.S. Geological Survey, Hawaiian Volcano Observatory, Hilo, USA, [4]U.S. Geological Survey, California Volcano Observatory, Moffett Field, USA, [5]GNS Science, Lower Hutt, New Zealand, [6]The School of the Earth and Environment, University of Canterbury, Christchurch, New Zealand, [7]Alaska Volcano Observatory and Wilson Alaska Technical Center, Geophysical Institute, University of Alaska Fairbanks, Fairbanks, USA, [8]USGS Cascades Volcano Observatory, Vancouver, USA, [9]GNS Science, Wairakei Research Centre, Taupo, New Zealand, [10]Vanuatu Meteorology and Geohazards Department, Port Vila, Vanuatu

We present results from a campaign seismo-acoustic field deployment at Yasur volcano, Vanuatu, providing locally dense broadband seismic and infrasonic network coverage from 27 July to 3 August 2016. We corroborate our seismo-acoustic observations with coincident video data from cameras deployed at the crater and on an unoccupied aircraft system. The waveforms contain a profusion of signals reflecting Yasur's rapidly occurring and persistent explosive activity. The dominant seismic signals are numerous repetitive very-long-period (VLP) signals with periods of ~2–10 s. The VLP seismic events are "high-rate", reoccurring near-continuously throughout the dataset with short interevent times ~20 to 60 sec. We observe variability in the synchronization of seismic VLP and acoustic sources. Explosion events clearly delineated by infrasonic waveforms are underlain by seismic VLPs. However, strong seismic VLPs also occur with only a weak infrasonic expression. Multiplet analysis of the seismic VLPs reveals a systematic progression in the seismo-acoustic source decoupling. Full-waveform inversion of the dominant VLP seismic multiplet stack under a point-source assumption indicates a composite source consisting of either a dual-crack (plus forces) or pipe-crack (plus forces) mechanism directly beneath the summit vents with centroid depths in the range ~900-1,000 meters below topography. We interpret the results in the framework of gas slug ascent through the conduit responsible for Yasur explosions. The dominant VLP at Yasur captured by our experiment has a source depth and mechanism separated from surface processes and is stable over time.

See also: Matoza, R.S., B.A. Chouet, A.D. Jolly, P.B. Dawson, R.H. Fitzgerald, B.M. Kennedy, D. Fee, A.M. Iezzi, G.N. Kilgour, E. Garaebiti, and S. Cevuard (2022), High-rate very-long-period seismicity at Yasur volcano, Vanuatu: source mechanism and decoupling from surficial explosions and infrasound, Geophys. J. Int., 230, 1, 392-426, doi:10.1093/gji/ggab533

842

A model for repetitive explosive eruptions through magma plugs: new insights from Shinmoedake volcano, Japan

Dr Keiko Matsumoto[1], Dr Nobuo Geshi[1]
[1]*Geological Survey of Japan, AIST, Tsukuba, Japan*

To understand the mechanism that induces repetitive explosive eruptions from lava ponds, we investigated the fracture and healing processes of the 'plug' at the top of a volcanic conduit by examining proximal deposits and vent wall outcrops of the 2018 activity at Shinmoedake volcano, Japan. Most of the proximal deposits in the survey area were dense and angular fragments with red surfaces, sometimes with red tuffisite veins. In addition, some blocks exhibiting black and deformed tuffisite veins were present. The walls of the 2018 vent in the summit crater were composed of angular blocks and red tuffisite veins. Density measurements indicated that the black tuffisite-bearing blocks were denser (2.21–2.51 g/cm³) than red tuffisite-bearing blocks and red surface blocks (1.85–2.48 g/cm³). This suggests a deeper origin for the black tuffisite blocks and a shallower origin for red types. Microscopic observation and EDS analysis revealed that the surface color of red fragments and ash grains in tuffisite veins originated from fine (<1 µm) Fe oxide(s) on pyroxene microlites, indicating they were formed by the oxidation of fragments at high fO_2 after fracturing occurred. These results indicate that the plug architecture consists of a fragile and permeable upper plug through which atmospheric air circulates, and a dense and less permeable lower plug due to ductile deformation. Within this framework, repetitive explosive eruptions are explained by the following model: (1) fracturing of a dense plug due to an explosion, (2) healing of fractures by ductile deformation in the lower plug, which inhibits the gas supply from beneath it whilst air penetrates the upper plug and oxidizes the fragments (3) explosion of the lower plug due to the overpressure of accumulated gas. These new findings contribute to understanding the mechanisms of intermittent explosions and degassing in lava domes.

518

Evaluation of the eruptive activity since AD 2006 at Sakurajima volcano, Japan: the petrological index for forecasting the eruptive activity

Dr Akiko Matsumoto[1], Prof Mitsuhiro Nakagawa[1], Prof Masato Iguchi[2]
[1]Faculty of Science, Hokkaido University, Sapporo, Japan, [2]Disaster Prevention Research Institute, Kyoto University, Kagoshima, Japan

Sakurajima volcano, located in the southwestern Japan, is one of the most active volcanoes in Japan. This volcano has continued the vulcanian and strombolian eruptions since AD 2006. To understand the magma plumbing system beneath the volcano, we have carried out the petrological studies of the historical juvenile materials since the 15th century and it is revealed that dacitic and andesitic magmas were mixed until the 18th century and a basaltic magma injected into this mixed magma since the 20th century. We estimated the supply volume of basaltic magma since AD 2006, and it was found that its volume increased in the four periods. These periods are corresponding to those that the intensity of eruptive activity became larger clearly (e.g., larger inflation of edifice). This suggests that the scale of eruptive activity is controlled by the supply of basaltic magma. One of the petrological evidence for the input of basaltic magma is the existence of olivine in the juvenile materials. Based on chemical composition and texture, olivine phenocrysts can be divided into two types: high-Fo olivine with no or thinner reaction rim, and lower-Fo olivine with thick pyroxene mantles. Comparing the ratio of two types of olivine to geophysical monitoring data, the former is often recognized in the period of strong intensity of eruptive activity, and the latter occurs in that of relatively weak one. This correlation suggests that the texture of olivine is available for forecasting the scale of eruptive activity. Although the dense precise geophysical monitoring has been carried out at Sakurajima volcano recently, the migration of basaltic magma cannot be detected probably because of small supply volume of basaltic magma. If the similar eruptive activity is continued, the texture of olivine in the juvenile materials is useful for forecasting the future eruptive activity.

1214

Numerical modeling of volcanic hydrothermal system based on resistivity structure: A case study for Kusatsu-Shirane Volcano, Central Japan

Dr Yasuo Matsunaga[1], Dr Wataru Kanda[1]
[1]*Volcanic fluid research center, School of Science, Tokyo Institute of Technology, Meguro , Japan*

Numerical simulation is a useful method for studying the complex behavior of volcanic hydrothermal systems. However, most previous studies on the numerical simulation use highly simplified structures, and few studies have taken into account the natural heterogeneity of permeability distribution. This is mainly because it is difficult to establish the distribution of permeability in subsurface regions, which have a significant impact on fluid flow within the volcano.

In this study, as a first step towards establishing a comprehensive scheme for constructing a realistic permeability structure, we attempted to numerically reproduce steady-state hydrothermal system of Kusatsu-Shirane Volcano (KSV), Central Japan, by using a permeability structure constructed based on three-dimensional resistivity structure revealed by magnetotellurics (Matsunaga et al., 2022). Several scenarios with different permeability structure were prepared to determine what structures have a significant impact on hydrothermal flow. In each scenario, saline fluids were injected from the bottom of the domain to simulate hydrothermal circulation within the volcanic edifice.

Some of the simulation results reproduced actual observed phenomena. For example, when a sealing zone was assumed around the conduit, the sub-vertical conductive region like in the observed resistivity structure model was well reproduced. Also, the fluid that ascended to near the summit area flowed in the east and west due to the downward flows toward the foot of the volcano caused by the topographical effect and discharged mainly along the valleys. This well reproduces the distribution pattern of hot springs around KSV, where hot springs are concentrated on the east and west flanks of the volcano.

Although the constructed permeability structure was relatively simple, the simulation results closely reproduced several observed data, suggesting incorporating information on the resistivity structure can greatly reduce the uncertainty of the hydrothermal fluid flow simulations.

1460

What happens in between two super-eruptions? What is the meat between two slices of bread?

Miss Kate Mauriohooho[1], Prof Colin J.N. Wilson[1], Dr Bruce Charlier[1], Dr Simon Barker[1], Dr Isabelle Chambefort[2], Dr Graham Leonard[3]

[1]Victoria University Of Wellington, PO Box 600, New Zealand, [2]GNS Wairakei Research Centre, Private Bag 2000, New Zealand, [3]GNS Avalon Research Centre, PO Box 30-368, New Zealand

How magma systems evolve and assemble eruptible melt-dominant magma bodies, and how magmatic/volcanic systems behave in between supereruptions remain unresolved questions in volcanology. Volcanic products between the two youngest TVZ supereruptions: Whakamaru (~349 ka) and Oruanui (~25 ka) were analysed to understand how many magma systems existed in the North Taupō-Maroa area and how/when they interacted during this ~300,000 kyr time span.

40Ar/39Ar geochronology, XRF, ICPMS, EPMA and Sr isotopic ratios using TIMS were used to discriminate grouped or individual magma batches and identify their parental sources. This enabled reconstruction of the temporal and spatial magma systems responsible for the chemically and isotopically distinct domes and pyroclastic deposits, north, northwest and south of Lake Taupō, including buried domes in the northern Taupō geothermal fields.

40Ar/39Ar dates imply that the Western Dome Belt, is in part, a pre-existing linear dome complex pre-dating the Whakamaru caldera formation and dome eruptions have been a continuous over ~400,000 years. Whole rock geochemistry show a clear distinction between magma types that form discrete individual magma batches but are not always spatially concentrated. The magma system that fed the WDB lavas is separate to those that supplied the Whakamaru eruption. Two types of amphibole were identifed; a shallow formed (~4-5 km) and a deeper forming (~13.5 km) amphibole. Sr isotope signatures illustrate a bimodality with two long lived magma systems active over ~400 kyr. We infer that these patterns reflect the composition of two distinct crustal basement domains. These magma systems co-existed up to ~50,000 years ago and appear to lead into the two modern systems under the modern Taupō area. The results of this work have global implications into the magmatic workings and behaviour of large rhyolitic volcanoes.

1223

The solubility of sulfur in silicate melts at pressures from ambient to uppermost mantle.

Professor Hugh STC O'NEILL[1], DR Antony Burnham[2], Professor John Mavrogenes[2]
[1]School of Earth, Atmosphere and Environment, Monash University, Clayton, Australia, [2]Research School of Earth Sciences, ANU, Canberra, Australia

A large number of experimental measurements of the solubility of sulfur in silicate melts at both S2- (reduced conditions) and SO42- (oxidized conditions) are now available as a function of temperature and melt composition under controlled atmosphere at ambient pressure, from a range of laboratories, including our own. The results can be systematized to thermodynamic models for the sulfide capacities and the sulfate capacities of the silicate melts based on a two-sublattice treatment of the melts (i.e., cation and anion sublattices). These models may then be combined with further experimental data at super-ambient pressures, again from several sources, for sulfide contents at sulfide saturation (SCSS) and sulfate contents at anhydrite saturation (SCAS). The resulting models are not well constrained as regards the effects of pressure, and in particular there remains considerable ambiguity regarding the effect of pressure on the oxygen fugacity of the sulfide/sulfate transition at high pressures. It has been suggested (by Matjuschkin et al, 2016) that the sulfide-sulfate join moves to higher fO2 with increasing pressure. If true, this would encourage decompressing arc magmas to remain within the sulfide field, something at odds with many field relations. To address this problem, we performed new experiments in which silicate melt in equilibrium with both Fe-S-O sulfide matte and anhydrite, was equilibrated over a pressure range from 5 to 45 kbar. Oxygen fugacity was subsequently determined by XAS measurement of Fe2+/Fe3+ in the quenched glass. A new model based on these experiments will be presented and the results applied to arc systems.

Matjuschkin, V, Blundy, JB and Brooker, RA, 2016, Contributions to Mineralogy and Petrology, v. 171, number 66.

1210

Mt Hagen, PNG, a view of a deep-arc crystal mush, displaying continuous sulfur and volatile saturation throughout its history.

Professor John Mavrogenes[1], Ms Monika Misztela[1], Professor Ian Campbell[1]
[1]*ANU, Canberra, Australia*

Mount Hagen, a stratovolcano in Papua-New Guinea, resides within a complex tectonic setting and an unclear magmatic history. Samples covering a bulk MgO range from 2 to 11.5 wt.% contain abundant olivine, clinopyroxene, hornblende and plagioclase megacrysts which are clearly out of equilibrium. We interpret this mélange as crystal mush and believe this to be a rare view of a deep arc setting. Despite the incredible complexity of the system, various magma mixing events can be identified by reverse zoning in plagioclase, high-Cr zones in clinopyroxene and two olivine populations, with the most significant occurring at 5.5wt.% bulk MgO.

Within the array of megacrysts, sulfide inclusions were identified across the entire compositional range. These 10 m sulfide blebs were analysed for trace-element and PGE contents by electron microprobe. These sulfide inclusions record continuous sulfide saturation across the entire sub-volcanic magmatic history. They also provide a temporal axis independent of silicate fractionation trends. The Ni/Cu range shown (by Georgatou et al) across an entire system is herein recorded within single samples. Despite the abundant silicate compositional reverses, sulfide inclusions evolve to high copper contents through time. This allows an independent relative chronometer. Furthermore, evidence of volatile saturation is found in megacrysts throughout. This study shows that sulfide and volatile saturation was continuous across the entire suite.

Mush zones are very challenging to unravel, however, magmatic sulfides provide an additional chronometer. Additionally, these mushes allow transport of immiscible sulfide within and between phases from great depths, thereby overriding the increasing solubility of sulfur as pressure decreases (as shown by Mavrogenes and O'Neill, 1999).

Georgatou, A, Chiaradia, M, Rezeau, H and Walle, M, 2018, Lithos, v. 296, p. 580-599.
Mavrogenes JA and O'Neill, HStC, 1999, Geochimica et Cosmochimica Acta, v. 63, p. 1173-1180.

661

L-LIVE (Livelihoods and Livestock Impacted by Volcanic Events): A tool to improve preparedness and management of livestock during volcanic emergencies

Ms Gari Mayberry[1,3], Katinka deBalogh[2], Andrew Sobey[2], Ian Dacre[2], Norma Hurif[2], Christine Jost[3], Leslie Brooks[3], David Ramsey[1,3]
[1]US Geological Survey, , , [2]UN Food and Agriculture Organization, , , [3]US Agency for International Development, Washington, United States

Volcanic eruptions can injure or kill livestock. Immediately following an eruption, water and feed may be contaminated or in short supply. Weeks to months after eruptions, ash can continue to affect the respiratory system and mucous membranes of animals and humans leading to chronic health issues. To mitigate the risks and impacts of volcanic eruptions on livestock and their keepers, identification of safe livestock production zones and mechanisms for mobilizing emergency funds and timely interventions are required.

To build volcano hazard resilient communities, a regional tool called L-LIVE (Livelihoods and Livestock Impacted by Volcanic Events) was developed to improve emergency preparedness and emergency management of livestock. L-LIVE draws together knowledge from diverse sources, case studies, and consultancy. The tool was tested by field actors and stakeholders involved in volcano response in Indonesia and the Philippines to ensure functionality. L-LIVE has global applications and includes a range of options such as care for translocated livestock, compensation schemes, host community arrangements, and co-location of livestock keepers with their animals, and determination of safe livestock production zones.

The Food and Agriculture Organization of the United Nations' (FAO) Regional Office for Asia and the Pacific, with support from the U.S. Agency for International Development's Bureau for Humanitarian Assistance (USAID/BHA), collaborated with stakeholders in Indonesia and the Philippines to strengthen planning, preparedness, response, and recovery mechanisms to mitigate the effects of volcanic eruptions on livestock-related livelihoods. Emergency management plans for livestock in areas with high volcanic risk were developed and tested in collaboration with public, private, NGO, and community actors, and by bringing together a wide variety of experts including veterinarians, volcanologists, disaster risk reduction specialists, anthropologists, and economists. Procedures for livestock resettlement after an eruption considered prevailing local conditions, practices, and cultures to develop an effective volcano-risk mitigation tool.

602

Developing a daily global volcanic activity report: a call for feedback

Ms Sally Sennert[1,2], Ms Gari Mayberry[1,3], Dr. Heather Wright[4], Dr. Sarah Ogburn[4], Dr. Jake Lowenstern[4], Dr. Ben Andrews[2], Mr. Ed Venzke[2], Ms. Kadie Bennis[2]
[1]USGS, Reston, United States, [2]Smithsonian Institution, Washington, United States, [3]BHA/USAID , Washington, United States, [4]USGS/USAID Volcano Disaster Assistance Program, Vancouver, United States

After more than 20 years of producing the US Geological Survey (USGS) and Smithsonian Institution's Global Volcanism Program (GVP) Weekly Volcanic Activity Report, there is an increasing need for a reliable daily report about worldwide volcanic activity. We anticipate that a daily report will be used by various sectors, including disaster response, humanitarian, diplomatic, military, energy, aviation, and the general public based on the requests of more timely reporting we have received from these sectors. To fulfill this need, the US Agency for International Development (USAID) Bureau for Humanitarian Assistance (BHA), USGS Volcano Disaster Assistance Program (VDAP), and GVP are partnering to develop a daily global volcanic activity report. These daily updates will collate information from worldwide sources and is considered a top priority by potential users. It will promote the documentation, understanding, and dissemination of information about global volcanic activity by providing ongoing situational awareness of volcanic unrest and crises, including regional hazard forecasts and risk-mitigation planning. Automatic data collection from volcano observatories, Volcanic Ash Advisory Centers (VAACs), other official sources, and social media platforms will be developed with partners to increase the sustainability of the report and related products. The information will be formatted to seamlessly populate events in GVP's Volcanoes of the World and VDAP's Global Eruption Chronology databases. The daily report will be viewable on the GVP and USGS websites and through subscription options. During the current developmental stage, we are soliciting feedback about the content, formatting, and product delivery from partners and users.

1080

MONITORING VOLCANIC DEGASSING AT RUAPEHU, NEW ZEALAND

Dr Agnes Mazot[1], Santiago Arellano[1], Jonathan Hanson[1], Cameron Asher[1]
[1]*GNS Science, Taupo, New Zealand*

Gas monitoring of New Zealand volcanoes (including White Island and Ruapehu) has relied heavily on measuring SO_2 emission rates by using ultraviolet-sensing correlation spectrometer (COSPEC). At Ruapehu volcano, the first-ever measurements of SO_2 emission at Ruapehu were made during the 1995–1996 eruptions and varied between 300 and 15,800 t/d. In 2004, more frequent measurements were made and the SO_2 emission rates were low consistent with quiescent degassing of the volcano and the presence of a crater lake. SO_2 emission abruptly increased to 446 t/d on 29 October 2007, a month after the September eruption.

In June 2022, GeoNet with the collaboration of the Network for Observation of Volcanic and Atmospheric Change (NOVAC) community installed two scanning mini-Differential Optical Absorption Spectrometer (DOAS) around Ruapehu volcano offering for the first time semi-continuous SO_2 emission data around this volcano. The SO_2 emission rates data were compared to the COSPEC measurements from gas flights and the data were in the same order of magnitude. This higher frequency data provides unprecedented information on the short-term (during a day) SO_2 emission changes related to the gas releases from the bottom vents of Ruapehu crater lake. This could provide unprecedented information in volcanic processes and in the assessment of volcanic activity.

292

Detecting nm-scale titanomagnetite in high silica rhyolite pumice with novel applications of rock magnetism

Kelly McCartney[1], Julia Hammer[1], Thomas Shea[1], Stefanie Brachfeld[2], Bruce Houghton[1], Thomas Giachetti[3]
[1]*University of Hawaiʻi at Mānoa, Honolulu , United States,* [2]*Montclair State University, Montclair, United States,*
[3]*University of Oregon, Eugene, United States*

The high viscosity of silica rich melts delays bubble nucleation until a supersaturation pressure threshold (ΔPN) is reached, dictated by nucleation style. Homogeneous nucleation (crystal free) maximizes this requirement (ΔPN>100-150 MPa, ≥6km storage depth), whereas heterogeneous nucleation (occurring on a crystal) minimizes it (<50 ΔPN, <2km). Many eruptions of crystal-poor magmas are generated from magma storage depths too shallow to occur via homogeneous nucleation, suggesting that heterogeneous nucleation may prevail. Titanomagnetite is known to facilitate heterogeneous bubble nucleation, yet it is typically un-observable via conventional methods of electron microscopy and/or x-ray computed tomography due to small grain size (nm-scale). We seek to characterize the abundance of nm-scale titanomagnetite in pumice from four crystal poor subplinian to Plinian eruptions: Glass Mountain, USA; Diamante, Chile; Novarupta, USA; and Taupo, New Zealand.

We constrained vesicularity, permeability, and bubble number density (BND) in a total of 547 pumice clasts. A subset of 64 clasts that represent the average and ±2σ endmembers of vesicularity and permeability were selected for magnetic analysis. Rock magnetic characterization allowed us to constrain the volume% of magnetic material present, estimate Fe-Ti oxide composition, bracket crystal size ranges, and estimate titanomagnetite number density (TND). Curie temperature analysis confirmed the presence of titanomagnetite in all clasts. Rock magnetic analyses indicate superparamagnetic behavior, consistent with nm-scale titanomagnetite grains, with TND>BND in all clasts. Titanomagnetite appears to be a common mineral phase for the four eruptions, and shows no dependence on storage depth, melt composition, vesicularity, or permeability. Our results directly constrain the number densities of nm scale magnetic particles that pre-date magma ascent. We suggest that titanomagnetite crystals serve as heterogeneous bubble nucleation sites across many silicic eruptions, even in systems that meet the ΔPN requirement for homogeneous bubble nucleation.

1097

Volcanic resilience options and co-benefits within dynamic agriculture systems

Dr Nicola McDonald[1], Prof Anita Wreford, Dr Alana Weir, Prof Thomas Wilson, Prof Mark Bebbington, Dr Nam Bui, Dr Stuart Mead, Mr Roger Fairclough, Dr Christina Magill, Dr Heather Craig
[1]*ME Research, Auckland, New Zealand*

Although Taranaki Mounga is the most likely New Zealand (NZ) volcano to cause national scale impacts over current lifetimes, its dormancy since the last eruption is one of the longest. On the surrounding ring plain where a variety of volcanic hazards will occur, the fertile and free-draining soils have supported wide establishment of dairying and other intensive pastoral farming activities.

If we are to successfully move towards more resilient agriculture systems in NZ and abroad, we need to be cognisant of the many factors driving system change and integrate resilience-thinking into wider decision-making. Over recent years NZ's agriculture sector has been subject to significant pressures, and these will continue. Freshwater policy management and climate change mitigation are at the forefront of policy agenda. New legislation, for example, sets emissions reduction targets and there is a requirement to price agricultural emissions by 2025. A changing climate is also creating new challenges (and possibly opportunities), which will intensify over time. On top of this, the sector is inherently dynamic, needing to respond to constantly evolving consumer demands and preferences, commodity prices and technologies. We aim to discover whether there are volcanic resilience co-benefits, or potentially maladaptation associated with land use and system change options farmers and government decision makers may be considering, and vice versa. We seek to promote and integrate resilience thinking within wider decision-making, and at different decision-making scales.

The project is collaborative and multi-disciplinary. It involves integrating models and expertise in volcanic event simulation, disaster risk reduction, hazard impact analysis, farm system modelling and applied economics. We draw on methodologies from 'Decision Making Under Uncertainty', an emerging theme particularly in climate change research, to collate, make sense of and communicate the various uncertainties that confront decision makers in the agriculture sector before, during and after volcanic crises.

420

Post-glacial melt generation in Southern Chile and the development of the Carrán-Los Venados volcanic field (40’20oS)

Lucy McGee[1], Katy Chamberlain[2], Mark Reagan[3]
[1]*University of Adelaide, Adelaide, Australia,* [2]*Teesside University, Middlesbrough, United Kingdom,* [3]*University of Iowa, Iowa, USA*

The Carrán-Los Venados (CLV) volcanic field (40’20oS) in the Southern Volcanic Zone of Chile has been volcanically active from approximately 5ka to its last eruption in 1979 CE. It consists of approximately 70 basaltic scoria cones and maars, constructed over extensive late glacial to early postglacial basal basaltic lava flows. Mafic rocks erupted in this setting therefore provide an ongoing record of melt generation associated with deglaciation.

Whole rock major and trace element compositions combined with U-Th and Sr-Nd-Pb isotopic ratios and olivine compositions show a profound difference between the basal lavas underlying the volcanic field and the later monogenetic basalts. Differences in fluid mobile/immobile element ratios and incompatible trace element contents, in addition to changes in olivine Fo contents suggest that the former were produced by melting of a drier, more enriched source, whilst the monogenetic field was sourced by a significantly wetter, more depleted source. The most recent eruption within the field (Mirador) displays characteristics of both sources. We hypothesize that deglaciation drove the decompression and subsequent melting of relatively dry and enriched mantle at higher upwelling rates allowing the eruption of extensive lava flows. As deglaciation slowed and upwelling rates decreased, more isolated fluid-fluxed melting events dominated magma genesis. This change occurred over a narrow window of time – a few thousands of years – suggesting that in such conditions shifts in melting dynamics and eruption style can occur relatively rapidly.

421

Time-scales of metal transport at active volcanoes: Insights from Cu isotopes

Lucy McGee[1,3], Justin Payne[2,3], Juraj Farkas[1,3], Conor Dalton[1]
[1]University of Adelaide, Adelaide, Australia, [2]University of South Australia, Adelaide, Australia, [3]MinEx CRC, , Australia

Ascending magmas laden with magmatic volatile phases (MVPs) such as chlorine, fluorine and water have the potential to transport base metals such as copper (Cu) to the subsurface where they may become enriched to form economic ore deposits. Metal species are highly compatible in MVPs, however the timescales and mechanisms by which metals may be transported through crustal magma reservoirs are currently poorly known. Studies of active volcanic systems can be useful to determine volatile transport where parameters such as depth of melting and magma storage can be ascertained. We can also apply time-sensitive uranium-series studies to active or young volcanic samples. Ratios such as (210Pb/226Ra)0 (where 210Pb has a half-life of 22.6 years) can reveal important information about volatile accumulation or loss as 222Rn (a gas) sits in the decay chain between 226Ra and 210Pb.

We combine (210Pb/226Ra)0 ratios with copper isotope signatures (δ65Cu) to investigate the relative timescale of copper transport at two active volcanoes: Soufrière Hills volcano (SHV, Montserrat, Caribbean) and Arenal (Costa Rica). Mafic samples from both volcanoes have excesses of 210Pb, showing persistent volatile fluxing leading up to eruption. Mafic samples from SHV have strongly fractionated, negative copper isotope signatures (i.e. δ65Cu < 0, relative to typical igneous sources) indicating that volatiles and Cu were accumulating in mafic magma on a timescale of a few decades. Copper isotope fractionation at SHV is therefore due to magmatic volatile involvement rather than fractional crystallisation, which operates over much longer timescales. Host volcanic rocks to the enclaves at SHV show less isotopic fractionation, suggesting that in this scenario copper and volatiles that ultimately form ore deposits are likely to be predominantly derived from deeper within the magmatic plumbing system as opposed to removal from near surface magmas.

1172

Insights into the 15 January 2022 Hunga volcano, Tonga eruption using infrasound, lightning, and particle properties

Dr Kathleen McKee[1], Dr. Verity Flower[2], Dr. Ralph Kahn[1], Dr. Jelle Assink[3], Chris Vagasky[4], Dr. Sonja Behnke[5], Dr. Alexa Van Eaton[6], Dr. Larry Mastin[6], James Limbacher[1], Dr. Katherine Junghenn Noyes[1]
[1]NASA Goddard Space Flight Center, Greenbelt, United States, [2]University of Stirling, Stirling, Scotland, [3]Royal Netherlands Meteorological Institute, , Netherlands, [4]Vaisala, Inc., , United States, [5]Los Alamos National Laboratory, Los Alamos, United States, [6]United States Geological Survey, Cascades Volcano Observatory, , United States

We examine the 15 January 2022 eruptive episode of Hunga volcano, Tonga by combining infrasound from nearest International Monitoring System arrays, lightning data, and Multiangle Imaging Spectroradiometer (MISR) particle properties. Infrasound analysis suggests the eruption started between 3:50 and 3:57 UTC and had additional pulses, most notably one around 8:30 UTC, with lightning, which is linked to plume height and presence of ash, starting after 4:00 UTC. MISR, aboard NASA's sun-synchronous Terra satellite, has a 380 km observational swath and provides a snapshot of aerosol characteristics: altitude, relative velocity, and microphysical properties. Microphysical characteristics (radius, sphericity, and light absorption) enable us to infer if particles are sulfate/water, ash (non-spherical, weakly to strongly absorbing), or ice for a volcanic plume. Analysis of the MISR observation at 22:05 UTC on 15 January shows an ash-rich plume at 10-14 km a.s.l., swath centerline ~330 km to the west of Hunga. Preliminary particle property analysis shows a decrease from about 1-3 microns to ~0.5 micron ash particle radius with increasing distance from Hunga. We combine atmospheric wind and temperature profiles, GOES data, and NOAA HYSPLIT, and Ash3D modeling to investigate the particles' time history, in order to relate particle characteristic changes to infrasound and lightning changes. Initial HYSPLIT and Ash3D modeling suggest the particles were emplaced at least ~15 km a.s.l, lower altitude winds were westerly, and may have been part of the >30 km a.s.l. umbrella cloud and fell ~20 km in 15-20 hours, to the observed height at MISR overpass time, respectively. Thus, a considerable rate of fallout would be necessary to have ash where MISR observed it, which would require a process beyond simple gravitational settling, such as ash aggregation or downward meteorological advection. Subsequent MISR retrievals of the plume downwind do not observe any ash particles supporting possible early deposition.

1113

Effect of high oxygen fugacity on petrology of extrusive ferrobasaltic angrite meteorites

Dr Seann McKibbin[1], Prof. Hugh O'Neill[1]
[1]*Earth, Atmosphere, and Environment, Monash University, Clayton, Australia*

Angrite meteorites are igneous rocks with sub-basaltic silica contents, elevated Ca/Al and Fe/Mg, and a strong depletion in volatile lithophile elements such as Na and K (e.g., Mittlefehldt et al. 2002). Such highly 'ferrobasaltic' meteorites seem to have been extracted from a moderately reduced planetesimal mantle that had undergone some kind of core formation, extracting some siderophile elements, such as Ni and Co, but not others, such as Fe. This is indicative of moderately reducing conditions, possibly slightly below the iron-wüstite redox buffer, even though these magmas became moderately oxidised near the surface of their parent body, possibly to slightly above the iron-wüstite buffer (Steenstra et al. 2017).

During crystallisation, the lack of alkali elements in angritic magmas resulted in anorthite rather than plagioclase, and in angrites this phase contains Fe at high minor element and even major element levels. Previous experimental studies at moderately oxidised conditions established angritic phase equilibria at the conditions that likely prevailed during their crystallisation (Jurewicz et al. 1993; McKibbin and O'Neill 2018). Following these studies, we are investigating more oxidising conditions that may be relevant to the late evolution of angritic melts. Our experiments at higher oxygen fugacities have reproduced the high Fe-contents in anorthite of some angrites, typically at ~4 wt.% FeO with a similar deficiency in Al2O3 (e.g., Jambon et al. 2008). This suggests that substitution of Fe3+ into the anorthite lattice is greatly enhanced in oxidised, low-silica, low-alumina ferrobasalts such as angrites.

Angrites contain substantial volatile element contents, such as S (Warren and Kallemeyn 1995) and even H (Sarafian et al. 2017). In ongoing work, we are adding water and sulfide to angritic and similar ultra-ferrobasaltic compositions under moderate pressures to investigate the effects of these volatiles on such magmas.

1290

There she blows! Unravelling the eruptive history of Aso volcano (Japan) using distal ash deposits

Dr Danielle Mclean[1], Dr Paul Albert[2], Sophie Vineberg[1], Dr Richard Staff[3], Prof. Takehiko Suzuki[4], Prof. Jun-Ichi Kimura[5], Dr Q Chang[5], Dr Christina Manning[6], SG14 Project Members[1,7], Prof. Takeshi Nakagawa[7]
[1]University Of Oxford, Oxford, United Kingdom, [2]Swansea University, , United Kingdom, [3]University of Glasgow, , United Kingdom, [4]Tokyo Metropolitan University, , Japan, [5]Japan Agency for Marine-Earth Science and Technology, , Japan, [6]Royal Holloway University of London, , United Kingdom, [7]Ritsumeikan University, , Japan

Aso (southwestern Japan) is one of the largest active volcanoes in the world, with a caldera that was formed and modified by a series of at least four catastrophic VEI 6 – 7 eruptions between ca. 270 to 90 ka. These caldera-forming events produced widespread ash deposits blanketing Japan and the surrounding seas, with the final Aso-4 event generating pyroclastic density currents that can be mapped over 160 km from source. Between these cycles Aso is known to have remained very active, but the frequency and dispersal of these events are poorly constrained. This is unsurprising since the proximal exposures are limited and the numerous cataclysmic events have destroyed older deposits. Here, we highlight the critical role that distal records play in evaluating the eruptive history and hazard potential of Aso. We review distal occurrences of tephra deposits erupted from Aso, integrating new data from lake and marine sedimentary records across the East Asian/Pacific region. This tephrostratigraphic framework highlights inconsistencies in tephra correlations and suggests large magnitude events were more frequent and widely-dispersed than previously anticipated. To further supplement this record, we used high-resolution sedimentary cores to identify non-visible ash (cryptotephra) deposits erupted from Aso, which provide insight into the timing and dispersal of both pre- and post- caldera-forming events. The precisely dated Lake Suigetsu sediment core (central Japan) provides the most comprehensive distal eruption record for Aso, despite being over 530 km NE from the vent. The Suigetsu record is utilised to date and geochemically fingerprint (using major, minor and trace element glass compositions) thirteen ash fall events from Aso that reached the now densely populated regions of central Honshu. This work serves as a critical reminder that even in volcanic regions that are intensely studied, numerous large Quaternary explosive events remain poorly understood and many are undocumented.

453

Volcanic ash layers to synchronise archaeological and climate records in NW Africa

Dr Danielle Mclean[1], Professor Nick Barton[1], Dr Julie Christin Schindlbeck-Belo[2], Dr Emma Horn[1], Dr Holger Kuhlmann[3], Dr Adriano Pimentel[4], Dr Amy Styring[1], Dr Kevin Uno[5], Ms Vaneshree Vidyarthi[1], Professor Victoria Smith[1]

[1]University Of Oxford, Oxford, United Kingdom, [2]GEOMAR Helmholtz Centre for Ocean Research Kiel, , Germany, [3]MARUM, Research Faculty, University of Bremen, , Germany, [4]The Azores Volcano Observatory (CIVISA) / University of the Azores, , Portugal, [5]Columbia University, , USA

Archaeological sites in NW Africa are rich in human fossils and artefacts, emerging at the forefront of evolutionary studies. However, these records do not have a precise chronology, preventing assessments of the drivers of cultural/behavioural transitions. Investigations reveal numerous volcanic ash (tephra) layers are interbedded within the Palaeolithic sequences and are likely to have originated from large volcanic eruptions in the Atlantic (e.g., Azores, Canary Islands, Cape Verdes). Critically, the same ash layers will also be preserved in offshore marine records situated downwind of these volcanoes, meaning they can be used as time-stratigraphic markers to synchronise the archaeological and paleoenvironmental records in this region for the first time. Here we outline the initial investigations into the eruptive history of the source volcanoes and discuss diagnostic glass compositions essential for correlating. Moreover, we present the detailed tephrostratigraphic record preserved in the nearby marine cores (including ODP 958) which has been established using density separation techniques. The sediments contain numerous non-visible (cryptotephra) layers and the volcanic glasses have been geochemically fingerprinted to correlate them to their eruption source. The marine tephrostratigraphy provides a new record of explosive eruptions dispersed to NW Africa over the last ~300 ka and highlights ash layers that will be targeted for identification in the archaeological sequences. The tephrostratigraphy from the ODP 958 core will provide both relative and absolute age-constraints (via 40Ar/39Ar ages of the eruptions) for plant wax and other biomarker analysis, that will be used to generate regional vegetation, fire, and hydroclimate records of the habitats of early humans. The data are also useful for constraining the dispersal and magnitude of past eruptions from these islands. This work provides the first step in establishing a tephrostratigraphic framework for NW Africa and offers new possibilities for comparing climatic and cultural transitions during the Palaeolithic.

833

GENERATIVE ADVERSARIAL NETWORKS TO FORECAST DEBRIS AVALANCHE HAZARD

Dr Stuart Mead[1], Dr Gabor Kereszturi[1]
[1]*Massey University, Palmerston North, New Zealand*

Numerical models of hazardous environmental flows are tools frequently applied to hazard and risk assessment, scenario modelling and understanding of the underlying processes. The complexity and level of detail in numerical models have increased as computational power has become more available as parallelism and new computational techniques have reduced the computational burden of numerical modelling. However simulations through these numerical models still pose a large computational challenge. This can limit the applicability of numerical models to probabilistic hazard assessment, where a large number of simulations are required to adequately sample the probability space, and for rapid hazard/crisis assessment where simulation results need to be generated at short lead times.

One approach to alleviating these limitations is through construction of a surrogate model. A surrogate (or metamodel) is a model of the simulation results within a defined parameter space. Surrogate models typically learn from simulation results to create a fast approximation to the numerical model. Here, we explore the use of neural networks as a surrogate model to generate debris avalanche footprints from Ruapehu volcano, New Zealand. Neural networks have shown promise for approximating Partial Differential Equations and may therefore produce a suitable trained surrogate model. A generative adversarial network (GAN) architecture is used as the surrogate, trained using depth-averaged debris avalanche simulation outputs.

Our trials of GANs as a surrogate highlight a few key points: (1) well-trained GAN surrogates have high accuracy in reproducing model footprints, (2) the surrogate GANs show better accuracy when constrained to groups with similar simulation inputs (i.e. it is not generalizable), and (3) different loss functions (mean-square error vs. mean absolute error) affect trainability and accuracy.
These results, and future perspectives on the use of GANs for hazard assessment will be highlighted.

1041

New evidence of syn-eruptive magma-carbonate interaction: the case study of the Pomici di Avellino eruption.

Professor Daniela Mele[1], Professor Roberto Sulpizio[1], Dr Marco Knuever[1], Professor Pierfrancesco Dellino[1], Professor Annamaria Fornelli[1], Professor Maria Lacalamita[1], Dr Silvia Massaro[1], Dr Antonio Costa[2]
[1]*University of Bari, Bari, Italy,* [2]*Istituto Nazionale di Geofisica e Vulcanologia, Bologna, Italy*

The interaction of magma with country rocks, especially with carbonate basament, is a process of paramount importance in driving eruption dynamics. The magma-carbonate interaction can produce crustal volatiles into the magmatic system and can drive explosive eruption at hazardous volcanoes like Vesuvius, Merapi, Popocatépetl and Yellowstone.

The long-term magma-carbonate interaction, which occurs from magma source to the shallow conduit system, is a well-known process. Little is known instead, about the short-term magma-carbonate interaction, that is, when it occurs as a syn-eruptive process, which can be defined as a short-lived event compared to the process of long-term magma-carbonate interaction.

The occurrence of a reaction rim on carbonate xenoliths within juvenile fragments of the EU3 fallout deposit of the Pomici di Avellino eruption (3.9 cal. ky BP, Somma-Vesuvius, Italy) represents an example of the short-term magma-carbonate interaction.

In this work, a multi-analytical approach including petrography, scanning electron microscope (SEM) images, energy dispersive spectrometer (EDS), X-ray Powder Diffraction (XRPD) and micro-Computed X-ray Tomography analysis was performed on carbonate xenoliths and juvenile fragments.

The results show that these carbonate xenoliths experienced short-term magma-carbonate interaction, which took place in three steps: i) ingestion, i.e., the physic-mechanical process of carbonate xenoliths entrainment, ii) decarbonation, related to high-temperature reaction, and iii) digestion or dissolution due to the chemical migration of incorporated carbonate xenoliths. Therefore, the CO2 released during the syn-eruptive decarbonation processes provided extra volatiles to the rising magma, which maintained the magma buoyancy longer than what can be expected if only magmatic volatiles were involved in the eruptive processes.

946

Gas-Water-Rock interaction at Campi Flegrei geothermal system

Dott Federica Meloni[1,2,3], Dott Giordano Montegrossi[2,3], dott Monica Piochi[4], dott Barbara Cantucci[5], dott Gilda Currenti[6]

[1]university of florence, florence, Italy, [2]national research council (NRC), Florence, italy, [3]National Interuniversity Consortium for Materials Science and Technology, Florence, italy, [4]National Institute of Geophysics and Volcanology, Naples, Italy, [5]National Institute of Geophysics and Volcanology, Rome, Italy, [6]National Institute of Geophysics and Volcanology, Catania, Italy

Campi Flegrei, near Naples, is one of the world's most famous and hazardous volcanic caldera. It is assumed that the dynamics of the geothermal system of CF have a crucial role in the monitored unrest phases and in the eruption triggering as well. In order to understand the interaction effects between rock and fluid at CF, a 0-D reactive model was constructed, taking into account: 1) petrographic dataset of the San Vito wells cores, used to define the geochemical and petrophysical properties representative of the rock formations, 2) implementation of the thermodynamic and kinetic database calibrated on site-specific data. Geochemical batch-reaction simulations of the most important deposits in the area (Campanian Ignimbrite formation) were performed by the TOUGHREACT V2.1code with the EOS2 module, at variable PCO2, and at high (165°C) and low (85°C) temperatures. To validate the thermodynamic dataset and to build a consistent geochemical model, results were compared with waters sampled at the Tennis Hotel, which are considered representative of the shallow hydrothermal reservoir in the area. The results of modelled fluid-rock interaction are in agreement with the Tennis Hotel fluid composition. Best match falls within 10 years of simulation, prompting that geochemical reaction and fluid circulation toward the surface are quite fast. This phenomenon was also confirmed by the soil exhalation values and from the high gas flows sampled at fumaroles. The validate geochemical model will constitute the base for future reactive transport numerical simulations of CF as part of the “Pianeta Dinamico” Project.

551

Cryovolcanism as a source of volatiles on Charon and other Kuiper belt objects

Ms Stephanie Menten[1], Dr Michael Sori[1], Dr Ali Bramson[1]
[1]*Purdue University, Lafayette, United States*

Cryovolcanism is an icy volcanic process occurring in the outer solar system that is not well understood and may be important in the geological evolution of icy bodies. Data from NASA's New Horizons spacecraft revealed that Pluto's moon Charon is geologically diverse, with a history of being cryovolcanically active. Charon's southern hemisphere is covered in cryovolcanic terrain (named Vulcan Planitia) that could have erupted as a result of the freezing of an ancient subsurface ocean 2–4 Ga. Additionally, Charon's north pole contains a region known as Mordor Macula which consists of a thin layer of irradiated methane products covering the surface.

We hypothesize that the episode of cryovolcanism on Charon that created Vulcan Planitia supplied the methane that created Mordor Macula. We determined the thickness, overall volume, and methane content of the Vulcan Planitia cryoflow through analysis of various geologic features entrained within the flow. We then used a volatile transport model to track methane particles as they would migrate across Charon's surface after degassing from the cryovolcanic eruptions. We find that the majority of methane expelled by a cryovolcanic eruption would migrate to Charon's poles and become cold-trapped. Overall, ~nine meters of methane ice sourced from the emplacement of Vulcan Planitia would accumulate at each pole, which is enough to create the Mordor Macula feature observed today after irradiation over geological timescales. Therefore, we conclude that a cryovolcanic source of Mordor Macula through the eruption of Vulcan Planitia is plausible. Other large Kuiper belt objects, such as Makemake, show evidence of methane and methane products on their surfaces. Therefore, cryovolcanism delivering volatiles from interior to surface could be an important and common process across the Kuiper belt, just as silicate volcanism is on Earth and other rocky planets.

936

Volcano research: where, when, and by whom? A global bibliometric analysis

Dr Geoffrey Lerner[1,2], Dr George Williams[2,3,4], Elinor Meredith[2,3], Dr Susanna Jenkins[2,3], Dr Jenni Barclay[5]
[1]Instituto de Geofísica, Universidad Nacional Autónoma de México, , Mexico, [2]Earth Observatory of Singapore, Nanyang Technological University, , Singapore, [3]Asian School of the Environment, Nanyang Technological University, , Singapore, [4]Verisk, Extreme Event Solutions, , Singapore, [5]School of Environmental Sciences, University of East Anglia, , United Kingdom

The global and transdisciplinary nature of volcanology means that research takes place across institutions in a wide variety of locations around the world. The concentration of volcanic activity within certain regions means that researchers frequently conduct research outside their own borders. Collaboration between international and local researchers has the potential to produce mutual benefit and improve research. For local scientists, international collaboration can provide niche expertise that may not be currently available in the region where the volcano is located, in addition to resources, analyses, or equipment. For international researchers, in addition to different scientific perspectives, collaboration with local scientists can provide vital knowledge of local and regional information, access to field sites, and greater research relevance to the communities and organizations the research is often intended to benefit.

Despite these noted benefits, there is often a lack of inclusivity of local scientists in international research. In this study we use a bibliometric approach to understand who is doing and leading volcanic research, and in which countries the research is taking place. We assessed the metadata of ~24,000 volcanological works from 1901-2021 with 768 volcanoes identified across 68 countries. Our evaluation of affiliations shows that 40% of articles that name a volcano do not include any authors affiliated with the volcano's country. We also look at case studies of island territories to explore to what extent local scientists are involved in doing research compared to the mainland or foreign countries. We find that only 23% of studies on volcanoes located on island territories have an author affiliated with the territory. Our assessment of bibliometric data provides insights and support for ongoing conversations on the inclusiveness of international research, both spatially and temporally, and can be used to identify geographical areas for improvement, as well as trends in inclusion and leadership.

934

Insights into the vulnerability of structures to lava flows

Elinor Meredith[1,2], Dr Susanna Jenkins[1,2], Dr Josh Hayes[3], Dr David Lallemant[1,2], Dr Natalia Deligne[4], Denny Jian Hao Chee[1,2]

[1]Earth Observatory of Singapore, , Singapore, [2]Asian School of the Environment, Nanyang Technological University, , Singapore, [3]GNS Science, , New Zealand, [4]U.S. Geological Survey, Hawaiian Volcano Observatory, , USA

The destruction of thousands of homes by lava flows from Cumbre Vieja, La Palma, Spain and Nyiragongo Volcano, DRC, in 2021, serves as a reminder of the devastating impact of lava flows on communities living in volcanically active regions. However, studies of impacts from effusive hazards on the built environment are relatively rare compared to explosive hazards and little is known about building-lava interactions. We draw on available post-eruption field missions, aerial and satellite imagery from recent case studies including the 2014-2015 lava flows of Fogo, Cape Verde, the 2018 lower East Rift Zone lava flows of Kīlauea, Hawai`i and the 2021 lava flows of Cumbre Vieja, La Palma, Spain, as well as information published in past literature. We compiled a building-level database of structure damage, including building typology (material, shape), damage severity (damage state) and hazard characteristics (lava thickness). The database contains over 6,000 structures classified as damaged or destroyed. Coupling the damage severity of each structure to hazard characteristics for each building type, provides insights into structure vulnerability and the mechanisms of damage. On the lava flow periphery, structures exhibit a range of damage, depending upon building typology and lava morphology. For our dominant building types — masonry, timber and metal — we identified a positive relationship between damage state and lava thickness, whereby increasing thicknesses are correlated with higher damage states, with total destruction of all building types impacted by lava flows >2 m thickness. We found circular and/or masonry structures relatively more resistant to thinner flows. This work can support the development of fragility curves to forecast damage during future lava flow events, and contribute to risk assessments and mitigation efforts.

961

Working with communities for seismometer network deployment around Taupō volcano, Aotearoa New Zealand

Eleanor Mestel[1], Bubs Smith[2], Kelvin Tapuke[3,4], Dr Finnigan Illsley-Kemp[1], Lucy Kaiser[4,5], Professor David Johnston[4], Ian Connon[6]

[1]Te Herenga Waka Victoria University Of Wellington, Wellington, Aotearoa New Zealand, [2]Ngāti Tūwharetoa, Tūrangi, Aotearoa New Zealand, [3]Representative of Te Arawa, Rotorua, Aotearoa New Zealand, [4]Joint Centre for Disaster Research, Massey University, Wellington, Aotearoa New Zealand, [5]GNS Science, Wellington, Aotearoa New Zealand, [6]Taupō Civil Defence and Emergency Management, Taupō District Council, Taupō, Aotearoa New Zealand

From October 2019 to May 2022, a temporary seismometer network was deployed in the areas around Lake Taupō to learn about the volcano that lies beneath the water. This formed a key component of the multi-disciplinary, multi-institution ECLIPSE research programme. A core part of this work involved partnering and building relationships with members of the community, local indigenous iwi and hapū, as well as others involved in civil defence, emergency management and geohazard monitoring. Before, during, and after the deployment of the network, we have worked to communicate about and discuss the research, involve people in the work, and share results. This co-production approach to geophysical network deployment is unique in volcano-related studies in Aotearoa New Zealand and has improved outcomes both for communities and for researchers. As a result, and because of a desire to show a pathway for future studies of this kind, we have worked to reflect upon the approach we have taken: what was done well and what could be improved. Here we present some findings from these reflections on our mahi (work).

958

Three years of earthquake activity at Taupō volcano, Aotearoa New Zealand, investigated with an enhanced seismic network

Eleanor Mestel[1], Dr Finnigan Illsley-Kemp[1], Professor Martha K. Savage[1], Professor Colin J.N. Wilson[1], Bubs Smith[2]

[1]Te Herenga Waka Victoria University Of Wellington, Wellington, Aotearoa New Zealand, [2]Ngāti Tūwharetoa, Tūrangi, Aotearoa New Zealand

Taupō volcano, in the centre of North Island, Aotearoa New Zealand, is a frequently active rhyolitic caldera volcano that was the site of Earth's most recent supereruption (Oruanui ~25.5 ka) and also of one of the most violent eruptions globally of the last 5000 years (Taupō 232 ± 10 CE). It has erupted 28 times since 25.5 ka, and continues to display signs of unrest (seismicity and surface deformation), with periods of elevated unrest on roughly decadal timescales. Any resumption of eruptive activity at the volcano poses a major source of hazard, and interactions between the magma reservoir and the regional tectonics that lead to unrest and possible eruption are not well understood. We use data from a temporary seismometer network (ECLIPSE), combined with data from the permanent local GeoNet seismometers, to yield a detailed picture of the present state of the volcano. The ECLIPSE broadband seismometer network was deployed across 14 sites from October 2019 – May 2022, taking a co-production approach to the research to work with local communities and colleagues. We present results of the analysis of the seismicity at Taupō over the last three years including: automatic picking and event association; locations; relative relocations; magnitudes; and focal mechanisms. The earthquakes are located using a new 1D velocity model inverted specifically for the region below and around the volcano. Characterising the background seismicity at Taupō and relating it to past unrest events (in 2019) and models of the young magmatic system improves our understanding of one of Aotearoa's most dangerous volcanoes. This study in particular will aid in interpretation of ongoing and future seismic activity at Taupō, including the most recent period of elevated seismicity, which began in May 2022.

867

Glass in Phreatic Ash at Turrialba and Rincón de la Vieja Volcanoes, Costa Rica

Ms Emily Mick[1], Dr Geoffroy Avard[2], Dr John Stix[1]
[1]McGill University Department of Earth and Planetary Sciences, Montreal, Canada, [2]Observatorio Volcanológico y Sismológico de Costa Rica (OVSICORI), Heredia, Costa Rica

Juvenile material is generally taken to mean some amount of new magma is entering or moving within a volcanic system and, increasingly, juvenile material of uncertain origin is being identified in the products of phreatic eruptions. Samples collected from Turrialba volcano between 2014 and 2022 and Rincón de la Vieja between 2017 and 2021 reveal variable amounts of fresh-looking glass (<5% to >20%) in eruptions classified as phreatic to phreatomagmatic. In both systems microlites of plagioclase and pyroxene have been found in glassy components with variable proportions of larger (growth regime) and smaller (nucleation regime) crystals indicative of variations in degassing and crystallization conditions. Glassy material includes both vesicular and blocky grains whose proportions vary between samples and between size fractions of a given sample as a result of origin and eruption dynamics. At Turrialba mud pellets and hydrothermally altered grains make up a significant portion of samples between 2014 and 2017, indicative of wet eruptions and a highly active hydrothermal system, while fresh lithics and free crystals make up a small proportion of samples. At Rincón de la Vieja an increasing tendency in hydrothermal grains is noted in more recently erupted samples (2020-2021) while mud pellets are rarely seen. A significant component of free crystals is found in multiple samples (typically <15% but as high as 80%). Further investigation of major element chemistry coupled with water concentration and speciation data (H2Otot, OH-, H2Omol) obtained by FTIR-ATR and isotopic signatures will be used to distinguish between magmatic degassing and rehydration trends within the glass to determine if the fresh glass is juvenile material representing a freshly intruded magma, or if it represents a magma body that has stalled, degassed, and rehydrated at a shallow level.

1176

Generation, storage, and eruption of abundant silicic magma within a transcrustal magmatic system, Miocene Colorado River Extensional Corridor, Nevada, USA

Professor Calvin Miller[1], Professor Guilherme Gualda[1], Blake Wallrich[1], Professor Jonathan Miller[2]
[1]*Vanderbilt University, Nashville, United States,* [2]*San Jose State University, San Jose, United States*

Large plutons and associated volcanic rocks in the northern Colorado River Extensional Corridor (CREC; Nevada, USA) represent the upper portion of a Miocene transcrustal magmatic system, exposed to depths of as much as ~13 km. Although mingled mafic rocks are widespread and intermediate rocks comprise the lower part of the coeval volcanic section and earlier portion of some intrusions, plutons are dominated by granite and upper volcanics by rhyolite. Isotopic data (Nd, Sr, Hf, O) suggest that mafic magmas (both mingled within plutons and as sequence-capping lavas) were derived from ancient, enriched lithospheric mantle, whereas both intermediate and silicic magmas were hybrids that included large Proterozoic crustal components.

Most granite is coarse grained and reveals evidence for crystal accumulation and/or melt extraction. Sparser but widespread fine-grained granites — low-silica granite dikes, sills, and quenched margins — document compositions of crystal-poor magmas that fed the plutons, and thus provide more direct insights into generation of the voluminous silicic CREC magmas. These highly uniform magmas (73+1 wt% SiO_2) are isotopically indistinguishable from other granites and rhyolites. We conclude that the compositional variability of these granites and rhyolites is a consequence of closed-system, upper crustal fractionation.

Rhyolite-MELTS barometry (Gualda et al, this meeting) indicates that feeder magmas were extracted from qtz+feldspar-bearing mush in the middle crust (~400 MPa [15 km]). Barometry reveals that leucogranites and almost all erupted rhyolite (76-78% SiO_2) represent melt extracted from mush within the plutons at ~4-8 km depth. The CREC system thus appears to have included a lower crustal "hot zone" where mantle-derived magma interacted with ancient crust to form an intermediate hybrid; a mid-crustal mush zone where interstitial silicic melt formed and was extracted; and upper crustal lenses where the extracted granitic melt formed cumulates and fractionated, eruptible melts.

1188

Building damage from tephra fall during the 2020-21 eruption of La Soufriere volcano

Dr Victoria Miller[1], Dr Susanna Jenkins[2], Eleanor Tennant[2], Monique Johnson[3], Dr Christina Magill[1], Dr Thomas Wilson[4]

[1]GNS Science, Lower Hutt, New Zealand, [2]Earth Observatory of Singapore and Asian School of the Environment, Nanyang Technological University, , Singapore, [3]The University of the West Indies Seismic Research Centre, St. Augustine, Trinidad and Tobago, [4]University of Canterbury, Christchurch, New Zealand

The explosive eruption sequence of La Soufrière, St Vincent commenced on 9 April 2021, disintegrating the lava domes produced during both the 1979 and 2020/21 effusive phase and carving out a new crater geomorphology. The explosive events resulted in plumes to greater than 15 km above the volcano with tephra fallout affecting all of the island of St Vincent as well as Barbados to the east and the French islands to the north. The eruption resulted in significant building damage, including collapse, in the northern part of the island.

Empirical impact data are one of the most important sources of information for impact forecasting, and yet only three published datasets of structural tephra fall damage to buildings exist (Pinatubo 1991; Rabaul, 1994; Calbuco, 2015). Such data provide an evidence base from which advice on future impacts and mitigation strategies can be developed for communities living close to the volcano. Furthermore, damage data collected following an eruption can be used for developing vulnerability functions needed in quantitative risk assessments, to support emergency preparedness and response.

The explosive events from La Soufrière in April 2021 provided an opportunity to assess damage from the extensive tephra deposits, with a view to using the empirical impact data to develop vulnerability functions tailored for a regional context. A ground-based impact survey was undertaken in August 2021 that captured 500+ buildings in settlements surrounding the volcano and encompassing a wide range of building types and construction materials. We provide an overview of the damage to buildings and identify key advice for mitigating future impacts. Drawing from the lessons learned, we examine future strategies for collection of impact datasets during such events.

383

Probing beneath the waves to understand hazards from New Zealand's volcanic islands

Dr Craig Miller[1], Dr Lydia di Caprio[2], Dr Gert Lube[3], Dr Ben Kennedy[4], Dr Victoria Miller[5], Dr Xiaoming Wang[2]
[1]GNS Science, Taupo, New Zealand, [2]GNS Science, Lower Hutt, New Zealand, [3]Massey University, Palmerston North, New Zealand, [4]Ben Kennedy, Christchurch, University of Canterbury, [5]GNS Science , Auckland, New Zealand

Aotearoa New Zealand's island volcanoes, Whakaari and Tuhua, directly threaten more than 1.5 million New Zealanders and a multibillion-dollar economy through multiple severe, volcanic and non-volcanic hazards; pyroclastic flow, ashfall, flank collapse and tsunami. Appropriate mitigative actions can only be implemented if the magnitude of their impact and likelihood of occurrence can be quantified. A new 5 year research programme, Beneath the Waves will leverage international expertise to create three-dimensional multi-physics models of volcano structure including magma locations, hydrothermal systems, and areas of weak and strong rock. The large underwater component makes these tasks highly challenging, requiring a multi-disciplinary approach to exploring the anatomy of Whakaari and Tuhua volcanoes. We will further simulate the likelihoods of pyroclastic flow, ashfall and tsunami, analyse their impacts and integrate results into next generation probabilistic forecasts and alerting. Simulations with New Zealand's PELE, large-scale eruption simulator will advance theoretical models of volcanic and non-volcanic mass flows and their ability to generate tsunami, while probabilistic ashfall models calibrated with offshore tephra cores quantify risk to communities. To ensure maximum uptake of science results our programme is linked with diverse end-users to ensure relevance for them. Indigenous Māori, council and emergency management partners will both shape and use research outputs in sectoral plans, programmes and policies. Industry user groups ensure tailored advice reaches relevant sectors. Probabilistic forecasts of hazard likelihood for inform existing monitoring efforts through GeoNet. Partnership with existing research outreach agencies accelerates community engagement and novel "serious-games" target schools and difficult-to-reach audiences. Communicating island "state of health" through media, internet and the international science community ensures global uptake of our research for benefit of all communities.

380

The integrated history of repeated caldera formation at the Okataina Volcanic Centre: Insights from 3D gravity and magnetic models

Dr Craig Miller[1], Jenny Barretto[3], Dr Vaughan Stagpoole[3], Dr Fabio Caratori-Tontini[2], Thomas Brakenrig[1], Dr Edward Bertrand[3]

[1]GNS Science, Taupo, New Zealand, [2]Department of Earth Sciences, Environment and Life (DISTAV), University of Genova, Genova, Italy, [3]GNS Science, Lower Hutt, Wellington

Multistage collapse caldera create complex geological structures, often buried by kilometers of pyroclastic infill and late stage lava domes, making study of their origins difficult from outcrop alone. New gravity and aeromagnetic data compilations derived from terrestrial, lake and airborne surveys allow us to investigate the buried internal structure of the Okataina Volcanic Centre (OVC) and interpret its stages of development. Magnetic highs (1300 nT) are caused by a combination of thick lava flows and domes that infill the collapse structures, and a deeper feeder structure/dyke complex that extends into the basement. Magnetic lows caused by hydrothermal alteration are associated with topographically low areas near the topographic and structural collapse margins suggesting fluid circulation within the caldera exploits both deep and shallow structures.

A -62 mGal residual gravity low occupies the OVC, with the steepest gradients inside the topographic margins. The gravity low is stepped towards its lowest point near the outlet of Lake Tarawera. Each step is interpreted as relating to the buried structural collapse margins of the Utu, Matahina, Rotoiti and possibly Kawerau, caldera forming eruptions, creating an overlapping and nested caldera structure. 3D gravity inversion, including models numerically constrained by a 3D magnetotelluric model, suggest a caldera depth of 5000±500 m that accumulated over multiple collapse episodes along with rifting induced subsidence in the past 550 ka. Buried caldera margins associated with oldest Utu eruption may play a role in the location of the youngest Tarawera eruptions. We propose smaller amplitude gravity lows that extend outside the topographic margins of the caldera are related to lateral magma migration towards eruption vents within the caldera, exploiting regional tectonic stress regimes.

Detailed geophysical models of caldera structure are rare globally, and our findings are consistent with analogue and numerical models of caldera formation.

1218

CHANGES IN ERUPTIVE STYLES AT A STRATOVOLCANO DURING A COLLAPSE CYCLE

Ms Shannen Mills[1], Professor Jonathan Procter[1], Dr Anke Zernack[1], Dr Stuart Mead[1], Professor Georg Zellmer[1], Professor Shane Cronin[2], Dr Ian Schipper[3]

[1]Massey University, Palmerston North, New Zealand, [2]The University of Auckland, Auckland, New Zealand, [3]Victoria University of Wellington, Wellington, New Zealand

Mt. Taranaki has experienced 14 volcanic debris avalanche deposits within its eruptive history providing a unique chance to study the pre and post collapse effects on volcanic activity at a Stratovolcano. Between 20-30,000 years ago Mt. Taranaki experienced two collapse events which produced the 27.3ka Ngaere Formation (5.85km3) and the 24.8ka Pungarehu Formation (7.5km3). Over this period there was 28 sub-Plinian eruptions forming the Poto and Paetahi Formations.

These tephra formations show that unlike other studied formations at Mt. Taranaki there is not a variety of eruptive and effusive products within this collapse cycle. Eruptive parameter data from the Poto and Paetahi Formations indicates only sub-Plinian events occurred producing column heights ranging from 10-20km with eruptive magnitudes of VEI 3 to 4 which produced duration times between 1-2.5 hours. We also observe smaller magnitude, sub-Plinian events occurring immediately prior to the collapse and larger magnitude sub-Plinian events immediately post collapse. Componentry analysis of the depositional layers indicate systematic change within the conduit. Throughout the Poto and Paetahi Formations there are 17 open vent phases evident through the dominant percentage of juvenile clasts indicating a higher degree of fragmentation, 7 closed vent and 4 unstable column events identified through the dominance of lithic clasts showing increased excavation of the conduit walls and basement rock.

The results from this work will aid in understanding the hazards associated with a collapse phase at a stratovolcano and inform computational simulations of ash fall.

1471

Hydrothermal system of Aso volcano, Central Kyushu, Japan, as inferred by electromagnetic soundings

Dr Takuto Minami[1], Dr Marceau Gresse[2], Dr Mitsuru Utsugi[3]
[1]Kobe University, Kobe, Japan, [2]National Institute of Advanced Industrial Science and Technology, Tsukuba, Japan, [3]Aso Volcanological Laboratory, Kyoto University, Asogun, Japan

Aso volcano, Central Kyushu, Japan, is well-known for its distinct activity cycle consisting of mud, strombolian, and phreatic/phreatomagmatic eruptions with a period of about 15 to 20 years. Since the phreatomagmatic eruptions of Aso volcano are most devastating during one activity cycle, we aim at revealing the hydrothermal system of Aso volcano and understand the mechanism of the phreatic/phreatomagmatic eruptions. To reveal its shallow resistivity structure, two kinds of electromagnetic (EM) soundings have been performed in Aso volcano: AMT and ACTIVE (Array of Controlled Transient-electromagnetics for Imaging Volcano Edifice, Utada et al. 2007). ACTIVE is an EM volcano monitoring system based on transient EM method composed of a source electric dipole with two earthing electrodes and induction-coil receivers for measurement of the magnetic vertical component. Our previous study (Minami et al., 2018) revealed the temporal change in the three-dimensional (3-D) resistivity structure through the magmatic eruptions of Aso volcano from August 2014 to August 2015 using the ACTIVE campaign datasets. On the other hand, Kanda et al. (2019) inferred a detailed 3-D resistivity structure of Aso volcano based on AMT survey data obtained in 2004 - 2005. With the aid of the hydrothermal simulation code TOUGH2 (Pruess, 1991), we recently found that a hydrothermal model assuming empirical porosity, permeability, and heat source at depth of the active crater explains well the 3-D resistivity structure based on AMT data. We are currently integrating the hydrothermal model from the AMT dataset and the temporal variation in the resistivity structure revealed by the ACTIVE datasets. In the presentation, we present how our hydrothermal model explains the 3-D resistivity structure inferred from the AMT dataset and our project to integrate AMT and ACTIVE datasets into a hydrothermal model of Aso volcano.

1359

Reconstructing tephra fall deposits via ensemble-based data assimilation techniques

Dr Leonardo Mingari[1], Dr. Antonio Costa[2], Dr. Giovanni Macedonio[3], Dr. Arnau Folch[4]
[1]Barcelona Supercomputing Center, Barcelona, Spain, [2]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Bologna, Bologna, Italy, [3]Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Vesuviano, Naples, Italy, [4]Geociencias Barcelona (GEO3BCN-CSIC), Barcelona, Spain

In recent years, there has been a growing interest in ensemble-based based approaches for modeling volcanic plumes. The development of advanced ensemble modeling techniques enables the exploration of novel methods for the incorporation of real observations into tephra dispersal models using ensemble-based data assimilation techniques. However, traditional data assimilation algorithms, including ensemble Kalman filter methods, can yield suboptimal state estimates for positive-definite variables such as volcanic aerosols and tephra deposits. We present two new ensemble-based data assimilation techniques for semi-positive-definite variables with highly skewed uncertainty distributions, such as deposit mass loading. The proposed methods are applied to reconstruct the tephra fallout deposit resulting from the 2015 Calbuco eruption and the 946 CE eruption of Baekdu volcano, the so-called Millennium eruption, one of the largest eruptions in historic times based on widespread tephra dispersal.

The FALL3D dispersal model was used to perform an ensemble of runs in order to simulate the transport and deposition of tephra for different model configurations. Subsequently, deposit thickness measurements are assimilated to reconstruct the tephra deposit and improve the first-guess results, obtained from a simple ensemble forecast. An assessment of the assimilation methods is carried out using an independent dataset of observations in terms of different evaluation metrics. The methodologies presented here represent promising alternatives for the assimilation of real observations in operational models.

352

The October 14, 2021 explosive eruption of Nakadake first crater, Aso Volcano, Japan

Dr Yasuo Miyabuchi[1], Dr Yoshiyuki Iizuka[2], Dr Takahiro Ohkura[3]
[1]*Center for Water Cycle, Marine Environment and Disaster Management. Kumamoto University, Kumamoto, Japan,* [2]*Institute of Earth Sciences, Academia Sinica, Taipei, Taiwan,* [3]*Aso Volcanological Laboratory, Kyoto University, , Japan*

An explosive eruption producing ballistic clasts and tephra-fall deposits occurred at the Nakadake first crater, Aso Volcano in central Kyushu, southwestern Japan, on October 14, 2021. A large number of ballistic clasts (maximum size 70 × 32 × 31 cm) were scattered within about 450 m from the center of the crater. Several impact craters (< 1 m in diameter) were observed on the surface of ash layer at the crater rim. The ballistic clasts were dominated by basaltic-andesite accessory fragments of lavas and pyroclastic rocks interpreted not to originating from a newly ascending magma. The tephra-fall deposit was distributed to the southeast, extending to about 30 km of the source crater. At the crater rim, the fallout deposits were composed mainly of sand-size particles with small amounts of lapilli (<17%), and were aggregated at sizes of a few mm to 1 cm. The aggregated muddy ash (a few millimeters in diameter) adhered on plant leaves and the surface of man-made constructions in the southeastern part of Aso caldera (4–10 km), indicating that the rising plume contained large amounts of condensed water vapor. Based on the isomass map, the total discharged mass of the October 14, 2021 eruption was calculated at about 2,500 tons. Gray to white lithic grains (40–50%) were dominant in the tephra deposits (0.125–0.25 mm fraction), and black to brown glass shards (8–16%) were also contained. Although very small amounts of glass particles seemed to be fresh, most of glass shards showed varying degrees of alteration based on microscope observation and micro-probe analysis. These evidences suggest that the October 14, 2021 eruption of the Nakadake first crater was probably a phreatic eruption.

754

Transition from Column Forming to Collapsing during the 1783 Eruption, Asama Volcano, Japan, Inferred from Rock Microtexture and Physical Properties

Mr Tatsuki Mizuno[1], Dr Fukashi Maeno[1]
[1]*Earthquake Research Institute, University of Tokyo, Bunkyo-ku, Japan*

Plinian eruptions are often followed by a transition of the eruption style to pyroclastic flows (PDCs). Determining parameters controlling such changes in eruption style is important to predict the eruptive activity and its transition. Bubble textures reflect such parameters including the magma storage conditions, intensity, and style of eruptions; therefore, in some cases, they enable us to estimate the magma ascent process by quantifying the bubble texture of eruptions. In this study, we focus on the 1783 eruption of Asama Volcano, Japan and discuss the mechanism of eruption transition through physical and textural analyses. Pyroclastic fall deposits are characterized by stratified pumice fall or ash fall units. Some deposits contain reddish-brown silt derived from small-scale PDCs that occurred at the same time. Three types of deposits: fallout pumice, fallout pumice associated with PDCs, and PDC pumice, are selected for measurement of density and microscopy. The average apparent densities show PDC pumice have slightly low vesicularity. Bubble size distribution shows that bubbles smaller than 5 µm are significantly included in pumices from the PDCs. The bubble number density is the order of 10^{14}-10^{15} /m³. Decompression rates were estimated to be 4.2-12 MPa/s for fallout pumice, 16-21 MPa/s for fallout pumice associated with PDCs, and 15-36 MPa/s for PDC pumice, using a theoretical model. These high decompression rates suggest that rapid decompression caused effective bubble formation. Juvenile lava fragments suggest that the lava-plug was formed onto the upper conduit. Considering that the low vesicularity and minimum size bubble (< 5µm), bubble growth and coalescence were not promoted in the PDC phase, and the exsolved gas phase might decrease or not be easily separated from the interior of particles to the outside. This process will reduce the amount of gas supplied to the plume and is possible to contribute to generating PDCs.

1032

UAV time-lapse photogrammetry of the Las Lajas lahar channel morphology, Volcan de Fuego, Guatemala

Mr Jerry Mock[1], Mr Armando Pineda[4], Ms Ashley Bosa[1], Mr Roberto Mérida Boogher[2], Dr Jeffrey Johnson[1], Mr Gustavo Bejar[3], Ms Tamara Satterwhite[1]

[1]Boise State University, Boise, United States, [2]Instituto Nacional de Sismologia, Vulcanologia, Meteorologia e Hidrologia (INSIVUMEH), Guatemala City, Guatemala, [3]Michigan Technological University, Houghton, United States, [4]Independent, Guatemala City, Guatemala

Volcán de Fuego in Guatemala regularly erupts pyroclastic material during small Strombolian eruptions (every 15-20 minutes) and during sporadic larger paroxysmal events. During rainy seasons (May-September), the unconsolidated material is unstable and prone to secondary lahars during intense rainstorms. Abundant pyroclastic material was deposited in the Las Lajas drainage during the major paroxysm of 2018. Since then, smaller pyroclastic density currents have contributed material available for mass wasting, including in February and September of 2021.

Our mapping from 2021 focuses on Las Lajas drainage to quantify erosional and depositional processes for secondary lahars at intermediate distances (~5-10 km) from the summit. We used Unoccupied Aerial Vehicle (UAV) imagery from four repeat surveys to create time-lapse Structure from Motion (SfM) Digital Elevation Models (DEMs) at approximately one month intervals. Our products are orthoregistered DEMs and their differences provide detailed and quantitative estimates of erosion and depositional volumes along the channels.

Results indicate greater rates of erosion on the upper portions of the drainage that shift to a depositional regime as the slope in the channel decreases. The point at which the regime changes from erosion to deposition seems to shift throughout the season. The analysis also quantifies bank collapse along the channel as a significant contributor to the material lost. For example, in a single ~1 km long section approximately 4-5 km from the crater, 88,000 cubic meters of material was removed from June to October.

The quantitative measurements made at intermediate distances (5-10 km) are important because they cover the area where Fuego's small recurrent lahars both erode steep canyon walls, bulk up, and deposit much of their sediment load. These data, along with observations of other contributing variables, add to a growing body of knowledge to better assess these frequent events, which present hazards to the local community.

1458

Estimating minimum eruptive volumes to generate large calderas at Ascraeus Mons.

Mr Kyle Mohr[1], Dr David A. Williams[1], Dr Amanda Clarke[1,2]
[1]Arizona State University, Tempe, United States, [2]Istituto Nazionale di Geo sica e Vulcanologia, Sezione di Pisa, Pisa, Italy

Ascraeus Mons is the northeastern most of the large shield volcanoes located in the Tharsis province on Mars reaching 18 km in height and ~350 km in diameter. The large caldera complex at the summit of Ascraeus Mons is nearly 60 km in diameter and ~ 3 km deep at its deepest point. Previous mapping campaigns have documented the caldera complex in great detail, however, measurements of the displaced volumes associated with each caldera forming event were not calculated.

We mapped the caldera complex of Ascraeus Mons in greater detail at a 1:100,000 scale to represent tectonic, volcanic, and surficial features not able to be seen from coarser mapping resolutions. From the mapping we identified nine distinct calderas and four unique wall units, mapped based on different erosional and tectonic regimes: caldera steep fluted, caldera slump, caldera stepped, and caldera mass-wasting.

Magma chamber and minimum erupted volumes for each newly mapped caldera were calculated using the model of Geshi et al., (2014). Calculated erupted volumes were compared against volume estimates using the Polygon Volume Tool within ArcGIS 10.5 and a 463 m/pix MOLA DEM. Minimum erupted volumes for the calderas of Ascraeus Mons range from 10-10^3 km^3, which are comparable to some of the largest silicic eruptions on Earth. Calculated chamber volumes for each caldera pit range from 10-10^5 km^3 and are an order of magnitude or two larger than their earthly silicic counterparts at respective caldera diameters. This suggests Ascraeus Mons is able to maintain, partially empty, and refill enormous volumes of magma for long intervals of time, which could shed light into the overall evolution of Mars' internal heat flux and magma budget below Tharsis.

1459

Simulating large explosive basaltic eruption plumes and their tephra dispersal

Mr Kyle Mohr[1], Dr Federica Pardini[2], Dr Amanda Clarke[1,2], Dr Mattia de' Michieli Vitturi[2], Dr Kurt Roggensack[1], Dr Fabrizio Alfano[1], Dr Emily Zawacki[1], Dr Chelsea Allison[1]
[1]Arizona State University, Tempe, United States, [2]Istituto Nazionale di Geo sica e Vulcanologia, Sezione di Pisa, Pisa, Italy

We successfully modeled the well-documented 24 November 2006, eruption of Mt. Etna using a plume dynamics model (PlumeMoM) coupled with an atmospheric dispersal model (HySPLIT). The simulated plume characteristics (e.g., bent-over to the SE; 5.5 km a.s.l.) and corresponding isopachs closely match field-based data. Grain-size distributions and mass-loadings at individual sites were captured well by the model except at sample locations near the vent (<5 kms) and far from the main dispersal axis (>8 kms). The coupled model can account for the dynamics of a density current within the spreading umbrella portion of the volcanic plume. The overall match between modeled and field-based deposit characteristics greatly improves with the addition of density current dynamics. These comparisons demonstrate that density current dynamics within the spreading cloud are important even for a weak, bent-over volcanic plume such as this Mt. Etna test case.

With this benchmarked code we will simulate prehistoric explosive basaltic eruptions such as those of Sunset Crater, Arizona (~1085 AD; ~27 km-high plumes), and Tecolote volcano, Sonora, Mexico (27 ka; ~12 & 18 km-high plumes). This new approach provides better constraint on column height and mass eruption rate, and better extrapolates deposit characteristics beyond their well-preserved regions. The simulated prehistoric eruptions will serve to constrain tephra hazards from future eruptions in distributed volcanic fields of the American southwest. A future eruption the size of Sunset (27 km plume), Tecolote (18 km plume), or even a small bent-over plume the size of Mt. Etna, 2006 (5.5 km), could be very disruptive and cause significant infrastructure damage to the local region.

1164

Controls on explosive phreatomagmatic versus magmatic volatile-dominated styles of volcanic eruptions

Dr. Pranabendu Moitra[1], Dr. Ingo Sonder[2], Dr. Greg Valentine[2]
[1]*University Of Arizona, Tucson, United States,* [2]*University at Buffalo, Buffalo, United States*

Magma cools rapidly in the presence of external water such as ground water and seawater. Rapid heat transfer and energetic interactions between magma and water lead to phreatomagmatic and explosive submarine eruptions. However, geological record shows that such explosive magma-water interactions are not as common as their non-explosive as well as magmatic counterparts, even though nearly all erupting magmas encounter liquid water during ascent. Also, magmatic volatile-driven eruptions are often explosive, but with negligible role of externally derived water on the process. This raises the question – what factors control and limit an energetic interaction between magma and external water? As soon as magma comes in direct contact with water, a film of water vapor forms at the magma-water interface, which is thought to be a key process for pre-mixing required for energetic interactions. Recent laboratory experiments showed that vapor film stability increases, whereas the effective heat flux decreases, with increasing water temperature. Also, the longer a water domain stays liquid, the greater is the possibility of vapor film break-up and a direct contact between hot magma and cold liquid water facilitating an efficient heat transfer. We show that the transient water temperature in contact with magma, the size of an entrained water domain, and the stability time scale of vapor film play key roles in determining the non-explosive versus explosive fate of a magma-water system. The effects of the thermophysical properties of magma and water, and the Leidenfrost temperature on the possible energetic interactions are also investigated. The implications of our findings on phreatomagmatic versus magmatic volatile-dominated explosive eruption styles are discussed.

1168

Rheological arrest vs. rapid growth of bubbles in crystal-rich magmas: Implications for effusive to explosive transition in eruption styles

Dr Pranabendu Moitra[1]
[1]*University of Arizona, Tucson, United States*

Effusive to highly explosive volcanic eruptions of crystal-rich magmas may be more common than previously thought of. The competing effects of rheological stiffening of crystalline magma and bubble overpressure build-up drive volcanic explosivity. The growth of a bubble exerts extensional stress on its wall (melt+crystal matrix) surrounding it. The rheological properties of crystal-rich magmas under such extension and their effect on bubble growth are poorly understood. Using analog experiments, this study finds that crystalline magma likely exhibits yield stress and power-law rheology with comparable values under both extensional and shear deformation. Modeling bubble growth in crystallizing magma, it further shows that for a range of crystal content, yield stress in bubble walls can exceed overpressure preventing bubble growth. The model parameter search exhibits four regimes of bubble growth in crystallizing magmas for a wide range of magma decompression and crystallization rates. A complete halt in bubble growth, unlike viscous quench, occurs at a relatively small crystal content of ~20-40 % (normalized by the maximum packing limit) while bubble may grow rapidly at a relatively high normalized crystal content of >90 %, causing magma fragmentation. This study further demonstrates that small changes in parameters such as decompression and crystallization rates can likely cause changes in bubble growth regimes with implications for transitions in volcanic eruption styles.

1018

Volatile exsolution triggered by magma-carbonate interaction

Dr Simone Colucci[1], Dr Gianluca Sottili[2], Dr Federico Brogi[1], Dr Chiara Paola Montagna[1], Dr Paolo Papale[1]
[1]Istituto Nazionale Di Geofisica e Vulcanologia, Pisa, Italy, [2]Dipartimento di Scienze della Terra, Sapienza - Università di Roma, Roma, Italy

Short-term, extensive interaction of magma with carbonate wall rocks can occur in a syn-eruptive regime during ascent of mafic alkaline magmas. This process promotes the extensive generation of CO2-rich gas bubbles and Ca-enriched, low viscosity melts, affecting the degassing rate and the eruptive dynamics.

In this work, we take a cue from literature experiments to explore the volatile exsolution following the formation of a Ca-rich melt. First, we perform thermodynamic equilibrium calculations to quantify the amount of gas released by carbonate dissolution, as a function of pressure and volatile content; then we study the timing of this process, simulating mixing and mingling between the Ca-, CO2 -rich magma, produced by carbonate dissolution, and a reference basalt-andesite magma.

A consistent amount of gas is produced after homogenization between the two magmas. However, the amount of gas present in the system before homogenization (i.e., just after carbonate dissolution) can be up to 50% of the amount reached after homogenization. The remaining gas is liberated at a later stage (i.e., during the mingling-mixing process) due to the buffer effect of the high CO2 solubility in the Ca-rich melt. Our model is consistent with the experimental evidence of small bubbles forming at the contamination front. Quantifying the homogenization time scale is thus of fundamental importance for the volcanic dynamics associated with the short-term magma-carbonate interaction process.

1014

Role of buoyancy and overpressure in magma chamber replenishment dynamics

Dr Antonella Longo[1], Dr Deepak Garg[1], Dr Paolo Papale[1], Dr Chiara Paola Montagna[1]
[1]*Istituto Nazionale Di Geofisica e Vulcanologia, Pisa, Italy*

Active magmatic reservoirs are periodically replenished by magmas ascending from depth due to a combination of buoyancy and pressure forces. These events concur to determine the chemical evolution of shallow magmas, they are often associated to volcanic unrests, and they often precede shortly the occurrence of a volcanic eruption. In this study we simulate shallow magma chamber replenishment and investigate the different roles of buoyancy and pressure forces in driving the dynamical evolution of the system. Our numerical results refer to volcanic systems that are not frequently erupting, for which magma emplaced at shallow level is isolated from the surface (often called “closed conduit” volcanoes). The results depict a variety of dynamic conditions: buoyancy-only conditions are associated with effective convection and mixing dynamics and generation of no or negative overpressure in the shallow chamber, while overpressure-only conditions translate into shallow pressure increase without any convection and mixing. Mixed conditions with variable extents of buoyancy and pressure forces driving shallow magma injection illustrate a variety of dynamics dominated by overpressure at the earlier stages, then, over the longer term, by buoyancy forces. The results suggest that many shallow magmatic systems may evolve during their lifetime under the control of buoyancy forces, likely triggered by shallow magma degassing. Such configuration leads to long-term stable dynamic conditions characterized by periodic injections of volatile-rich magma from depth into partially degassed, heavier magmas residing at shallower levels of the feeding system, similar to those reconstructed from the petrology of many shallow-emplaced magmatic bodies.

720

The Víti eruption at Krafla volcano (Iceland): field and laboratory insights into explosive eruptions in geothermal areas

Phd Cristian Montanaro[1], Dr. Anette K. Mortensen[2], Dr. Tobias B. Weisenberger[3], Prof. Donald B Dingwell[1], Prof. Bettina Scheu[1]
[1]Ludwig-Maximilians-Universitaet Muenchen, Muenchen, Germany, [2] Landsvirkjun , Reykjavík , Iceland, [3]Institute of Earth Sciences, University of Iceland, Reykjavík, Iceland

Krafla central volcano in Iceland has experienced localised and frequent explosive steam-driven eruptions throughout its history. The most recent example that produced the Víti crater occurred at the opening of the Mývatn Fires (1724–1729). By analysing stratigraphy and lithology of the erupted breccia and of undisturbed bedrock at the explosion sites, and by conducting decompression experiments using erupted material, we interpret the eruption sequence and enlighten the mechanisms that formed the Víti crater. The Víti eruption was a complex event with three phases, and its occurrence was favoured by the presence of a surficial scoria cone complex "cap". The injection of rhyolite below a pre-existing convective hydrothermal system heated and pressured the shallow thermal fluids driving an initial series of very shallow (~60 m depth) and small explosions, disrupting an altered weak zone. A second series of larger, broader, and dominantly hydrothermal explosions involved highly porous, poorly compacted tuffaceous hyaloclastite (down to ~200 m depth), and was triggered when pressurised fluids broke through the bulk of the scoria cone. Alongside, deep-rooted and confined explosions (~1 km depth) began to feed the eruption with large inputs of fragmented juvenile and host rocks from a deeper zone. Shallow explosions enlarging the crater dominated the third phase. Preliminary experimental results further suggest that significant energy is spent to fragment high strength and low permeable unaltered lavas – making a large fraction of the scoria cone complex. Conversely, smaller amounts of the bulk explosive energy is required to break through altered and fractured lavas, as well as to disrupt the low strength and high permeable hyaloclastite making most of the shallow hydrothermal reservoir.

Altogether, field and experimental data elucidate how the eruption progression, crater formation and the explosive energy partitioning were all influenced by the local geology and the reservoir hydrology.

719

Prehistoric hydrothermal eruptions at the Rotokawa Geothermal Field in New Zealand: a study on frequency, priming and trigger

Phd Cristian Montanaro[1,2], Professor Shane J. Cronin[2], Dr Geoffrey Lerner[3], Dr Mark Simpson[4], Isabelle Brooks-Clarke[2], Gina Swanney[2], Dr Sarah D. Milicich[5], Dr Aimee Calibugan[6], Dr Candice Bardsley[6], Prof. Bettina Scheu[1]

[1]Ludwig-Maximilians-Universitaet Muenchen, Muenchen, Germany, [2]School of Environment, University of Auckland, Auckland, New Zealand, [3]Universidad Nacional Autónoma de México, Mexico City, Mexico, [4]GNS Science, Wairakei Research Centre, Taupo , New Zealand, [5]GNS Science, Avalon Research Centre, Lower Hutt , New Zealand, [6]Mercury NZ Ltd, Rotorua, New Zealand

Hydrothermal eruptions are one of the most common phenomena disrupting active geothermal settings. Several triggers (e.g., earthquakes, water-table changes, magmatic injection, etc.) can perturb and disrupt confined hot hydrothermal aquifers containing steam and pressurized water. Here we investigate a series of large prehistoric hydrothermal eruptions at the Rotokawa geothermal field in New Zealand. Breccia stratigraphy, componentry, and distribution, coupled with crater morphology and subsurface geological structure were used to determine eruptive frequency, and to unravel priming processes, eruption triggers, and dynamics.

Eighteen major hydrothermal eruptions have occurred mostly asynchronous with major volcanic eruptive events from the nearby Taupo Caldera. Large hydrothermal eruptions have occurred centuries to millennia apart in the period ~22 to ~3.4 cal. ka BP. Eruptive events since ~7 ka produced a series of larger craters within and possibly forming the Rotokawa depression. The youngest eruptions occur to the northeast of earlier eruption centers and have narrower and elongated vents. In the central part of the depression, newly formed large craters, rimmed by thick breccia deposits and high-relief areas likely set the stage for the formation of temporary lakes tens of meters deep. To the northeast, hydrothermal alteration produced cap rocks above intensively fractured areas. Eventual crater-lake breakout(s), and breaking of cap layers induced by seismicity, resulted in sudden pressure reduction above the hydrothermal system, and triggering a series of eruptions.

This study highlights how a complex chain of natural phenomena of tectonic, magmatic, and hydrologic processes have led to multiple prehistoric disruptive events in geothermal fields, largely dependent on the right priming and trigger conditions that can exist.

1021

Influence of permeability on the hydrothermal system at Vulcano Island (Italy): inferences from numerical simulations

Giordano Montegrossi[1,2], Gilda Currenti[3], Santina Stissi[3], Andrey Afanasyev[4], Barbara Cantucci[5], Rosalba Napoli[3]

[1]Institute of Geosciences and Earth Resources (IGG), National Research Council of Italy (CNR), Firenze, Italy, [2]Consorzio Interuniversitario Nazionale per la Scienza e Tecnologia dei Materiali, Firenze, Italy, [3]Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo, Catania, Italy, [4]Institute of Mechanics, Moscow State University, Moscow, Russia, [5]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Sismologia e Tettonofisica, Roma, Italy

Volcano-hydrothermal system is governed by complex interactions among fluids transport, geochemical and mechanical processes. To understand the relationship among fluid circulation and geochemical and geophysical manifestations, we carried out a parametric study to explore different scenarios. A hydro-geophysical model, based on the equations for heat and mass transfer in porous media and thermo-poroelastic theory, was developed and implemented. Numerical simulations allow us to define the controlling role of permeability distribution on the different modeled parameters as well as on the geophysical observables. Changes in the permeability within the highly fractured crater area could be responsible for the fluctuations in gas emission and temperature recorded during the crisis periods, which are accompanied by shallow volcano-seismicity in the absence of significant deformation and gravity variations. Our attempt to simulate the cyclic episodic unrest at Vulcano island highlights the important role of permeability transients, within the highly fractured crater area, in controlling fluctuations in gas emission and rapid temperature changes at surface. These fluctuations may be alternatively explained by permeability transients and not only by increases in the flow injection rate at depth.

455

Modeling deformation from simple to complex

Dr Emily Montgomery-brown[1]
[1]Us Geological Survey - Cascades Volcano Observatory, Vancouver, United States

Volcano deformation sources can be represented by very simple models, and these models are sometimes sufficient to provide useful interpretations. Although simple approximations can provide good fits to observed data, oversimplification can result in incorrect interpretations of the source processes if the simplifying assumptions are not valid. Also, geodetic changes resulting from multiple simultaneous processes can sometimes be well modeled by a single simple source leading to erroneous interpretations. Nonetheless, before increasing the complexity of a model, we need to know whether the data can support that additional complexity. For example, Long Valley is a well-known restless caldera that has experienced multiple episodes of tumescence over several decades that are well-modeled by an ellipsoid embedded in an elastic half space. On longer time scales, however, the superposition of multiple deformation signals from volcanic, tectonic, and hydrologic processes complicate interpretations. Incorporating multi-disciplinary data, time-series decomposition methods, and finite element modeling, different components of the deformation can be extracted and highlighted to constrain their influence on the volcanic system and associated hazards. In other cases, like Kīlauea's 2018 eruption, many different models to appear to produce "good" fits to the data, even if they are not geologically viable. Geodetic data showing Kīlauea's 2018 lower East Rift Zone dike, for example, are substantially impacted by the M6.9 earthquake, contraction of the upper and middle rift segments, and later by the collapse of the summit caldera. These effects can result in unrealistic dike models (and vice versa for earthquake models). Careful data analysis and potential for multiple sources will need to be considered in future modelling efforts as workflows evolve to be more autonomous.

493

National Volcano Information Service: Planning for a new era of data services in the USGS Volcano Science Center

Dr Emily Montgomery-brown[1], Thomas Parker[2], Tina Neal[2]
[1]U.S.G.S. Cascades Volcano Observatory, Vancouver, United States, [2]U.S.G.S. Volcano Science Center, Anchorage, United States

Volcanoes are a unique natural hazard for which many types of data from various disciplines are analyzed for accurate and timely hazard assessments as well as research. The USGS Volcano Observatories plan to modernize and centralize key data services by developing the USGS National Volcano Information Service (NVIS) with a mission to "enhance public safety by combining real-time and long-term monitoring signals and other information on volcanic unrest." The variety and volume of data used by observatories drive unique computational needs for data storage and access, security infrastructure, and user interface development. Given the breadth of the NVIS project, we are moving forward with a community governance model in which a Scientific Advisory Committee with representation from the USGS and key interagency partners to prioritize NVIS goals with managerial guidance on policy and budget. IT professionals and software developers are advising on technical capabilities. Although the service is in early stages of development, a pilot project is underway to explore how imagery data could be served through NVIS.

976

Understanding the initiation phase of the 1886 basaltic Plinian Eruption at Tarawera, Aotearoa New Zealand

Miss Hannah Moore[1], Associate Professor Rebecca Carey[1], Professor Bruce Houghton[2], Professor Colin Wilson[3], Acacia Clark[1], Dr Michael Roach[1], Dr Geoff Kilgour[4], Cameron Asher[4], Dr Ery Hughes[5], Dr Paul Jarvis[5]
[1]Centre for Ore Deposit and Earth Sciences, University Of Tasmania, Hobart, Australia, [2]Department of Geology and Geophysics, University of Hawai'i, Honolulu, United States, [3]School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand, [4]Wairakei Research Centre, GNS Science, Taupō, New Zealand, [5]Avalon Research Centre, GNS Science, Lower Hutt, New Zealand

Basaltic Plinian eruptions are the rarest, most extreme, and least understood endmembers of basaltic volcanic activity. The 1886 Tarawera eruption is the only such eruption on Earth with quantitative constraints and eye-witness accounts from visual observations of the eruption and exceptional proximal exposure. The initiation of the eruption was phreatomagmatic (forming Unit 1) and was immediately followed by the Plinian (Unit 2/3) and a final phreatomagmatic (Unit 4/5) phase. The contact between units 1 and 2 is time transgressive along the fissure. The Plinian plume was primarily fed by four aligned high-intensity vents, with numerous separate vents simultaneously erupting at lower intensities along the same fissure.

We examine Unit 1 stratigraphy and components on a crater-by-crater basis, to understand further the nature and timing of changes between phreatomagmatic and magmatic eruptions along each fissure segment. Specifically, we collected proximal-distal thickness data of Unit 1, using UAV drone photogrammetry to obtain data in previously inaccessible locations. The resultant isopach maps suggest that Unit 1 thicknesses are greatest in the craters that hosted the four known Plinian 1886 vents. We further find complex stratigraphy of Unit 1 in some segments of the fissure; different vents along the fissure began their initial phases at different times, which agrees with eye-witness observations of the eruption. Additionally, we find that thicknesses of Unit 1 in some craters (e.g., crater F) are significantly asymmetric across the fissure, possibly reflecting either varying ejection angles of eruption jets, or that the crater formation related to the final phreatomagmatic phase was not symmetric. Our results show that conduit and vent formation during the initiation of basaltic explosive eruptions was an important driver of the nature and style of subsequent eruption activity.

254

Magma emplacement, fracturing and surface deformation in a non-elastic host rock: A new Distinct Element Method model

Dr Alexandra Morand[1], Dr Sam Poppe[1], Dr Claire Harnett[2], Dr hab. Marek Awdankiewicz[3], Ms Anne Cornillon[4], Prof Michael Heap[5,6], Prof Daniel Mège[1]

[1]Centrum Badań Kosmicznych PAN, Bartycka 18A, 00-716 Warsaw, Poland, [2]UCD School of Earth Sciences, University College Dublin, Science Centre – West Belfield, Dublin 4, Ireland, [3]Institute of Geological Sciences, Wrocław University, pl. Maksa Borna 9, 50-204 Wrocław, Poland, [4]Department of Geosciences, École Normale Supérieure, 45 Rue d'Ulm, F-75260 Paris cedex 05, Paris, France, [5]Université de Strasbourg, CNRS, Institut Terre et Environnement de Strasbourg, UMR 7063, 5 rue René Descartes, Strasbourg F-67084, France, [6]Institut Universitaire de France (IUF), Paris, France

The intrusion of high-viscosity magma at shallow depth in the crust of terrestrial bodies, including Earth, often produces dome-shaped surface displacements. Most models simulating deformation around such intrusions assume a homogeneous elastic medium. However, geological observations show complex, non-elastic deformation and pervasive fracturing of heterogeneous host rocks. To investigate magma emplacement in those conditions, we created a two-dimensional Distinct Element Method (DEM) application using the software Particle Flow Code 7.0 from Itasca Consulting Group. DEM models consist of circular rigid particles linked together by force contact laws that allow particle bonds to break and so effectively explore how fractures propagate in the rock. We first calibrated the DEM model by numerically reproducing laboratory experiments. Input parameters were adjusted to reach published values of Young's modulus, compressive and tensile strength for both sedimentary and basaltic rocks. Displacements, fracture development, in-situ strains and stresses were monitored in 2D space and time for different initial magma emplacement depths. Results show a systematic tensile opening mode for fractures and a dependency of fracture distribution and density on host rock strength. All simulations produce an early crack at the surface above the intrusion center, which propagates downward and links with highly-fractured zones developing upward from the intrusion roof. At shallow emplacement depth, simulations also produce fractures at the intrusion edges that propagate laterally. Future work will focus on calibrating our DEM model with structural and mechanical observations from Permian laccoliths exposed in SW Poland. We can expect this new model's findings to help understand fracture distribution patterns in magmatic hydrothermal systems on Earth, but also magma emplacement mechanisms that produced floor-fractured craters on the Moon and surface domes on Mars.

565

Quasi-real-time hazard analysis of lava flows prior to the 2021 Fagradalsfjall eruption, Iceland

Dr William Moreland[1], Professor Ármann Höskuldsson[1], Dr Muhammad Aufaristama[2], Professor Thor Thordarson[1], Dr Ingibjörg Jónsdóttir[1], Jacqueline Grech Licari[1], Professor Joan Martí[3]
[1]University Of Iceland, Reykjavik, Iceland, [2]University of Twente, Enschede, Netherlands, [3]Geosciences Barcelona, CSIC, Barcelona, Spain

On 24th February 2021 after a year of unrest, a seismic crisis began on the Reykjanes peninsula, with a series of M3-5 earthquakes affecting the southwest corner of Iceland including Reykjavík. For a month over 3000 earthquakes >M2 occurred on the Reykjanes peninsula, 63 of which were over M4. This was accompanied by crustal inflation with geodetic inverse models inferring a dyke intrusion.

In preparation for a potential eruption in the region, probabilistic lava modelling was carried out to identify areas most at risk of lava inundation. The primary input to the model was a long-term volcanic susceptibility map computed several years prior using the QGIS plugin QVAST. The long-term susceptibility map takes geological information such as the location and age of volcanic vents, fissures, and fractures. A probability density function of each feature class is given a different weight through the elicitation of expert judgement and combined through a Poisson point process.

To move from long-term to short-term volcanic susceptibility, contemporary seismic information was incorporated with recent events given more importance than older events, with events older than several days removed altogether.

The short-term volcanic susceptibility map was then used as an input to the QLavHA whereby areas with a susceptibility higher than a given threshold are considered areas which may host an eruption. Together with a digital elevation model of the area, thermo-rheological parameters of lavas typical to Reykjanes were used to simulate a series of lava flows from vents hosted within the high-susceptibility zones.
This methodology was applied twice daily from 24th February up until the start of the eruption on 19th March and results were distributed to the authorities and public. Results were increasingly accurate, with the map that was released just hours prior to the onset of the eruption almost perfectly predicting the final result.

1468

Volume and duration of explosive eruptions inferred from eruption tremor and explosive earthquakes

Ms Azusa Mori[1], Dr Hiroyuki Kumagai[2]
[1]Kyushu University, Fukuoka, Japan, [2]Nagoya University, Nagoya, Japan

Eruption volume (V) has been shown to be related to duration (T) by a power law relation from eruption tremor (TR) associated with sub-Plinian eruptions at Tungurahua (Ecuador) and Kirishima (Japan). In this study, we further investigated this relation by using additional data of TR and explosion earthquakes (EX) associated with explosive eruptions including sub-Plinian and Vulcanian eruptions at Pavlof (Alaska), Nevado del Ruiz (Colombia), Sakurajima (Japan) and other volcanoes in Japan. We estimated the source amplitude function (SAF) of each TR and EX using high-frequency (5-10 Hz) envelope seismograms corrected for geometric spreading and intrinsic attenuation in 10-s sliding time windows. We calculated the cumulative source amplitude (Is) as time-integration of SAF and the envelope width (p) as the ratio of Is to the peak amplitude of SAF. We estimated T from p assuming that SAFs of TR and EX are approximated by trapezoidal and triangular shapes, respectively. We estimated V from Is using the proportional relation between them estimated by a previous study for TR. Our V estimates were related to T estimates by a single power-law relation, although data scatter existed. We found that this relation was similar to that estimated by fitting a power-law function to previously reported V and T data of Plinian eruptions. These results suggest that the power-law relation between T and V holds for various sizes of explosive eruptions regardless of eruption styles. We also found that the slopes between onset and peak amplitudes of SAFs for EX were clearly larger than those for TR, implying that the eruption style (either Plinian or Vulcanian) is controlled by the eruption rate at the beginning of an eruption. Our results demonstrate that SAFs of TR and EX are useful to investigate physical processes of explosive eruptions.

531

Detailed time series of sulfur dioxide flux in the 2021 eruption of Fukutoku-Oka-no-Ba submarine volcano (Japan) using TROPOMI

Dr Masaaki Morita[1,2], Dr Toshiya Mori[3], Dr Ryunosuke Kazahaya[2]
[1]Earthquake Research Institute, The University of Tokyo, Tokyo, Japan, [2]Geological Survey of Japan, AIST, Tsukuba, Japan, [3]Graduate School of Science, The University of Tokyo, Tokyo, Japan

The 2021 eruption of Fukutoku-Oka-no-Ba submarine volcano (Japan) was a large-scale Surtseyan eruption. A sustained eruptive plume reached 16 km asl and produced a subaerial tuff cone and pumice rafts. Although the total erupted volume has been estimated to be ca. 0.1 km^3 (Maeno et al., preprint; Fauria et al., preprint), this value is not so large as that of the eruption in which the plume reached the tropopause. To constrain the erupted volume and reconcile this discrepancy, we have analyzed hourly sulfur dioxide (SO_2) flux based on daily images of the Tropospheric Monitoring Instrument (TROPOMI).
The SO_2 fluxes during the first sustained plume phase (P1) were estimated to be 23–75 kt/day. In the following pulsating activity phase (P2), the SO_2 fluxes decreased to 6–37 kt/day. During the last intermittent activity phase (P3), the SO_2 fluxes were 0.3–7 kt/day and often below the detection limit (ca. 0.1 kt/day). The total amount of SO_2 emitted during the eruption was 36 kt. This value is comparable to the amount estimated from the petrological analysis (Maeno et al., preprint). The averaged e-folding time of SO_2 (decaying time scale of SO_2 converted to sulfate aerosols) for P1 and P2 were 1.5±0.3 and 0.8±0.3 days, respectively. These values are lower than those in the upper troposphere. These findings indicate that SO_2 in the plume was converted to sulfate aerosols rapidly due to the high water content in the plume and such high water content made the plume reach the tropopause.

423

High pressure and temperature experiments to determine the source depth of erupted melts

Miss Beitris Morrison Evans[1], Dr Elena Melekhova[1], Professor Jonathan Blundy[1]
[1]*University Of Oxford, , United Kingdom*

Magmatic systems are today thought of as crystal-rich magma mushes rather than melt-dominated magma chambers. This change of view raises new questions including the understanding of the dominant processes controlling melt evolution. Many long-lived volcanic systems erupt a limited compositional range of lavas over their entire eruptive history. Additionally, igneous rock suites from a variety of tectonic settings show very similar ranges in mineralogy and major element chemistry. We propose that the chemical diversity observed in magmas erupted at the surface is controlled by multiply-saturated assemblages in the melt source region. The testable hypothesis is that melts extracted from crystal-rich magma mushes will be multiply-saturated with up to seven mineral phases plus a fluid phase near their liquidus, at certain P-T-H2O-CO2 conditions. These points give an average depth of extraction, with the liquidus mineral phases defining those of the mush at the extraction point. To test this hypothesis, we performed equilibrium piston cylinder experiments on basaltic andesite from the recent (2020-21) eruption of La Soufrière volcano, St Vincent, Caribbean. Previous water and fO2 estimates for La Soufrière basaltic magmas range from 2 to 6 wt% H2O and Ni-NiO ± 1 (NNO buffer), respectively. The pressure range for crustal xenoliths erupted with basaltic magmas varies between 2 and 6 kbar. Based on these constraints, near liquidus experiments were carried out with water contents from 4 to 9 wt% H2O, at NNO and between 4 and 8 kbar.
We compare solid residues of experimental run products with the mineralogy and chemistry of crustal xenoliths from St Vincent. The main characteristic of these xenoliths is high anorthite plagioclase (An≤95), which often coexists with high forsterite olivine (Fo70). Our preliminary results show that La Soufrière basaltic andesite magmas have more than 6 wt% water and come from pressures ≥ 4 kbar.

502

Pyroxenes as Crystal Clocks: Diffusion Chronometry Reveals Timescales of Magmatic Processes Preceding the 2009 Eruption of Redoubt Volcano, Alaska

Mr Jamshid Moshrefzadeh[1], Doctor Jessica Larsen[1], Doctor Pavel Izbekov[1], Doctor Matthew Loewen[2]
[1]UAF Alaska Volcano Observatory, Fairbanks, United States, [2]US Geological Survey, Alaska Volcano Observatory, Anchorage, United States

As part of the NSF-funded PREEVENTS eruption forecasting project, we are investigating the rates of magmatic processes using diffusion chronometry on products of the 2009 eruption of Redoubt Volcano, Alaska. Resulting timescales from diffusion chronometry aid in the interpretation of seismic, geodetic, and gas monitoring data by informing conceptual models of the volcano's plumbing system.

We collected electron microprobe analyses including targeted core-rim transects on both normally and reversely zoned clinopyroxene and orthopyroxene crystals, as well as quantitative x-ray maps using wavelength dispersive spectrometers to reveal detailed zoning of Fe, Mg, Ca, Al, and Si in pyroxene crystals. The resulting maps provide two-dimensional compositional transects with 1:1 pixel to micron resolution. The quantitative x-ray maps show detailed concentric zoning. The boundaries between these chemical zones are more pronounced in Al maps, as Al diffuses more slowly than Mg and Fe. We use the Al zones to identify distinct magmatic events, and then model the more diffuse Mg# boundaries to determine the age of those events.

Our diffusion modeling results indicate that the distinct stepwise boundaries in Redoubt pyroxene zones formed on timescales ranging from years to decades before the onset of the 2009 eruption. Our results suggest that magma recharge and ascent may have occurred at Redoubt during inter-eruptive periods, with some diffusion timescales suggesting residence at magmatic temperatures since before the previous 1989–1990 eruption. The range in diffusion timescales can be explained by protracted magma recharge and varying crystal residence times preceding the eruption. Our hypothesis of protracted magma recharge correlates well with the inter-eruptive seismic activity, as well as the observed increase in diffusive heat along the flanks of the volcano in the years leading up to the 2009 eruption.

630

Experimental constraints on the crystallization conditions of nanoscale crystals in a rhyolitic melt

Mr. Hiroki Yasukawa[1,2], Dr Mayumi Mujin[1], Dr. Shizuka Otsuki[1,3], Prof. Michihiko Nakamura[1]
[1]Tohoku University, Sendai, Japan, [2]Mitsubishi Materials Co.,Ltd, Joso, Japan, [3]Nippon Steel Technology Co.,Ltd., Futtsu, Japan

Nanoscale crystals in the groundmass of volcanic pyroclasts have recently been studied to determine the shallow magmatic conditions that control eruption styles (Mujin & Nakamura, 2014; Mujin et al., 2017). Because nanoscale crystals increase magma viscosity, their impact on magma fragmentation has been reported for Plinian eruptions (Di Genova et al., 2017, 2020) and Vulcanian explosions (Mujin et al., 2020). However, the pressure, temperature, and timing of nanoscale crystallization are poorly constrained despite their crucial importance for these volcanological implications. To examine if and how nanoscale crystals control the fragmentation condition of magma, we performed a series of heating experiments of andesitic pumice with rhyolitic groundmass glass at a vapor pressure of ~0.08–40 MPa and a temperature of 650–1,000°C, to simulate rapid decompression of pre-eruptive magma to a shallow conduit and subsequent cooling. Oxygen fugacity was controlled with nickel-nickel oxide (NNO) and magnetite-hematite (HM) buffers and the heating duration was 0.5–32 hours. The starting material was natural andesitic pumice from a 1914 Plinian eruption of the Sakurajima volcano, with a groundmass composed of rhyolitic glass (~70 wt.% SiO_2) with few groundmass crystals.

The run products were classified based mainly on the crystals' modal abundance and nucleation density using BSE images of up to 100 k-fold magnifications. We found that the pervasive crystallization of nanoscale crystals with high number density, which may affect the magma rheology and thus, fragmentation conditions, occurred at 2–40 MPa and 800–900°C at NNO and HM; 0.08 MPa and 650–800°C at NNO; and 0.08 MPa and 650–750°C at HM. Therefore, we conclude that nanoscale crystals do not control the fragmentation of Plinian eruptions of high temperature porphyritic andesitic magma, but significantly affect Vulcanian explosions and ash plume formation, in which nanoscale crystallization occurs at a shallower conduit.

594

Multistage response to topography of an extremely high temperature pyroclastic density current: from flow to deposition and deposit remobilisation

Professor Maurizio Mulas[1], Phd Laura Pioli[2], PhD Filippo Mundula[2], Professor Raffaello Cioni[3]
[1]FICT - Escuela Superior Politecnica del Litoral (ESPOL), Guayaquil, Ecuador, [2]Università di Cagliari, Cagliari, Italy, [3]Università di Firenze, Firenze, Italy

High grade (HG) ignimbrites are deposits 'which are densely welded even when less than 5 m thick' (Walker, 1983). HG ignimbrites display a high potential of preserving syndepositional structures and record variation of eruption dynamics. Erosional surfaces, en masse vs. stepwise aggradation, flow remobilization, depositional pulses, thermal heterogeneities of components are preserved by syndepositional welding and rheomorphism. HG ignimbrites show unique properties due to particle agglutination in the current, and their collapse to form a non-particulate (lava-like) underflow. HG ignimbrites present features which are also indicative of general processes associated to high energy, dilute PDCs, such as interaction between flow and topography and boundary layer (sedimentation) processes. In this study we present the main features of the Monte Ulmus Ignimbrite (MUI), a rhyolitic, slightly peralkaline, welded Miocene ignimbrite of the Sulcis area (SW Sardinia, Italy). The MUI covers an area of at least 300 km2 and was likely associated with a caldera eruption from the Oligo-Miocene volcanic arc which extended across the western Mediterranean. MUI is composed of two units, a lower one, with typical HG, lava-like features and an upper one which show slightly lower welding degree and limited rheomorphism. The lithofacies recognized in MUI, and their vertical and lateral variations are discussed in terms of paleotopographic conditions and proximity to the eruptive centre to model transport and sedimentation processes and how these were influenced by basin morphology. Results suggest a complex interaction of both the high temperature PDC (and related underflows) and the deposit with topography, and multistage slope-induced mass flow resulting in multiple generations of rheomorphic structures developing from the micro- (mm) to the macro-scale (10^2 m).

588

Gold mineralization in Ecuadorian volcanic environment: new petrographic and geochemical data of the Ponce Enriquez mining district

Miss Pierina Mendoza[1], Miss Melanie Menoscal[1], Ing. Michelle Villalta[1], Phd Silvia Fornasaro[2], PhD Paolo Fulignati[2], PhD Anna Gioncada[2], Ing. Erwin Larreta[3], PhD Paola Romero Crespo[1], Professor Maurizio Mulas[1]
[1]FICT -ESPOL, Guayaquil, Ecuador, [2]Dipartimento di Scienze della Terra - Università di Pisa, Pisa, Italia, [3]Instituto de Investigación Geológico Energético , Quito, Ecuador

Ponce Enriquez Mining District (PEMD; Ecuador) is one of the most important gold mining areas in Ecuador. Gold hydrothermal mineralization is hosted within Cretaceous mafic volcanic rocks of Pallatanga Units, covered by Miocene ignimbrite. The genetic processes for this mineralization and the relationship with the magmatic systems is not fully understood. With the aim to shed light on the origin and genetic mechanisms of PEMD mineralization, a petrographic and geochemical characterization of the host rocks and of the hydrothermal alteration paragenesis was carried out.

Native gold and gold-silver-tellurium alloys occur in quartz veins in association with a sulfide assemblage, mainly consisting of pyrite, chalcopyrite, arsenopyrite, sphalerite and pyrrhotite. The host rocks are generally tholeiitic basalts, but locally porphyritic rocks with calc-alkaline affinity outcrop. The calc-alkaline rocks present geochemical analogies with the intrusive stocks of the nearby Gaby-Papa Grande porphyry Au deposit. Hydrothermal alteration is widespread and the paragenesis is dominated by the occurrence of chlorite and epidote, typical of propylitic alteration. Petrologic investigation of the mineralization is carried out with the aim to characterize temperatures and composition of hydrothermal fluids involved in the genesis of PEMD. Chemical composition of chlorite is used to calculate the equilibrium temperature, which results in the range between 265 – 300 °C.

In addition, anomalous concentration of potentially toxic elements (PTEs) (e.g., As, Cu, Cd, Zn, and Pb) in stream sediments and other matrixes (surface water, soil, and biological) nearby the mining area has been observed in several recent studies. These PTEs can be due to the superposition of geogenic and anthropogenic sources. Thanks to our new data, detailed maps of the geochemical anomalies for selected PTEs in rock and stream sediments are also provided.

These data can help to increase the regional geological knowledge and to promote the sustainable development of Ecuador mineral sector

647

Mechanism of pulse-like infrasound accompanying 2018 phreatic eruption of Iwo-Yama volcano, Kirishima Volcanic Complex, Japan

Dr Dan Muramatsu[1,2], Dr Mie Ichihara[1], Dr Takeshi Matsushima[3], Dr Osamu Kuwano[4], Dr Yasuhisa Tajima[5]
[1]Earthquake Research Institute, University of Tokyo, Bunkyo-ku, Tokyo, Japan, [2]Department of Earth and Planetary Sciences, Graduate School of Science, Kyushu University, Nishi-ku, Fukuoka, Japan, [3]Institute of Seismology and Volcanology, Faculty of Science, Kyushu University, Shimabara, Nagasaki, Japan, [4]Japan Agency for Marine-Earth Science and Technology, Yokohama, Kanagawa, Japan, [5]Research and Development Center, Nippon Koei Co., Ltd., Tsukuba, Ibaraki, Japan

The 2018 phreatic eruption of Iwo-Yama volcano, Kirishima Volcanic Complex (Japan) was recorded by infrasonic, seismic, and visual (video) observations within 1 km from eruption vents. Infrasound data of the eruption is characterized by intermittent pulse-like signals. Such pulse-like infrasound from hydrothermal eruptions is thought to be excited by bubbles bursting in mud suspension (Jolly et al., 2016; Yukutake et al., 2017). Edwards et al. (2017) suggested that the rheological properties of the mud suspension control the bursting style of the bubbles. In this study, we carried out seismoacoustic analysis focusing on the pulse-like infrasound, and also referred to rheological properties of mud suspension sampled from the rim of the eruption vent to consider mechanical processes of the infrasonic pulse generation. The infrasonic pulse showed a change in waveform and spectral character with progress of the eruption. The viscosity and yield stress of the mud suspension decreased with increasing water fraction. Based on these results and those of previous studies, it is inferred that the change in infrasonic pulse was caused by a change in bubble bursting style at the surface of the mud suspension, through decreases in yield stress and viscosity that resulted from increasing water fraction. We suggest that yield stress is one of the key parameters controlling bubble bursting and the occurrence of infrasound during hydrothermal eruptions.

937

A record of fragmentation, decompression, and hydration during the subaqueous 2012 Havre eruption

Dr Arran Murch[1], Dr Tobias Dürig[2], Prof James White[3], Dr Alexander Nichols[4], Ass Prof Rebecca Carey[5]
[1]Unafliated, , , [2]University of Iceland, Reykjavik, Iceland, [3]University of Otago, Dunedin, New Zealand, [4]University of Canterbury, Christchurch, New Zealand, [5]University of Tasmania, Hobart, Australia

The 2012 rhyolitic submarine eruption of Havre volcano occurred in water depths of 700-1300 m. The eruption produced a sea surface pumice raft in addition to effusive and clastic sea floor deposits. Post-eruption AUV mapping along with ROV observations and sampling make Havre an ideal laboratory for studying water's effect on subaqueous eruption processes.

Here we present high spatial resolution synchrotron-FTIR measurements of water speciation in glassy ash (125 – 500 µm) from subunits 1, 2 and 3 of the 2012 eruption's widespread Ash with Lapilli deposit. Measurements record depletion profiles of OH around vesicles caused by degassing with half distances of 1 to 6 µm. Enrichment profiles in H2Omol are often found around the same vesicles with similar half distances. In several thick vesicle walls in ash grains far-field regions unaffected by processes at the bubble margins have also been identified. These features are common across ash of different morphologies and in each subunit.

Knowing water's pressure dependent solubility in magma, that OH is a non-diffusing species below the glass transition, and the high cooling rates of ash in water, we can derive a precise record of syn-eruptive exsolution conditions by measuring water species. Far field OH concentrations of 0.86 to 0.94 wt% equate to quench pressures of between 7.8 to 9.7 MPa, appropriate for the inferred hydrostatic vent pressure of ~9 MPa, suggesting ash grains equilibrated at vent depth. The OH depletion profiles around vesicles indicate a subsequent phase of volatile exsolution prior to quenching driven by decompression of at least 2-4 MPa. Diffusion modelling suggests that at eruption temperature the observed profiles formed through exsolution in <2s. We will discuss the implications our findings have for using dissolved volatile contents to interpret submarine volcanism more broadly, including the formation of low-pressure signature during deep sea volcanism.

957

Geochemical constraints on bimodal magmatism in an active continental back arc basin, Okinawa Trough, Japan

Dr Arran Murch[1], Dr Kenichiro Tani[2], Dr Takashi Sano[2], Dr Shigekazu Yoneda[2]
[1]Unafliated, , , [2]National Museum of Nature and Science, Tokyo, Japan

The Okinawa Trough (OT) is an incipient continental back-arc basin that extends ~1200 km south from Kyushu to Taiwan with on going crustal extension. Volcanism in the OT is bimodal (basaltic to rhyolitic) and restricted to volcanic centres in en-echelon grabens in the middle (MOT) and central (SOT) sections. Here we present petrological descriptions, along with major, trace element and Sr–Nd isotopic data of lavas and pumice dredged from various seafloor knolls and ridges in the MOT and SOT during the R/V Sonne HYDROMIN1 and 2 cruises in 1988 and 1990, respectively.

The mafic end member, composed of basalts and basaltic andesites, is composed of tholeiite lavas collected from the SOT, and lavas with a calc-alkaline trend from the MOT. All mafic lavas display strong subduction signature with enrichment of incompatible elements, especially LREE, LIL, and Pb, along with the depletion of Nb and Ta. Several mafic enclaves have also been identified in lavas from the silicic end member. These enclaves generally show similar characteristics to lavas from the MOT with calc-alkaline tendencies and subduction signatures.

The silica end member, composed of rhyolites, displays significant diversity in incompatible element concentrations defining four magma groups. All groups preserve a significant subduction signature. Differences between silicic groups in calculated equilibrium pressure temperature conditions from various petrological thermobarometers suggest distinct magmatic evolution histories coexisting within the Okinawa Trough. The presence of a Triassic granitic crustal xenolith in one group also points to crustal input to the magmatic system and has significant implications for regional tectonics.

Using petrological descriptions, samples chemistry, along with MELTS modelling we plan to evaluate the conditions and processes of magma formation and evolution. In doing so we hope to provide an explanation of magmatism in the Okinawa Trough.

484

Understanding the magmatic evolution during the February-March 2021 lava fountain sequence at Mt. Etna (Italy) through mineral chemistry

Mr Alessandro Musu[1], Dr. Rosa Anna Corsaro[2], Dr. Oliver Higgins[4], MSc Corin Jorgenson[1], Prof. Maurizio Petrelli[3], Prof. Luca Caricchi[1]

[1]Department of Earth Science, University Of Geneva, Geneva, Switzerland, [2]Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo-Sezione di Catania, Catania, Italy, [3]Department of Physics and Geology, University of Perugia, Perugia, Italy, [4]Department of Geology, Trinity College Dublin, The University of Dublin, Dublin, Ireland

The South-East Crater (SEC) of Mt. Etna (Italy) went through an exceptional period of lava fountaining from December 2020 to February 2022, producing over 66 paroxysms. The activity went through an intensified phase from February 16th to April 1st 2021, during which the volcano produced 17 paroxysmal events separated by a repose time between 1 to 7 days. The extensive monitoring activity on Etna during the entire eruptive period offers a unique opportunity to relate the chemistry and texture of erupted products to eruptive dynamics. We studied the temporal evolution of the magmatic system during this particularly intense phase, quantifying compositional and textural changes of clinopyroxene along the sequence. Chemical zoning of minerals has the ability to reveal processes that occur at inaccessible depths, allowing us to quantify magmatic processes that precede volcanic eruptions. Major-element transects were acquired on clinopyroxenes of five representative lava fountains. We tracked the temporal evolution of the mineral populations and the source regions of the magma that fuels these events using unsupervised and supervised machine learning methods. Our results have produced quantitative relationships between mineral chemistry, mineral texture, monitoring parameters and eruptive dynamics. This approach has proven to be of fundamental importance in better linking monitoring parameters to pre-eruptive processes, contributing to the development of quantitative petrological monitoring. This allows for both improved interpretation of past eruption deposits and for understanding and anticipating the future behavior of volcanic systems.

486

Experimentally zoned crystals: investigating the competition between crystal growth and element diffusion

Mr Alessandro Musu[1], Prof. Luca Caricchi[1], Professor. Diego Perugini[2], Dr. Rosa Anna Corsaro[3], Dr. Francesco Vetere[4], Prof. Maurizio Petrelli[2], MSc Stefano Peres[5], Dr. Thomas Griffiths[5]

[1]Department of Earth Sciences, University Of Geneva, Geneva, Switzerland, [2]Department of Physics and Geology, University of Perugia, Perugia, Italy, [3]Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo-Sezione di Catania, Catania, Italy, [4]Department of Environment, Earth and Physical Sciences, University of Siena, Siena, Italy, [5]Department of Lithospheric Research, University of Vienna, UZA2, Vienna, Austria

Understanding trans-crustal magmatic processes is crucial for the correct interpretation of monitoring signals and for the development of quantitative models to forecast volcanic activity. Minerals are witnesses of the temporal evolution of the physico-chemical conditions within magma reservoirs recording variations of intensive parameters as chemical signals. However, competition between crystal growth and element diffusion can also modulate the chemical zoning in minerals, thus complicating the interpretation of zoning patterns. To disentangle this complexity, we grow chemical zoned minerals at the Petro-Volcanology Research Group Lab of the University of Perugia, under controlled P-T-X-H2O conditions. We use tephra from the 2002-03 Mount Etna eruption as starting material for the experiments. The zonation in minerals has been forced by oscillating the temperature (1170 – 1130 °C) under a constant deformation gradient (Concentric Cylinder Apparatus) inside a high-temperature furnace. Major element analysis has been conducted on the glass and mineral phases using an Electron Probe Micro Analyser (EPMA). This chemical dataset was investigated using custom-built machine learning algorithms to discriminate zonation related to variations in thermodynamic conditions of crystal growth from those produced by the effects of diffusion and growth competition. The effect of deformation on nucleation, growth and varying mineral proportions was quantitively investigated using Electron backscattered diffraction (EBSD) maps conducted at the Department of Lithospheric Research, University of Vienna. We show that competition between diffusion and growth rate is a dominant process in zoning development at low strain rates. The EBSD analysis also highlighted that larger deformation leads to the alignment and clustering of crystals and a reduction in the grain size of some phases. The aim of this contribution is to provide experiments and quantitative tools that will help to distinguish between equilibrium and disequilibrium growth, key to interpreting the chemical signals encrypted in magmatic crystals.

368

3D diffusion of water in melt-inclusion-bearing olivine phenocrysts

Dr Euan Mutch[1], Dr Megan Newcombe[2], Dr John Rudge[3]
[1]*Lamont Doherty Earth Observatory, Columbia University, New York City, United States,* [2]*Department of Geology, University of Maryland, College Park, United States,* [3]*Department of Earth Sciences, University of Cambridge, Cambridge, United Kingdom*

Rapid diffusion of hydrogen (as H+ ions) through the olivine crystal lattice can help and hinder the interpretation of volatile concentrations in the crystal record. Rapid diffusive re-equilibration obscures the melt inclusion record, but it can also be an exciting chronometer that can track magmatic processes that occur hours to even minutes before eruption, such as final magma ascent. Many studies often use spherical or 1D models to track melt inclusion dehydration that fail to account for complex geometries, diffusive anisotropy and sectioning effects. We have developed a finite element 3D diffusion model for H+ in olivine using FEniCS. The model includes physical domains for a spherical melt inclusion and the surrounding host olivine. The boundary between these domains accounts for olivine-melt partitioning behaviour and ensures conservation of flux, whilst an external degassing boundary condition can be imposed. We use the model to examine the fidelity of the water content of melt inclusions based on inclusion size, position, crystal size, diffusive anisotropy in olivine, olivine-melt partition coefficients and for different magma decompression rates. We then use the model to fit 2D observations of water profiles in olivine measured by SIMS from the 1977 eruption of Seguam volcano, Alaska. Our model is one of the first to account for the natural shape of olivine, and to include the diffusive properties of both olivine and melt. The model is also novel in that multiple melt inclusions can be modelled in a single crystal. We find that the presence of multiple melt inclusions can buffer the water composition of inclusions in the center of the crystal. This 'shielding' effect may have important implications for estimating magma storage depths or primary water compositions. By reducing uncertainties associated with crystal morphology and sectioning we hope to better reconcile short-term petrological and geophysical observations.

369

The dichotomous nature of Mg-in-plagioclase
partitioning: Implications for diffusion chronometry

Dr Euan Mutch[1], Dr John Maclennan[2], Dr Amber Madden-Nadeau[3]
[1]*Lamont Doherty Earth Observatory, New York City, United States,* [2]*Department of Earth Sciences, University of Cambridge, Cambridge, United Kingdom,* [3]*Department of Earth Sciences, University of Oxford, Oxford, United Kingdom*

Plagioclase is a widespread phase in magmatic rocks and is an important archive of magmatic processes. Modelling diffusion of Mg in plagioclase is used to estimate the timescales of magmatic processes that operate weeks to decades before eruption. To do this, however, requires knowledge of how the anorthite composition of plagioclase influences partitioning of Mg.

Here we compiled a database of 904 calculated Mg in plagioclase partition coefficients using mineral rim-melt pairs from phase equilibria experiments and natural samples. The dataset includes a comprehensive range of plagioclase compositions (An15 - An90), melt compositions (40 – 78 wt% SiO2) and temperatures (750 –1400 °C). We find that Mg-in-plagioclase partition coefficients depend on all of these parameters. Crucially, we find that the dependence on anorthite content has a major inflection at compositions that correspond to the C1-I1 structural phase transition (An60 at 1000 °C). Mg-in-plagioclase partition coefficients have a positive dependence on anorthite in the C1 domain, and a negative dependence in the I1 domain. We also find that this change in partitoning behaviour can account for Mg distributions in natural plagioclases observed in mafic to silicic systems.

The dichotomous nature of Mg-in-plagioclase partitioning has significant implications for diffusion chronometry. The shape of Mg ‘quasi-state’ equilibrium profiles will largely depend on the structural state of plagioclase. The temperature dependence of the C1-I1 transition means that equilibrium profiles in these crystals could be used to estimate crystal storage temperatures. Our new empirical partitioning relationship is particularly important for interpreting plagioclase Mg profiles in intermediate and silicic systems, and for setting up initial conditions for modelling. Profiles that were previously interpreted to show little diffusion, may be close to equilibrium and vice versa. This will be highly significant for understanding thermal states and magmatic histories of at a range of tectonic settings.

233

Lava dome morphology controlled by viscosity and cohesion: Insights from analogue modelling.

Miss Amy Myers[1], Dr Claire Harnett[1], Dr Eoghan Holohan[1], Mr John Ryan[1], Dr Edgar Zorn[2], Prof Thomas Walter[2], Prof Michael Heap[3]

[1]University College Dublin, Dublin, Ireland, [2]GFZ German Research Centre for Geosciences, Potsdam, Germany, [3]Université de Strasbourg, Strasbourg, France

Around 10% of active volcanoes form lava domes, which are subject to destabilisation and spontaneous collapse. To date, analogue studies of lava dome growth have investigated a simplified single rheology system, typically using sand-plaster mixtures, kaolin slurries, or silicone polymers, despite lava domes being composed of both fluid and solid materials. Here we present results from new analogue experiments employing both ductile and brittle materials, with which we explore the effects of viscosity and cohesion on lava dome growth and morphology. To simulate a crystal-bearing magma, we use a suspension of golden syrup and sugar. Adjusting the mass of sugar and the ratio of crystal sizes enabled us to simulate a range of magma viscosities. Rotational viscometry gives a viscosity range from ca. 32 Pa.s for pure golden syrup to ca. 5200 Pa.s for a 60 wt% suspension, representing viscosities in nature of 106-109 Pa.s. Increasing the proportion of sugar results in increasingly non-Newtonian flow and shear-thinning behaviour, consistent with that of crystal-bearing magma at shallow depth. A sand-gypsum mixture represents brittle rock and talus; cohesion increases with gypsum content. Post-experimental analysis includes Structure-from-Motion photogrammetry to create digital elevation models, which are differenced to obtain estimated volume changes. We compare modelled dome growth to natural observations and find that the two-material system allows for better replication of height-width evolution over time compared with previous analogue models. We observe rapid increase in dome height during early extrusion, followed by lateral spreading once a critical height-width ratio is reached. Height-width ratio increases when mixtures with higher viscosity and/or cohesion are used, leading to spine formation, and lateral spread onset is delayed as cohesion is increased. Additionally, we see viscosity controls lava dome growth style; exogenous growth is promoted by lower viscosity fluids, as fluid migrates through pathways in the upper plug material.

811

Insights into lithium movement in ascending rhyolitic systems: variations recorded in melt embayments from the Bishop and Huckleberry Ridge Tuffs

Dr Madison Myers[1], Dr. Roberta Spallazani
[1]*Montana State, Bozeman, United States*

The enrichment of lithium (Li) in rhyolitic volcanic deposits is a critical process to constrain given its increasing economic importance. Although research has focused on post-depositional movement in these systems, the origins of Li are magmatic, and therefore it is also necessary to refine its behavior during magma ascent. Here we present Li concentration gradients measured in 20 quartz-hosted melt embayments. These embayments respond to changing external conditions, preserving records of evolving melt compositions, degassing pathways, and ascent timescales when paired with appropriate diffusion coefficients. We focus our preliminary study on two silicic eruptions, the Bishop Tuff, CA, and the Huckleberry Ridge Tuff, WY, for which we have existing melt inclusion datasets (starting conditions), well constrained temperatures, and published decompression rates based on H2O and CO2 gradient modeling.

Lithium is enriched near the rim (reverse profile) in 80% of embayments, however, in all cases, we find that interior embayment values (20-50 ppm) are lower than co-erupted melt inclusions (30-105 ppm). Through application of a simplified diffusion model with published diffusion coefficients[12], we find that Li reequilibration from melt inclusion to embayment interior concentrations occurs within ~1-5 minutes, whereas all preserved reverse gradients form astonishingly fast, within 2-55 seconds. Both stages of Li diffusion provide timescales orders of magnitude faster than what is obtained from H_2O and CO_2 modeling (tens of minutes to hours). We interpret these results to represent two separate and contrary episodes of lithium movement during magma ascent, with reequilibration likely driven by degassing, and the reverse gradient potentially responding to the late-stage breakdown of a fluid phase[3].

[1] Holycross, et al. (2018). Geochem Perspect Lett, 6, 39-42.
[2] Spallanzani, R., et al. (2022). Contr Min Pet 177(8), 1-17.
[3] Charlier, B. L. A., et al. (2012). Earth Planet Sci Lett, 319, 218-227.

358

Parallel timelines: studying timescales of eruption and response at Volcán de Fuego (Guatemala) to evaluate community needs during eruptive crisis

Dr Ailsa Naismith[1], Professor Jenni Barclay[2], Professor Jeremy Phillips[1], Professor Matthew Watson[1], Dr Teresa Armijos[2]
[1]University Of Bristol, Bristol, United Kingdom, [2]University of East Anglia, Norwich, United Kingdom

During a volcanic crisis, risk mitigation is effective only if institutions and local people respond within the relevant timescales as determined by the style of volcanic activity. Volcán de Fuego (Guatemala) is a persistently active volcano that frequently provokes significant eruptive crises. In this work, we ask: does current disaster risk reduction (DRR) practice as implemented by the state allow people living close to the volcano enough time to evacuate during an eruption? We explore this question by comparing timescales of volcanic activity and human response in several recent eruptions. We use multiple geophysical datasets for individual paroxysmal eruptive episodes during the period 2015 –2018 to constrain timescales of eruptive evolution. In parallel, we determine timescales of response through qualitative interviews with both institutional and community actors. We then compare eruption and response timescales to explore uncertainties and variability within. We find that eruption and response timescales at Fuego are comparable. However, we also present evidence that timescales of response lag those of eruptive evolution due to relatively long periods associated with decision-making and emitting of warning information. We assess these findings with respect to current DRR practice at the volcano and through different actors' mental models of risk. We conclude that the current DRR practices at Fuego do not provide enough warning time of impending activity to facilitate effective evacuation and risk mitigation. We conclude with suggestions for how stakeholders can come together to discuss a community's needs during eruptive crisis and how actors with different mental models could work together to evacuate in time. We intend our work to be of practical use to both institutions and local people for collaborative volcanic risk mitigation before, during, and after future eruptions at active and populated volcanoes like Fuego.

362

Co-producing knowledge of past volcanic eruptions and impacts at Volcán de Fuego (Guatemala) through zine-making and participatory workshops

Dr Ailsa Naismith[1]
[1]University Of Bristol, Bristol, United Kingdom

Powerful natural events like volcanic eruptions can overpower the senses and create lasting impacts on peoples' lives, livelihoods, and landscapes. An eruption may be experienced as a traumatic event that is difficult for a witness to accept and integrate into their everyday life. Artistic methods have been used successfully to allow survivors of trauma to incorporate the event into their worldview. While disaster researchers have explored art as a tool for co-production of knowledge of some natural hazards (e.g., hurricanes), how art may be used to co-produce knowledge of volcanic disaster is a relatively new avenue of enquiry. Volcán de Fuego (Guatemala) had a series of large eruptions in the 1960s and 1970s that strongly affected livelihoods of local people and the surrounding landscape. Although local people who experienced these eruptions factor associated memories in their responses to current eruptions of Fuego, reliving past events through traditional interview methods can be powerfully emotive and even traumatic. In parallel to other participatory work at Fuego, here we explore how knowledge of past volcanic eruptions and impacts may be co-developed through artistic methods, namely zines and participatory workshops. We created an initial zine (a small-production, self-published art book) based on interviews and guided walks with residents of local communities. We then returned to these communities to host workshops where community members, scientists, and risk managers could co-develop the first zine into a second edition in which the story of Fuego's eruptions and impacts was shared and shaped by all workshop participants. The resulting product is a tangible and meaningful research output joinly owned by participants that explores how different people experience volcanic risk across their lifetime. This iterative approach emphasizes the importance of building trusting relationships over years to deeply understand dynamic risk at an active volcano.

645

Assessment of hazards following the July 2022 magma eruption at Ioto (Iwo To) Island (Ogasawara)

Professor Setsuya Nakada[1], Dr Masashi Nagai[1], Dr Eisuke Fujita[1]
[1]*National Research Institute For Earth Science And Disaster Resilience, Tsukuba, Japan*

After the Fukutoku Oka-no-Ba eruption in August 2021 and the Hunga Tonga Hunga Ha'apai eruption in January 2022, it has become important to assess risks from eruptions in shallow water in island countries surrounded by the sea, like Japan, Tonga and so on. Iwo To Island, ~1200 km south of Tokyo, is an active caldera (~10 km across) volcano, where inside caldera uplifting has continued since 2006 (~1m/year). There, phreatic eruptions repeated along the caldera margins, following both shallow earthquake swarms and uplift accelerating. A series of magmatic eruption events was confirmed offshore of the southeast coast (Okinahama) during July-August 2022. The events were characterized with water doming and brown-colored cock's tail jetting, and had repeated with the intervals of around a few minutes. Porous juvenile blocks having bread crusts and high temperature inside were drifted to the coast. The magma eruption at Iwo To is first in about ~1000 years. The eruption history in the Beyonesu Rock (Myojin Reef) can be referenced to assess the future volcanic hazards at Iwo To. Since the 19th century, Myojin Reef has repeatedly erupted 15 times, generating base surges (one of which wiped out a research vessel in 1952), tsunamis, and repeated short-term lava dome formations over the sea surface. The large explosive submarine eruption is considered to happen when conditions of high magma discharge rate and shallowness of the eruption point are satisfied. A rough correlation exists between the base surge radius and the eruption scale. On Iwo To, the nearest Maritime Self-Defense Force lodgings are about 2 km away from Okinahama, so that important is assessing the possibility of eruption of VEI 3 or more. The event tree was prepared during the eruption crisis (on August 5, 2022).

753

Eruption sequence of the 45ka caldera-forming eruption of Shikotsu volcano, Japan: Insights from stratigraphy of proximal deposits and drilling cores

Dr Mitsuhiro Nakagawa[1], Dr Mizuho Amma-Miyasaka[1], Dr Akiko Matsumoto[1]
[1]*Hokkaido University, Sapporo, Japan*

The 45 ka Shikotsu pyroclastic eruption is one of the largest late Pleistocene silicic eruptions in Japan, forming the Shikotsu caldera (14 X 12 km). We investigated stratigraphy and lithofacies of proximal deposits and drilling cores and correlated these with distal deposits. The deposits can be divided into 6 units, from A to F in ascending order. Based on the results, the eruption sequence is revealed. The eruptive activity began with a strong explosion forming pyroclastic surge or blast and shifted to phreatomagmatic and phreatoplinian eruptions (Unit A: 1.5 km^3 DRE). The activity subsequently changed to plinian eruption to build voluminous eruption column. In later stage, the column became unstable to produce pyroclastic surge and pyroclastic flow frequently at a proximal area (Unit B: 48 km^3 DRE). After the erosional gap, climactic activity started to produce voluminous ignimbrite and ended with effusion of lag breccia (Unit C: 70 km^3 DRE). After a dormant period, explosive eruptions occurred intermittently to produce pyroclastic flow and fall (Unit D: 14 km^3, E: 1 km^3, F: 0.2 km^3 DRE). Considering the sequence, caldera collapse progressed during Unit B and C depositions and almost completed at the end of Unit C with the deposition of lag breccia. Juvenile materials of the eruption mainly consist of crystal-poor (CP type) pumice, associated with small amount of crystal-rich (CR type) pumice and scoria. The 45 ka eruption were caused mostly by the CP type magma, whereas the CR type magma rarely occurred from the final stage of Unit C and was commonly recognized during the following eruptions (Unit D – F). The temporal change of juvenile materials suggests that the 45 ka eruption could be explained by sequential withdrawal from the huge mushy magma reservoir, in which voluminous silicic melt had been accumulated.

885

Grain-size characteristics of Kulanaokuaiki Tephra Units 1, 3, and 5 from explosive eruptions of Kilauea Volcano, Hawaiʻi, USA

Abigail Nalesnik[1,2], Johanne Schmith[2], Timothy Rose[3], Donald Swanson[2], Kendra Lynn[2], Jessica Warren[1]
[1]*University of Delaware, Newark, United States,* [2]*USGS Hawaiian Volcano Observatory, Hilo, United States,* [3]*Smithsonian Institution, Washington, United States*

Abundant lava flows of Kilauea Volcano have characterized Hawaiian volcanism for recent decades, but tephra-dominated units reveal a lesser-known explosive side of Kilauea. The Kulanaokuaiki-3 eruption (ca. 900 CE) had 14 to 18-km-high ash plumes with significant tephra and lithic block deposition. An eruption of this magnitude today would have devastating effects on the livelihood of island inhabitants.

There have been two explosive periods in the last 2,500 years, of which the younger Keanakāko'i Tephra (ca. 1500 - early 1800s) records numerous smaller explosive eruptions and two larger VEI 3 events. The Kulanaokuaiki Tephra (ca. 400 - 1000 CE) was deposited during the older explosive period known as the Uēkahuna Ash (ca. 200 - 1000 CE) and comprises five units: K-1 through K-5. These deposits are primarily preserved on Kilauea's south flank with few deposits north of the summit. Previous work determined the K-3 tephra was deposited from a subplinian eruption, with a basal lithic layer deposited from a gas-driven jet into the jet-stream. Our work considers the grain-size and density of K-1, K-3, and K-5 to take a comprehensive view of the Kulanaokuaiki Tephra depositional period.

Samples from 20 sites were processed for grain-size data using dynamic image analysis instruments CAMSIZERS X2 and P4. Bulk sample density data were obtained using high-precision gas pycnometers. We find that K-3 has both a wider grain-size range and encompasses coarser grain sizes than K-1 and K-5. K-1 is primarily juvenile, and K-3 and K-5 have juvenile and lithic components. K-1 is also consistently less dense (average of 2.80 g/cm3) than K-3 (2.87 g/cm3) and K-5 (2.88 g/cm3). Further analysis of the grain-size distributions and density of these three units may reveal their potential source areas, fragmentation characteristics, and plume dynamics, allowing for comparisons to other explosive eruptions at Kilauea and beyond.

884

Explosive Eruptions of Kilauea Volcano, Hawaiʻi: Constraints from Glass Chemistry of the Upper-Kulanaokuaiki Tephra

Abigail Nalesnik[1,2], Kendra Lynn[2], Timothy Rose[3], Jessica Warren[1], Kuan-Yu Lin[1]
[1]University of Delaware, Newark, United States, [2]USGS Hawaiian Volcano Observatory, Hilo, United State, [3]Smithsonian Institution, Washington, United States

Understanding the timing, causes, and conditions of explosive activity of Kilauea Volcano, Hawaiʻi is vital to prepare local communities for such events. There are two known dominantly explosive periods in the last 2500 years, evidenced by the Keanakāko'i Tephra (ca. 1500 - early 1800s CE) and the Kulanaokuaiki Tephra (ca. 400 - 1000 CE). The Keanakāko'i Tephra were likely emplaced after reservoir/magma supply depletion caused caldera collapse. The older Kulanaokuaiki Tephra, which comprises five units preserved primarily on Kilauea's south flank, is less studied. Here, we present new basaltic glass compositions from upper-Kulanaokuaiki Tephra and compare the magmatic processes of the two most recent explosive periods at Kilauea.

We find that glass MgO in upper-Kulanaokuaiki Tephra ranges from 5.8 to 12.6 wt% (consistent with other studies), suggesting different magma storage depths within the Kilauea crustal reservoir(s), comparable to the Keanakāko'i Tephra (3.4 to 11.2 wt% MgO). Thermodynamic MELTS modeling using parental melt with 12 wt% MgO shows that upper-Kulanaokuaiki data can be fit with olivine ± plagioclase ± clinopyroxene fractional crystallization with oxygen fugacity near the quartz-fayalite-magnetite buffer, at 350 bars, and with low water content (0.2 wt%; consistent with melt inclusion measurements [1]). These conditions are similar to MELTS modeling of Keanakāko'i Tephra.

The upper-Kulanaokuaiki Tephra have an overall more depleted trace element signature than Keanakāko'i, based on lower Cr, Ni, Ba, Sr, and Th abundances. These suggest that the former are from a slightly different mantle source composition. Kulanaokuaiki Nb/Y (0.39 to 0.50) is lower than Keanakāko'i Nb/Y (0.50 to 0.58) and much lower than the modern effusive period (0.53 to 0.89). Lower Nb/Y ratios suggest that a high degree of partial melting produced their parental melts, which contrasts with inferred low magma supply during explosive periods and warrants further investigation.

[1] Fiske et al., 2019. GSA Bulletin

286

An Oscillatory Rheometer for Measuring Mafic Magma Rheology

Dr Atsuko Namiki[1]
[1]*Nagoya University, Nagoya, Japan*

The rheology of the crystal-bearing bubbly magma is one of the most important physical parameters characterizing the eruption styles. More viscous magma flows slowly and sometimes fragments into small clasts. The crystallinity and bubble fraction change the rheology of the complex magma. The rheology of such suspension is texture-dependent, which evolves by measurement with deformation, resulting in challenging quantifying the complex magma. The oscillatory rheology measurement, widely used to measure the rheology of suspensions, can be conducted with a small displacement and is a valuable method to solve this problem. The high temperature of mafic magmas exceeding 1000 °C is not in the temperature range covered by the ordinal commercial rheometer. In this study, we developed a system to measure the rheology of mafic magma by combining a commercial rheometer (Anton Paar MCR-102) and a furnace. We located the furnace below the rheometer and used an alumina rod with a 10 mm diameter as a spindle. Inside the furnace, we located a cylindrical crucible with an inner diameter of 20 mm and 40 mm in depth. We measured a viscoelastic polymer material at room temperature as a standard material and obtained consistent values with the reference at the angular frequency range of 0.2 – 100 Rad/s and strain amplitudes of < 0.1. Next, we measured the standard glass 717a at 980-1180 ^{o}C and obtained a good agreement with the reference. In our poster, we will introduce the preliminary results measuring the melting volcanic ash from Aso Volcano.

939

The volcano-tectonic 2017 earthquake at Ischia island (Italy): geophysical and geological constrains.

Ms Rosa Nappi[1], Dr Rosella Nave[1], Dr Giuliana Alessio[1], Dr Valeria Siniscalchi[1], Dr Giuseppe De Natale[1], Dr Troise Claudia[1], Prof. Valeria Paoletti[2], Dr Alessandro Fedele[1], Dr Renato Somma[1], Dr Sabina Porfido[3], Prof. Luigina Vezzoli[4], Prof. Alessandro Maria Michetti[4]
[1]INGV-OV, Napoli, ITALY, [2]DISTAR University of Naples, Napoli, ITALY, [3]CNR-ISA, Avellino, ITALY, [4]UNINSUBRIA, COMO, ITALY

On 21 August 2017, a shallow earthquake of Md 4.0 struck the Casamicciola Terme village in the north of Ischia volcanic island (Italy). It caused two fatalities and heavy damage in a restricted area of a few square kilometers. The damaging earthquakes at Ischia Island are no exception. The earthquakes repeat with similar characteristics over the historical time window (1796, 1828, 1881, and 1883) and their epicentral location is systematically confined to the same area of few square kilometers at the base of the northern flank of Mt Epomeo.

Our study aims to show the vantages of multidisciplinary analysis based on integrated geophysical investigation and geological investigations for constrain the characteristics of the Casamicciola active/capable fault system of Ischia Island responsible of 2017 volcano-tectonic earthquake.
We performed a) a geophysical survey with use the impulsive electromagnetic method of the Ground Penetrating Radar (GPR); b) SAR data analysis; c) two new stratigraphic boreholes in the hangingwall and footwall of the Holocene graben.

For constrain the geological model of the E-W seismogenetic fault hypothesized in the literatures we have investigated the piedmont belt of the N slope of Mt. Epomeo where was mapped coseismic surface ruptures following the 2017 earthquake. We conducted a geophysical investigation with use the impulsive electromagnetic method of the Ground Penetrating Radar (GPR) that through low-frequency antennas perform deep stratigraphic analyzes up to about 100 m. With GPR we have identified the stratigraphic contacts in depth and the presence of synthetic and antithetic faults systems bordering the Holocene Graben. Moreover, we realized two new stratigraphic boreholes in the hangingwall and footwall of the Holocene graben for constrain the stratigraphic unit involved into displacement. Through satellite interferometric techniques we assess the space and time evolution of ground deformation rate and model the displacement field.

943

Comparing volcanic risk perception assessment after 10 years at Campi Flegrei active caldera (Italy)

Dr Rosella Nave[1], Dr Tullio Ricci[2], Dr Eliana Bellucci Sessa[1], Prof Matthew Davis[3]
[1]INGV Osservatorio Vesuviano, Napoli, ITALY, [2]INGV ROMA1, Roma, ITALY, [3]Psychology Dept. Dominican University of California , , USA

The highly urbanized Campi Flegrei active caldera, in the Neapolitan area, has been a peculiar context where to investigate citizens' volcanic risk perception. Since the first study published in 2008, relevant events connected both to the volcano dynamics to the volcano emergency planning, as well as volcanic hazard and risk communication and training activities, have occurred. Taking advantage of a National drill on volcanic risk planned in October 2019 at Campi Flegrei, we have in parallel carried out a new risk perception survey. The aim has been to assess the impact on resident's attitude towards volcanic hazard and risk, their trust in emergency planning and managing, and their evaluation of information and communication activities, consequent to the ongoing volcano unrest phase characterized by a tangible ground uplift accompanied by tens seismic events felt by residents. Other events took place in the same period, like the proposal of geothermal exploitation, the updated Campi Flegrei volcano Emergency Plan publication, the implementation of training and communication activities, and the concomitant boom of social media channels. Results put in evidence an increase in respondents' volcanic hazard awareness, and how crucial can be to work on residents' involvement in citizen science as well as in planning information and communication activities and tools.

1251

Stratigraphic architecture of an Archean mafic sill: implications for lateral and vertical differentiation

Ms Alyssa Negus[2]
[1]*Queensland University Of Technology, Brisbane, Australia,* [2]*Northern Star Resources , Kalgoorlie, Australia*

Lateral variations of differentiated mafic sills underpins physical and chemical models of fractionation and emplacement in the upper crust. However, these variations are poorly documented because of a lack of exposure and resources. The 2.69 Ga Williamstown Dolerite, a differentiated mafic sill in Kalgoorlie (Yilgarn Craton, Western Australia) hosts a gold resource and consequently, has been extensively drilled and geochemically sampled, thus providing new and unique perspectives. Using ~ 30 diamond drill holes spanning >5 km of strike length, >1500 whole rock multi-element geochemical samples, magnetic susceptibility data, 30 thin sections, and thermodynamic modelling (MELTS), the internal architecture and magmatic evolution of the sill is reconstructed. We demonstrate that in the study area, the 'sill' consists of at least two sills (each ~100-300m thick). Internal asymmetry and chilled margins indicate that the sills are separate cooling units and not products of structural repetition or folding. We are able to look beyond ubiquitous greenschist facies metamorphism to identify preserved relict mineral textures in what is classified as a siliceous high-Mg basalt. Both sills show distinct internal layering that can be broadly grouped into cumulate (mainly olivine and orthopyroxene), dolerite (plagioclase and pyroxene, crystals >1 mm), quartz dolerite and basalt (<1 mm grainsize) facies. Not only do the upper and lower sills show mineralogical layering, such as increased thickness of quartz dolerite in the upper sill (50+m), but lateral variations are marked by non-uniform distributions of cumulates, granophyric veins and pods, ophitic textures, and basaltic regions. We compare these lateral variations with thermodynamic models and develop a dynamic emplacement model. This research will be of interest to those modelling fractionation and emplacement of mafic-ultramafic sill, as well economic geologists, especially those in the field of orogenic gold, as quartz dolerites are a major trap for Au-bearing fluids in the Archean.

309

Lava flow hazard and its implication to geopark development for the active Harrat Khaybar intracontinental monogenetic field, Saudi Arabia

Professor Karoly Nemeth[1,2,3], Professor Mohammed Rashad Moufti[4]
[1]Massey University, Volcanic Risk Solutions, Palmerston North, New Zealand, [2]Saudi Geological Survey, Jeddah, Kingdom of Saudi Arabia, [3]Institute of Earth Physics and Space Science, Sopron, Hungary, [4]Faculty of Earth Sciences, King Abdulaziz University, Jeddah, Kingdom of Saudi Arabia

Harrat Khaybar is one of the most extensive monogenetic volcanic fields in the western margin of the Arabian Peninsula. The field hosts monogenetic volcanoes such as scoria cones, tuff rings, spatter cones and extensive lava flow fields mostly in basaltic compositions and several silicic lava domes and tuff rings. The region due to its high geodiversity and aesthetic values recently been listed among the UNESCO First100 Global Geosites. Establishment of a UNESCO Global Geopark is a long term aim of the area and for that geosite recognition and geohazard estimation are currently in the centre of research. Satellite imagery and field observations revealed that the youngest lava flows are above ~5000 years old human occupation sites. Sentinel satellite image analysis indicated that the field has at least 5 lava flow fields characterised with similar young surface patterns. The lava erupted on a gentle sloping surface. In proximal regions ponding, inflation and deflation textures are evident while where slope angle changes rubble pahoehoe flow developed. The longest lava flows reach 50 km. Applying Q-LavHA lava simulation the Euclidian model with 5 m average lava thickness performed well to model lava inundation. As lava fields formed on flat surfaces, long simulation distances were used. The simulations however were not able to model well the long lavas that is interpreted as an evidence of lava tube formations that successfully been able to carry lava far. In the simulations fissure eruptions following the same orientation as the aligned vents provided the best lava inundation estimates indicating that the mapped young lava flows are likely erupted through long fissures. Applying lava flow simulations to the present-day morphology, lava would inundate recently completed sealed road and planed geopark establishment hence the volcanic risk needs to be incorporated in future geopark operations and its geoeducation programs.

856

The Why, What, and How of Choosing Analogue Volcanoes

Dr Christopher Newhall[1]
[1]*Mirisbiris Garden And Nature Center, Sto Domingo, Philippines*

Why? First, given a volcano of concern, we can learn from eruption histories, deposits, and unrest of analogues, from their variability and dominant modes, and from the depth of study at some. If we want to understand strombolian eruptions at volcano X, study Stromboli! Second, in the growing use of probabilistic forecasting, estimates at some nodes will require more data than we might have from the volcano of concern. An early criticism of considering analogues was that “every volcano is unique.” True, no two volcanoes are identical, but they can show remarkable similarities. Larger data sets bracket variability and reduce surprises. But doesn’t that introduce new uncertainty? Yes, of course. Wise probabilists will use multiple data sets, including but not limited to data purely from their target volcano.

What? First, we should define exactly what would be a good analogue, which will depend on what we are trying to forecast. For PDC runout, we would consider only volcanoes with measured PDCs. For long-range eruption forecasting and hazard assessment, we want volcanoes that – over time – produce a similar suite of eruptions to ours, with similar magnitude-frequency relations. For short-term eruption forecasting, we might start with that long-term set but narrow it to those that show similar pre-eruptive unrest. We base our keys on what we want to forecast.

How? I don’t think there is one “best” way. Try a variety of statistical approaches, and also a variety of search parameters or keys. Most recent papers stress the importance of objectivity and reproducibility. In principle I agree, if available data are good enough. But if they aren’t, consider fuzzier, subjective approaches too. Eventually, we’ll have enough trials that some methods will prove more useful than others. Let’s devise clever ways to test our methods!

858

A new classification of volcanoes based on buffering of ascending magma from source to surface

Dr Christopher Newhall[1]
[1]Mirisbiris Garden And Nature Center, Sto Domingo, Philippines

Most current efforts to identify analogues for probabilistic eruption forecasting use statistical methods and emphasize objectivity. A laudable goal, but IMHO available data are insufficient. Some, like tectonic setting, are over-generalized, others, like eruption frequency, are useful and reasonably complete; still others, like magma ascent rates, are just on a wish list! As an alternative, I'm trying a subjective approach, using ANY AND ALL available data and proxies to assess buffering or inhibition of magma ascent in four zones: source (upper mantle-lower crust), mid- to upper-crust storage, shallow conduit (above the storage), and in interaction with shallow groundwater. Buffering has a profound effect on whether and how explosively magma will erupt, and is rated as Strong-Medium-Weak for each zone, producing a 4-letter characterization inspired by the Myers-Briggs classification of human personality.

After an excruciatingly slow, COVID-time review of many new and obscure papers guided by Google Scholar, I applied this scheme to the entire Smithsonian GVP Holocene volcano list. Some familiar 'families' or 'communities' emerge, e.g., volcanoes that erupt infrequently but violently after shallow plugging above crustal storage allows accumulation of excess volatiles, as at Pinatubo. Others include habitual dome-builders like Unzen, or volcanoes that degas continuously where magma convects in shallow, open conduits, like Stromboli. Families with strong buffering by groundwater are not as different as they seem. For example, many volcanoes with frequent small phreatic explosions and acid springs are close cousins to open-vent volcanoes with frequent strombolian eruptions.

This approach to selecting analogues for forecasting needs now to be tested. Several of us using different approaches plan comparative testing and invite collaborators. Our common goal is improved forecasting.

219

3D Numerical Modelling of Lava Dome Growth and Instability

Miss Kendra Ní Nualláin[1], Mr Zhi Zhang[2], Dr Claire E. Harnett[1]
[1]UCD School of Earth Sciences , University College Dublin, Belfield, Dublin 4, Ireland, [2]UCD School of Computer Sciences , University College Dublin, Belfield, Dublin 4, Ireland

Volcanic domes are inherently unstable structures as they grow incrementally, with varied extrusion rates, material properties, and directions of flow. These instabilities can bring about volcanic dome collapse, leading to turbulent and hot avalanches of material that can devastate communities surrounding a volcano, as well as affecting the volcano's eruptive dynamics.

Although we can use satellite imagery to observe surface deformation of volcanic domes, it remains difficult to investigate their internal structure. In recent years, computational simulations of volcanic domes have been successful in reproducing growth dynamics and exploring internal deformation of a dome during growth and collapse. Existing models, however, currently lack numerical complexity in that they are primarily 2D, and they do not consider different magma viscosities. This significantly limits their application to real-life systems in a number of ways. For instance, it is not currently possible to reproduce the full range of lava dome morphologies seen in nature, nor can we fully model their 3D interaction with existing volcanic topographies (e.g. growing within a crater). Additionally, it is difficult to infer collapse directions and material volumes from the models.

Following previous dome growth models, we use discrete element method modelling in Particle Flow Code from Itasca Consulting Group. This is a particle-based method, whereby spherical particles interact at interparticle contacts. Contact behaviour is primarily governed by user-defined stiffness, strength (compressive and tensile), and Young's modulus of interparticle contacts. Particle Flow Code has multiple built-in contact models, enabling the simulation of both fluid-like behaviour and solid brittle behaviour of volcanic rock.

Here, we present two key topics: (1) the first proof-of-concept 3D models showing lava dome collapse following material weakening; and (2) an initial investigation into simulating a range of magma viscosities.

801

Grain Size Spectra of Culturally-Modified Sediments Reveal Resilience to Explosive Volcanic Events in the Islands of Four Mountains, AK

Professor Kirsten Nicolaysen[1], Lydia Loopesko[1,2], Cait Mazzoleni[1,3], Dr. Virginia Hatfield[4], Wamuchii Mwangi[1], Dr. Lyman Persico[1]

[1]Whitman College, Walla Walla, United States, [2]ICOSMOS, Washington, United States, [3]Geosyntec Consultants, Los Angeles, United States, [4]Museum of the Aleutians, Unalaska, United States

To what extent have people and ecosystems rebounded resiliently from explosive volcanic eruptions, including the moderate to large eruptions that occur periodically in the Aleutian Islands of Alaska? An international team tested the hypothesis that in prehistory humans were resilient to climate change-related sea level rise, tsunamis generated by tectonic earthquakes, debris flow events, and explosive volcanic eruptions on two of the Islands of Four Mountains, a group of small islands located between the larger eastern and central Aleutian Islands. One aspect of this hypothesis was that the small area of these islands might have magnified the impacts of such events. Exposed by coastal erosion, large sediment fans (>30 m thick) consist of thick paraglacial debris flow deposits at their base, numerous volcanic tephras, and of sediments associated with villages established by at least 3,900 calibrated years BP. Deposits mantling the basal debris flows are primarily volcanic ashes with a significant pyroclastic sequence occurring circa 1,050 calibrated years BP. Likely originating from Mt. Cleveland volcano, the 1,050-year-old CR-02 tephra clearly caused temporary abandonment of two villages located within 8 km of the summit, however, earlier periods of occupation or abandonment due to volcanic activity are more cryptic. Grain size analyses of the fine fraction of fan sediments indicate that human modified sediments have distinct spectral characteristics compared to volcanic ash, tephra, and debris flows. For example, in the size range 0.59 to 2,000 microns, culturally modified soils register broader, flatter peaks (lower kurtosis) and spectra may have one unusual concave or convex shoulder. Data from more than 90 samples test whether possible site abandonments circa 2,200 yBP and 3,500 yBP co-occurred with volcanic events. The sedimentary and archaeological records concur in chronicling the high resilience of humans to explosive volcanic activity in prehistory.

442

High-temperature kinetics of halogen radicals and its influence on volcanic plumes

Mr Alexander Nies[1,2], Dr Jonas Kuhn[2,3], PhD Tjarda Roberts[1,4]
[1]Laboratoire de Physique et de Chimie de l`Environnement et de l`Espace, CNRS/University Orléans, Orleans, France, [2]Institute of Environmental Physics, Heidelberg University, Heidelberg, Germany, [3]Max Planck Institute for Chemistry, Mainz, Germany, [4]Laboratoire de Météorologie Dynamique, IPSL, CNRS, Ecole Normale Supérieure, Sorbonne Université, PSL Research University, Paris, France

During the first seconds of open vent volcanic degassing, hot magmatic gases mix with the ambient atmospheric air and undergo rapid cooling. Fast oxidation and aerosol processes occur, which depend on the dynamic interplay between mixing, cooling and chemical kinetics. Hence, the first seconds of open vent volcanic degassing play a crucial role for understanding and quantifying the reactivity and gas composition of the diluted plume and its impact on Earth's atmosphere.

Recent studies show that the transition between high-temperature emission and later plume stages cannot be captured by thermodynamic equilibrium models. We investigate the first seconds of plume evolution using a 1 D box model accounting for chemical kinetics along different cooling and mixing trajectories. The model is based on a C-H-O-S combustion mechanism, which was extended to include reactive nitrogen and halogen species. The model allows to systematically investigate the dependence on emitted gas composition, mixing scenario and emission temperature.

We present insights into the evolution of halogen species in hot volcanic emission plumes and respective implications for the chemistry in the cooled and diluted plume. Thereby, this modeling study contributes to the understanding of the impacts of halogens on the atmosphere and supports the interpretation of remote sensing data (e.g. bromine monoxide to sulfur dioxide ratios). In future, dedicated field measurements can refine our models by better constraining its initial and boundary conditions.

621

Temporal evolution of magma plumbing system beneath Aira caldera volcano, southwest Japan

Dr Ayumu Nishihara[1,2], Katsuya Kaneko[1], Qing Chang[3], Jun-Ichi Kimura[3], Nobuo Geshi[2], Takashi Miyazaki[3], Bogdan Vaglarov[3]

[1]Department of Planetology, Graduate School of Science, Kobe University, Kobe, Japan, [2]Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Japan, [3]Research Institute for Marine Geodynamics, Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Yokosuka, Japan

In order to advance the understanding of the origin and temporal evolution of magmas in caldera volcanoes, we investigated the volcanic activity of Aira caldera volcano, southwest Japan, from 100 ka to the present. Aira caldera volcano produced an over VEI-7 supereruption at 30 ka. In the Aira caldera volcano, several explosive and effusive eruptions occurred as pre-supereruption volcanism. Since 30 ka, post-supereruption activities have continued at Sakurajima and Wakamiko volcanoes at the south and northeast parts of the Aira caldera, respectively. We performed elemental and isotopic compositions analysis of whole-rock samples and in-situ micro-analysis of plagioclase phenocrysts. Especially, the in-situ micro-analyses of Sr isotopic ratios of the plagioclase phenocryst were important cues to reveal the hidden magmatic processes in the Aira's magma plumbing system.

Our elemental and isotopic data suggest that the magma plumbing system beneath the Aira caldera drastically changed at the 30-ka supereruption. In the volcanism from 100 ka to the 30-ka supereruption, silicic and mafic magmas were generated by low- and high-degree partial melting of an amphibolitic lower crust, respectively. These lower-crust-derived silicic and mafic magmas compositionally changed due to mixing with the mafic magma and assimilation of a shallow crust, respectively, and finally erupted at the surface. The magmas do not have any signature of the mantle components by this point. After the 30-ka supereruption, the Aira caldera volcano has two independent magma plumbing systems. One is Wakamiko's system, which erupted remnant magmas of the mafic magma in the 30-ka systems. The other is Sakurajima's system, which has erupted the mixture of mantle-derived basaltic magma and crust-derived magma produced by upper and lower crustal rocks. These temporal variations in magmatic sources and processes have controlled the origin and evolution of magma of the Aira caldera volcano since the last 100 ka.

408

Numerical simulation of the quasi-periodic behavior of effusive eruption and its application to the 1991-1995 eruption of Mt. Unzen

Mr Sora Nishikawa[1], Mr Ryo Tanaka[2]
[1]*Graduate School of Science, Hokkaido University, Sapporo, Japan,* [2]*Institute of Seismology and Volcanology, Faculty of Science, Hokkaido University, Spporo, Japan*

Geophysical observations have detected quasi-periodic changes in chamber pressure and discharge rate during eruptions. The behavior is caused by the interaction between the chamber, which acts as an elastic capacitance, and the variable flow resistance of the conduit. Previous numerical approaches have shown that one factor that changes the flow resistance, i.e., the conduit deformation during eruptions, causes damped oscillatory changes in the discharge rate and pressure fluctuations. However, there is a problem with overestimating the change in the conduit radius due to the influence of irrational modeling that does not consider changes in the physical properties of magma. In this study, we construct a new mathematical model that incorporates changes in the physical properties of ascending magma into a mathematical model of magma-supplying systems that consider conduit deformation and investigate its behavior. As a result, it was found that changes in the physical properties of magma during ascent affect the flow resistance by influencing the efficient bulk density and viscosity, which in turn affect the amplitude of damping oscillation and the scale of the conduit radius, respectively. The model was applied to the 1991-1995 eruption of Unzen, which showed two peaks of pulsating lava extrusion rate. The results were accommodative with those of the change of the radius obtained from the petrologic studies. As an application, the model estimates the chamber volume to be vch = \SI{1.1e10}{m^3}, and the model may reveal information on the chamber volume which is difficult to observe. The crustal viscosity is about 4 - 5 orders of magnitude smaller than typical values reported by geodetic observations, and the effects of partial melting of the host rock and/or the dike-shaped conduit need to be considered.

1441

The 1959-1988 Kīlauea Iki Lava Lake as a Long-term Natural Experiment to Investigate Olivine Re-equilibration in Basalt

Ms Nabila Nizam[1], Dr Thomas Shea[1], Dr Rosalind Helz[2], Dr Kendra Lynn[3]
[1]University Of Hawaii At Manoa, Honolulu, United States, [2]Florence Bascom Geoscience Center, Reston, United States, [3]Hawaii Volcano Observatory, Hilo, United States

In active magmatic systems, subsurface events such as magma recharge and mixing can lead to disequilibrium within the system. Details of these events can be recorded in minerals in the form of chemical zoning. The study of zoned crystals allows us to inspect the timing between a thermal and/or chemical perturbation using diffusion chronometry, a technique heavily reliant on robust diffusivity constraints for each element of interest.

In this study, we utilize a long-term natural diffusion 'experiment' to investigate elemental diffusion and the diffusive re-equilibration of an entire olivine cargo during the slow cooling of Kīlauea Iki lava lake. The lava lake was sampled periodically over the span of 29 years (1959-1988), providing snapshots in time of the compositional changes experienced by olivine crystals. Previous microprobe analysis and MgO thermometry of matrix glasses from this eruption showed the lava lake materials cooled from ~1140°C to ~100°C through its entire cooling period. Using EPMA, we examine temporal variations in chemical gradients of major (Fe-Mg), minor (Mn, Ca, Ni), and trace elements (Cr, Al, P) in the olivine cores of 1959 tephra and all the subsequent drill core samples. Applying diffusion chronometry on these measurements allow us to inspect the effects of time for diffusive re-equilibration on individual crystal transects and the whole crystal cargo. Since the time-temperature paths of the cooling of this lava lake are well constrained from thermocouple measurements made during drilling, glass thermometry and conductive cooling models from previous studies, we can compare the accuracy of timescales obtained from diffusion models to the actual eruption-to-drilling timeframe.

This long-term natural experiment provides a unique opportunity to test the validity of our diffusion chronometry timescales and obtain broad constraints on the average diffusivities for a variety of major, minor, and trace elements in a magmatic system.

461

The hole is greater than the sum of its parts: using morphometry to interpret complex monogenetic landforms

Mr Joseph Nolan[1], Dr. Alison Graettinger[1]
[1]*University of Missouri-Kansas City, Kansas City, United States*

Small volume volcanic landforms that experience changes in the eruption locus, or significant changes in eruptive processes, have more complicated final morphologies that are more challenging to remotely identify than more idealized landforms. Complex landforms are formed by a single dominate eruptive mechanism with migrating loci; like fissure ramparts in Laki, Iceland or Clover maar in Diamond Craters, Oregon, US. Multimodal landforms are those formed when the dominate eruptive mechanism changes and alters the final morphology such as a maar cutting a scoria cone or shifts between strombolian bursts to Hawaiian spatter. The Small-volume Monogenetic Igneous Landforms and Edifices Statistics (SMILES) catalog contains the morphometric characterizations of simple mafic small-volume volcanic landforms and was created using high resolution (<0.1-5 m/pixel) digital elevation models to establish what dimensionless morphometric parameters enable remote identification of volcanic landforms. Leveraging SMILES data complex and multi-modal monogenetic volcanic landforms were outlined and their component landforms were classified. The internal volcanic components (IVC) morphometric parameters were collected and compared to simple landforms in the catalog. Parameters include aspect ratio, isoperimetric circularity, depth ratio (crater depth/major chord), interior/exterior slope angles, base/height ratio (average height/ base major chord), crater to base ratios of area, perimeter, and major chord ratios. Accurate classification requires 75% of the IVC remain intact, and therefore not applicable to heavily eroded/modified landforms. This study found that IVCs exhibit similar morphologies and morphometric parameters as an idealized variant of the same classification, e.g., an internal maar resembles a simple maar. When applicable, this technique enables remote classification of non-idealized volcanic landforms and provides data on the dynamics of eruption mechanics during formation. The technique used in this study can be applied to other non-volcanic landforms, like impact craters, as well as non-terrestrial targets.

1311

Mechanical controls on volcanic uplift from a global analysis

Dr Camila Novoa[1], Dr Andrew Hooper[1], Dr Susanna Ebmeier[1]
[1]*University Of Leeds, Leeds, Royaume-Uni*

Deformation patterns at individual volcanoes are usually treated as isolated cases and interpreted on the basis of the individual characteristics of each volcano. Here we describe a temporal pattern in uplift that is common to all uplifting volcanoes with significant implications for the mechanical controls. These uplift signals have been observed worldwide and have classically been interpreted as the result of a magma reservoir filling at depth, and have therefore been identified as a possible precursor signal to volcanic eruptions. However, several studies have also shown that this link between uplift episodes and eruption does not always work. Currently, the processes that produce volcanic uplift episodes are unclear and the classical models used to interpret these episodes are now questioned because of their inherent assumptions that do not match the expected mechanical behaviour of a volcanic system. Here, we compile time series of several volcanoes extracted from the literature, computed using InSAR, GNSS and Tilt techniques. We focus our analysis on volcanoes that have experienced one or more periods of uplift, some, but not all followed by eruption. After normalising these uplift episodes in time and magnitude, we find that the transient evolution after a certain time follows the same pattern for all volcanoes studied, independent of their location, composition, etc, suggesting a common mechanism. To interpret this transient deformation and determine whether it can be related to the rheology of the crust, reservoir and/or magma injection itself, we use existing analytical models that allow us to test different rheologies, including elasticity, viscoelasticity, poroelasticity and poroviscoelasticity. By analysing and comparing each of these models, our results suggest that this common uplift pattern reflects the crustal mush system response to magmatic injection. These results highlight the importance of considering rheological heterogeneities in future models to advance in volcanic behavior prediction.

203

A review of the past and recent seismic activity in the Ceboruco Volcano region (Mexico)

Professor Francisco J Nuñez Cornu[1], Dr. Diana Nuñez[1,2], Prof Charlotte Rowe[3]
[1]Sisvoc, Universidad De Guadalajara, Puerto Vallarta, Mexico, [2]2. Departamento de Física de la Tierra y Astrofísica, Universidad Complutense de Madrid, Madrid, España, [3]Los Alamos National Laboratory, Los Alamos, USA

Ceboruco Volcano, located in the western region of the Trans-Mexican Volcanic Belt, is one of the most hazardous volcanoes of Mexico. As such, monitoring is critically important but over the last 25 years, seismic monitoring of Ceboruco has been discontinuous, with early temporary networks of one and four stations providing only general characteristics of seismicity in the vicinity of the volcano. During the initial observation period using one seismic station, volcano-tectonic, low frequency and hybrid events were observed, and seemed to be distributed randomly in the region. In 2012, a seismic network of four temporary stations provided data allowing insights into the structural features of the volcanic edifice and reactivated tectonic structures with ENE-WSW orientation but no obvious hypocentral location pattern was resolved. This sparse information, inadequate for establishing a baseline for the current state of the volcano, motivated the installation of a dense temporary seismic network of 25 stations covering an area of 16 × 16 km on and around the volcano.

This network allowed the detection of 81 earthquakes concentrated beneath the crater, with depths between 4 and 8 km. Much of this recent seismic activity occurs in swarms, and we specifically identify four sequences that have been characterized in detail, including the determination of the first focal mechanisms available for seismicity at this volcano.

Our results suggest a change in the local seismicity distribution compared to earlier observations, which reported seismic activity near the volcano edifice associated with fluid migration along zones of weakness related to the extensional stresses of the Tepic-Zacoalco rift. The changes in seismic patterns and associated focal mechanisms are consistent with observed fluid effects at many geothermal sites worldwide, but also could suggest resumption of activity at this currently dormant volcano.

282

Characteristics of pyroclastic ash fall deposits: the pre-historical explosive eruption of Ciremai volcano, West Java, Indonesia

Mr Wildan Nur Hamzah[1], Prof. Tsukasa Ohba[1], Mr. Andriansyah Gurusinga[1], Mr. Jananda N. Indriyanto[1], Dr.Eng Mirzam Abdurrachman[2], Dr. Idham A. Kurniawan[2]
[1]Akita University, Akita, Japan, [2]Institut Teknologi Bandung, Bandung, Indonesia

Ciremai is one of the active back-arc volcanoes in the Java volcanic arc, Indonesia, which has three centers of volcanic activities: Putri, Gegerhalang, and Ciremai periods. Several studies of the lavas from the central and flank eruptions have been reported; however, there is still a lack of information about the pre-historical pyroclastic products from the Ciremai periods. Our study focused on three episodes of pyroclastic fall deposits distributed on the west and southwest flank of the Ciremai volcano. We conducted a detailed field investigation combined with particle size distribution (PSD), particle componentry analysis (PCA), and particle shape analysis (PSA) of the eruption deposits. Three eruptive units of fallout deposits in the Maja area, namely Cpf1, Cpf2, and Cpf3, were separated by paleosoils. The Cpf1 deposit consists of 20 layers with a variable thickness ranging from 0.3 cm up to 6 cm, and the Cpf2 deposit comprises three layers with thicknesses up to 7 cm. The multiple layers in a unit indicate that each episode could have consisted of some different eruption events. The GSD result shows the unimodal distribution in the coarse size range from <-2 to 1 phi. The changing of maximum phi size in vertical stratigraphy may reflect the difference in eruption features. The eruption features are categorized into five types (Type A-E) by the various ratio distributions of componentry between the juvenile, lithic, and crystal, although the mineralogy of juvenile particles of each episode is similar (pl+cpx+opx+opq). The shape analysis result showed that the circularity value is lower in juvenile particles (avg. 0.591) compared to the lithic clast (avg. 0.696). However, the value solidity in lithic clasts is higher (avg. 0.931) than in juvenile particles (avg. 0.893).

1104

Providing a tephrochronological framework for 10myrs of deposition in the Southern Wairarapa

Miss Libby O'brien[1], Dr Jenni Hopkins[1], Mr Dene Carroll[1], Dr Michael Hannah[1]
[1]*Victoria University Of Wellington, Wellington, New Zealand*

The Southern Wairarapa occupies a fore arc section of the Hikurangi Margin and has been subjected to several changes in tectonic regime over the last 10myrs. The progressive shallowing of the depositional environment from deep sea sedimentation to shallow shore face and fluvial systems has resulted in a range of sedimentary facies. Superimposed on regressions and transgressions are several 40kyr glacio-eustatic motifs. Also discovered within this stratigraphy are a significant number of tephra deposits. These are likely from the Taupō Volcanic Zone (TVZ) as well as its understudied predecessors- the Tauranga (TgaVZ) and Coromandel Volcanic Zones (CVZ) and have helped to provide temporal markers within studies focused on the stratigraphy. However, due to limitations on tephrochronological methods at the time, as well as many newly identified deposits, it is time this area was revisited with a focus on creating a cohesive tephrochronology for the region.

In order to provide data which is comparable to a cohesive database, the methods and analytical conditions used will align with those outlined by TephraNZ (Hopkins et al., 2021). The identification of glass geochemistry through EPMA and LA-ICP-MS is being undertaken in tandem with the radiometric U/Pb/Th analysis of zircons. Primarily, this aims to further constrain the sedimentation rates and temporal deposition of multiple regional formations and in conjunction with this, information may be provided on the ash fallout of many understudied eruptions from the TgaVZ and CVZ.

475

IAVCEI Commission on Volcanic Hazard and Risk Volcanic Hazard Map Database: exploring variations in map design and content

Dr Sarah Ogburn[1], Dr. Danielle Charlton[2], Dr. Heather Wright[1], Professor Jan Lindsay[3], Professor Eliza Calder[4]
[1]*USGS/USAID Volcano Disaster Assistance Program, Vancouver, United States,* [2]*GNS Science, , ,* [3]*University of Auckland, , ,* [4]*University of Edinburgh, ,*

The IAVCEI Commission on Volcanic Hazard and Risk (CVHR) Volcanic Hazard Map Database is an online, searchable, global collection of volcanic hazard maps. The hazard map database grew from several related efforts that have been harmonized, combined, and expanded in conjunction with the IAVCEI CVHR State of the Hazard Map workshops. The primary purpose of this database and website is to serve as a resource for those making hazard maps (or other interested parties) to explore how common issues in hazard map development have been addressed at different volcanoes, in different countries, for different hazards, and for different intended audiences. The database can be searched via the website (https://volcanichazardmaps.org/) based on a variety of map metadata.

Map metadata include: volcano name, country, depicted hazard processes, timescale (short-term crisis vs. long-term background maps), construction methodology, probability definition, audience and purpose, and design elements (color scheme, base map type, etc.).

The database also records additional elements that vary depending on the map purpose and audience, such as: evacuation routes, safe areas, impact information, conditional validity, uncertainty information, actions to take, hazard travel or arrival times, alert level schemes, cell phone coverage, hiking trails, and population information.

Some of these map elements are quite novel, and as such, we hope that the database can serve as a 'menu' of map design that hazard map developers can use to solicit preferences from partners and audiences. This presentation seeks to explore how map design and content vary with the intended map purpose, audience, and timescale.

898

Detailed eruption chronologies of dome-forming eruptions as analog datasets for forecasting

Dr Sarah Ogburn[1], Hannah Kruse[1]
[1]USGS/USAID Volcano Disaster Assistance Program, Vancouver, United States

The global record of volcanoes and eruptions (e.g., Global Volcanism Program Volcanoes of the World database) is often used to derive different analog sets of volcanoes and eruptions for forecasting eruption onset and maximum eruption size. Detailed eruption chronologies, however, can also serve as analog datasets for forecasting the size, timing, and frequency of intra-eruptive hazardous events, such as individual explosions, pyroclastic density currents, dome growth and collapse.

Intra-eruptive forecasting of hazardous events during an eruption using analog eruption chronologies requires detailed information about the size, style, and timing of diverse hazardous events. We have begun to expand upon existing chronology databases by compiling a global database of pre-eruptive unrest and intra-eruptive events and their properties as part of the Echron project of the U.S. Geological Survey-USAID Volcano Disaster Assistance Program. These chronologies consist of many hundreds of intra-eruptive events as well as properties related to these events (e.g., volume, runout length, column height).

Here we present some results of this work highlighting the potential uses of detailed eruption chronologies of dome-forming eruptions, some of which are quite long-lived. We show how these analog sets of eruption chronologies can be used to answer common forecasting questions regarding frequency, timing, and size of intra-eruptive events. We additionally highlight similarities and differences in the activity between volcanoes we might consider as analogs. We hope to demonstrate the utility of compiling such information on a global scale and how such analog data can be used for intra-eruptive forecasting efforts.

777

Understanding volcanic edifice degradation and age by measuring drainage development and evolution

Dr Daniel O'hara[1], Roos M. J. van Wees[1], Dr Liran Goren[2], Dr Benjamin Campforts[3], Dr Pablo Grosse[4], Dr Pierre Lahitte[5], Dr Matthieu Kervyn[1]

[1]Vrije Universiteit Brussel, Brussels, Belgium, [2]Ben-Gurion University of the Negev, Beersheba, Isreal, [3]University of Colorado, Boulder, Boulder, U.S.A., [4]CONICET & Fundación Miguel Lillo, San Miguel de Tucumán, Argentina, [5]University of Paris-Saclay, Gif-sur-Yvette, France

The evolutionary state of a landscape is often assessed through a series of metrics that quantify the morphology of its drainage basins and divides. Such metrics have been well-explored in tectonically-active environments to evaluate the role played by different processes in sculpting topography. Yet, despite decades of work to understand landscape evolution in tectonic areas, relatively little work has been completed to apply these analyses to volcanic regions.

Volcanic edifices are dynamic primary landforms that evolve through a combination of both short-term eruptive events that can construct or catastrophically destroy topography, and long-term degradation related to erosion, leading to a wide variety of morphologies from simple, cone-like edifices to complex, non-axisymmetric massifs. Separating these processes to interpret edifice histories often requires extensive fieldwork and assumptions of initial volcano shapes. However, understanding how the state of an edifice's drainage basins and divides relates to its history remains an unexplored aspect of volcanic geomorphology that can provide new insight to interrogate global volcanic and erosional records.

In this study, we quantify drainage basin geometries on originally-simple, conical edifices with different ages from Indonesia, New Guinea, and New Zealand. In particular, we explore the evolution of drainage basin area-length relationships (i.e., Hack's Law), drainage density, and normalized number of basins on the edifice, as well as mean values of basin hypsometry, length, width, relief, and slope. Relating these measurements to the average age of each edifice, we show that drainage geometries can be quantified by temporal relationships that characterize the erosional state of the edifice. Using these relationships, we then develop a novel model for edifice degradation that provides new interpretations of edifice erosional and volcanic histories. Finally, we explore edifice drainage basin growth and competition in detail by conducting a divide stability analyses on select volcanoes.

773

Exploring the coupling between regional volcanism and climate in the Cascades Arc (U.S) with regional patterns of volcanic edifice erosion

Dr Daniel O'hara[1], Dr Leif Karlstrom[2]
[1]*Vrije Universiteit Brussel, Brussels, Belgium,* [2]*University of Oregon, Eugene, U.S.A.*

Volcanic edifices represent a primary interface between crustal magmatism and climate. The distribution, classification, size, and composition of edifices reflect underlying crustal magma plumbing and evolution; while edifice morphologies themselves provide a useful proxy for erosion and the overall relationship to climate. Over the scale of an arc, quantifying edifice morphology and erosion distributions represents a new avenue to interrogate the long-term interplay between the subsurface and surface environment. Data completeness has previously limited the resolution over which such analyses could be conducted, but improvements in landform catalogs and globally-available topographic models are a game-changer.
Here, we present a new dataset of volcanic edifice morphologies and Quaternary erosion rates from the Cascades Arc. Using a database of volcanic vents, epoch ages, and edifice boundaries, we determine general edifice morphology distributions from 10m Digital Elevation Models for 1654 volcanoes. Our study includes cinder cones, domes, shield volcanoes, and composite volcanoes. Afterwards, we derive eroded volumes for 1233 volcanoes by reconstructing primary edifice landforms with two simplified algorithms that provide upper and lower bounds to primary edifice shape, estimating ~45 – 250 km3 of material eroded over the past 2.6 Ma.

Finally, we compare edifice eroded volumes to contemporary Cascades precipitation values and Late Pleistocene – Holocene glacial extent. We find that edifice erosion distributions are spatially correlated with both along- and across-arc modern precipitation gradients. Furthermore, both glacial extent data and long-wavelength topography collocate with edifice density distributions. Based on these correlations, we propose a coupling between volcanism and climate, in which arc-scale volcanic edifice construction generates a topographic barrier that produces orographic precipitation gradients, enhanced regional glaciation, and subsequent across-arc erosional asymmetry over million-year timescales. We further propose that this asymmetric erosion contributes to arc-perpendicular migration of volcanism through long-term lateral transport of surface loads that influence vent locations.

216

Mechanisms of bubble coalescence during decompression

Dr Masatoshi Ohashi[1], Mr Takafumi Maruishi[1], Dr Atsushi Toramaru[1]
[1]*Kyushu University, Nishi-ku, Japan*

Bubble coalescence in ascending magma is a key process that controls the eruption violence and the texture of volcanic pyroclasts. In this study, we focused on the growth-driven coalescence during decompression, which is poorly understood, particularly in a highly viscous liquid like magma. We performed analogue experiments where we could observe the three-dimensional coalescence of two growing bubbles in viscous silicone oil. Our results indicate that the coalescence process is controlled by a capillary number $Ca=\eta R'/\sigma$, where η is the liquid viscosity, R' is the bubble growth rate, and σ is the surface tension. The capillary number represents the interplay between the viscous force arising from bubble growth and the capillary force. At $Ca \ll 1$, two adjacent bubbles retain their spherical shapes until the film ruptures, and the capillary forces control the drainage timescale. In contrast, at $Ca \gg 1$, bubbles largely flatten and bubble growth itself drives film drainage. We also provide a general formula for the drainage timescale that is consistent with experimental results over a wide range of the capillary numbers. Coalescence models, which were proposed separately in previous studies, can be fully explained by the behavior of the capillary number. One of the striking features of our study is that the drainage timescale scaled by the growth timescale increases as both the bubble growth rate and the liquid viscosity increase. This suggests that even low-viscosity magma like basaltic magma can erupt explosively without gas loss if it is decompressed rapidly in a volcanic conduit.

709

Possible Dyke Intrusion Event Inferred from Swarm Activity and Crustal Deformation in the Japan Alps Region, Central Japan, in 2020.

Dr Shiro Ohmi[1], Dr Takuya Nishimura[1]
[1]*Kyoto University, Uji, Japan*

In the central part of the Japanese Island, a mountainous region with peaks rising over 3,000 meters above sea level stretches approximately 300 km from north to south. These consist of the Hida Mountains, the Kiso Mountains, and the Akaishi Mountains, collectively known as the Japan Alps. Five active volcanoes have been documented in the Japan Alps region, and three of them still have fumarolic activity. Ontake volcano is one of them, and its eruption in September 2014, which left 63 people dead or missing, is still fresh in our minds. Yake-dake volcano, which continues to have moderate fumarolic activity, is located about 50 km to the north of Ontake volcano. An intense seismic swarm activity occurred in the vicinity of Yake-dake from April to July 2020, which was one of the largest seismic swarms since the late 1970s, when modern observations started in the vicinity of Yake-dake. The seismic activity started on the east side of the main ridge line of the Hida Mountains and extended beyond the ridge line to the northwest, which is an unusual behavior of the swarm activity in this region in these twenty years. During the period of activity, five moderate earthquakes of magnitudes equal to or greater than 5, which are rich in non-double-couple components, occurred, and accompanied by crustal deformation detected by GNSS network in the source region. The results of the analysis indicated that the earthquake was associated with the formation of a tensile crack fault caused by magma intrusion. This is possibly the first magmatic activity of Yake-dake volcano detected since the start of modern observations in 1970s.

642

Holocene explosive eruption history of Katla volcano, Iceland – a holistic approach

Bergrun Arna Oladottir[1,2], Gudrun Larsen[2], Olgeir Sigmarsson[2,3], Esther Ruth Gudmundsdóttir[2]
[1]Icelandic Meteorological Office (IMO), Bústaðavegur 7-9, 105 Reykjavík, Iceland, [2]Institute of Earth Sciences, University of Iceland, Sturlugata 7, 101 Reykjavík, Iceland, [3]Laboratoire Magmas et Volcans, CNRS and Université Clermont Auvernge, Campus Cézeaux, 63178 Aubiere, France

Explosive volcanic history of the ice-capped Katla volcano, Iceland, is preserved as tephra layers in soils around the volcano. Volcanic activity during historical time is well known through written documents and detailed stratigraphical work on large soil-sections, confirming 21 basaltic historical eruptions of which ten, or a half, left tephra east of the volcano. In addition, 150 prehistorical basaltic tephra units are preserved in a composite key-section east of the volcano. By assuming that ~50% of the prehistorical tephra also fell to the east, results in ~320 Katla eruptions for the last ~8500 years. Seventeen silicic Katla tephra layers serve as marker layers in the prehistorical stratigraphy around the volcano. Major element analyses of basaltic tephra from the key-section show systematic changes in magma composition interpreted as changes in its magma transfer system. The key-section shows prehistorical intervals of quiescence up to 160 years but assuming 50% of eruptions preserved in the east the true interval is reduced to ~80 years. Hence, the current quiescence interval, >100 years, could be the longest since Katla eruptions resumed after the large effusive Eldgjá eruption in 939 CE. The key-section shows long quiescence intervals preceding changes in the magma transfer system and glacial outbursts to the west. The aim here is to obtain a holistic eruption history of Katla volcano by analysing and correlating tephra layers in soil sections around the volcano to: 1) see how representative the eruption history and frequency pattern obtained from the eastern key-section really is, 2) see how reliable analogy the historical eruption history is for the prehistoric period, 3) obtain a better understanding of duration of quiescence intervals and 4) see if changes in the magma transfer system are predictable and affect eruption site locations under the ice-cap, as indicated by changes in jökulhlaup courses through time.

643

Long term volcanic hazard assessment in Iceland

Bergrun Arna Oladottir[1,2], Melissa A. Pfeffer[1], Sara Barsotti[1], Bogi B. Björnsson[1], Sigrún Karlsdóttir[1]
[1]Icelandic Meteorological Office (IMO), Bústaðavegur7-9, 105 Reykjavík, Iceland, [2]Institute of Earth Sciences, University of Iceland, Sturlugata 7, 101 Reykjavík, Iceland

More than 30 active volcanic systems exist in Iceland, most of which are located far from inhabited areas. This partly explains why few long-term volcanic hazard assessments exist. Long-term hazard assessments are suitable for long-term planning during quiescent time between eruptions. In 2012 GOSVÁ, a long-term holistic collaborative project on total risk assessment due to volcanic eruptions in Iceland began. The project is led by IMO and its subjects range from basic research on the nature of volcanoes and processes leading to, and during, volcanic eruptions, to the effects of volcanic eruptions on communities. Results of individual GOSVÁ projects can be accessed on the website www.icelandicvolcanoes.is, one of the first GOSVÁ projects. Long-term hazard assessment has been completed, or is in progress, for several populated areas in Iceland that could be particularly vulnerable to effusive eruptions. These include the capital area, communities on the Reykjanes Peninsula and Heimaey (Vestmannaeyjar). In these projects the spatial likelihood of eruptive hazards was explored in relation to location of homes and other critical infrastructure, focusing on tephra fall, gas dispersion and lava flows. Eruption scenarios were defined based on past activity and spatial probability of future vent openings calculated based on mapped features and surficial expressions of activity. Lava flow simulations were performed to capture a range of possible eruption strengths and vent locations. Tephra dispersion and deposition simulations were performed to capture a variety of weather conditions and vent locations where tephra may be produced from submarine eruptions. Likewise, gas dispersion simulations were performed to capture a variety of weather conditions and vent locations. The simulation results are used to assess regional vulnerability of critical infrastructure to the considered hazards. These results can be used to provide suggestions regarding more/less advisable locations for future infrastructure development.

373

How a Large Dilute Pyroclastic Current Erupts and Travels: The Campanian Ignimbrite, Italy

Michael Ort[1], Victoria Smith, Guido Giordano, Roberto Isaia, Aurora Silleni, Rose Gallo, Allyson Murray, Paige Laplant
[1]*Northern Arizona University, Flagstaff, United States*

The 39.8 ka Campanian Ignimbrite was emplaced by large (VEI 7) pyroclastic density currents from the Campi Flegrei caldera near Naples, Italy. Past work has demonstrated that the transport system was dilute and traveled radially from the vent, but the depositional system was dense and flowed downhill where there were slopes. Correlation of the complex proximal stratigraphic sequence with the distal sequence is difficult, but we use shard shape, glass chemistry, and lithic types to link the units. Several small-volume units are only present in the proximal zones, probably due to low mobility. The main distal units (Welded Grey Ignimbrite and Lithified Yellow Tuff) correlate with the Piperno and Breccia Museo in the proximal deposits, but they are not equivalents. We show that the proximal deposits record low mobility flows while the distal units are associated with high-mobility flows that were erosive or non-depositional in proximal areas. The currents were partially blocked by the Apennine Mountains after crossing the Campanian Plain. We use the heights of the first ridges and the amount of overthickening of the deposit on the ventward side to estimate the blocked amount and model the particle density gradient in the current at that point. Emplacement temperature estimates from thermal magnetization of lithic clasts and welding degree show the current was above 580 °C and below 680 °C for its entire runout, limiting the possible role of water and air as sources of gas. Apatite and melt inclusion data provide insights into the volatile history of the magmas and suggest re-equilibration at ~2% H_2O, which indicates shallow (1-2.5 km depth) storage of the voluminous magma prior to eruption. The exsolved gas that escaped with the eruption expanded and drove the hot dilute currents from the vent.

1474

Sub-volcanic architecture of the Paleoproterozoic Hart-Carson Large Igneous Province, northern Western Australia

Dr Karin Orth[1]
[1]*Codes University Of Tasmania, Hobart, Australia*

The Hart Dolerite is the intrusive portion of the Paleoproterozoic Hart-Carson Large Igneous Province (LIP) in the Kimberley region of northern Western Australia. It forms a series of sills that intrude some 2-3 km beneath the eruptive surface marked by basalt lava of the Carson Volcanics. The sills are well exposed for several hundred kilometres around the upturned and folded margins of the hosting basin. Composite sills are up to 1.25 km thick with individual units 500 m thick. Volumetrically, the Hart Dolerite sills and dykes comprise 83% of the LIP.

The architecture of the Hart Dolerite is dominated by multi-unit sills with some complex dykes up to 1 km across which ramp upsequence through the basin. Fifteen traverses across the sill complex reveal Internal textural features such as layering and mineral variations traceable over long strike lengths. Differentiated felsic sills are at particular levels within the sill architecture. The sill architecture hosts consistent stratigraphy in many areas which can be mapped based on geophysics and remote sensing. Within the unfolded, flatter portions of the lower Kimberley Basin, a distinctive feature in the magnetic signature known as 'elephant skin' is interpreted as dish-like intrusions of Hart Dolerite.

515

New age constraints and emplacement processes of a large-scale caldera forming eruption in Eastern Tasmania

Mr Till Gallagher[1], Dr Karin Orth[2], Miss Grace Cumming[1], Associate Professor Rebecca Carey[2]
[1]Geological Survey Branch, Mineral Resources Tasmania, Rosny Park, Australia, [2]Earth Sciences and CODES, School of Natural Sciences, University of Tasmania, , Australia

The St Marys “Porphyry” (SMP) is unique within the Lachlan Fold Belt, as it is the only middle Devonian large-scale, crystal-rich ignimbrite to have been emplaced in the Eastern Tasmania terrane. Previous workers (Turner et. al., 1986) modelled it as a massive, welded ash flow tuff, part of which was still connected to its feeder, but this interpretation was controversial because the unit is texturally similar to porphyritic granitic phases identified nearby. In order to re-evaluate the volcanic architecture of the SMP, the type, size and abundance of lithic clasts and aspect ratio, texture and distribution of “White Igneous Lenticular Domains” (WILDs) were described from distinct facies in the SMP using an on-ground quadrat-based mapping technique. Multiple ignimbrite flow units could be mapped out based on the occurrence of zones of high lithic abundance. Boundaries between units are difficult to identify now because they are masked by welding. The thickest facies within the SMP represents the most insulated portions of the SMP where welding textures became devitrified, and the matrix recrystallised into a granophyric texture.

Neighbouring and gradational to the SMP, the Piccaninny Creek Granite is interpreted to represent part of the intra-caldera complex, which likely intruded via the Southern Caldera Fault.

U-Pb zircon dating found that all units of the SMP are of a similar age: between 397 - 389 Ma. Further dating of surrounding granite phases and the hosting Scamander Formation showed that all units were emplaced within a short time frame of 8 Ma.

This project has confirmed that large scale silicic volcanism occurred in the Eastern Tasmania terrane during the middle Devonian. Furthermore, the new results define a slightly older age of the Tabberabberan Orogeny in eastern Tasmania (~391 Ma), indicating the Eastern Tasmania terrane is temporally distinct from the rest of the Lachlan fold belt.

1203

Infrasound observations of the 2018 Sierra Negra eruption in the Galápagos Islands

Mr Hugo Ortiz[1], Dr. Robin Matoza[1], Mr. Rodrigo De Negri[1]
[1]*University of California, Santa Barbara, Santa Barbara, United States*

Generally, eruptions in the Galápagos are effusive given the basaltic nature of their magmas. As a result, the infrasound signals are often emergent with no apparent onset and hard to track with a single instrument. Using the IS20 infrasound array from the International Monitoring System, we present the eruptive chronology of the 2018 Sierra Negra eruption at unprecedented time resolution in comparison to satellite, geodetic, and even seismic observations. The 5.4 Mw earthquake preceding the eruption is recorded at 9:19 on June 26, with back azimuth within 0.5° of the seismic inferred location. At 19:46, on the same day, we identify a persistent infrasound tremor indicating the eruption onset. The back azimuth corresponding to the tremor points approximately to Volcán Chico. Then progressively the eruption propagates down the north flank through a fissure system between 22:54 June 26 and 12:31 June 27, 2018. The average infrasound inferred speed of the eruption migration is ~0.2 m/s. For the next hours the eruption continues along the fissure system until it stops at 16:45 on June 28, 2018. After a few days of acoustic quiescence, we detect sporadic infrasound signals between 2 and 4 July 2018, with back azimuths pointing to additional short-lived fissures mapped on the field. On July 5, 2018, the eruption restarts at a fissure located about 11 km northwest of the eruption onset; the eruption from this fissure continues until August 18, 2018 with some periods of acoustic quiescence. These acoustic observations provide new insight into the Sierra Negra eruption in unparallel detail; thus, we discuss the implications for early warning systems and eruption migration along fissures. Further, this study reiterates the utility of regional (~85 km range) infrasound monitoring for characterizing and quantifying diverse eruption styles.

359

Using laboratory sliding tests to understand tephra loading on roofs for building design

Ms Sara Osman[1], Dr Mark Thomas[1], Dr Julia Crummy[2], Dr Stephen Carver[1]
[1]University Of Leeds, London, United Kingdom, [2]British Geological Survey, Edinburgh, United Kingdom

Global building standards take account of factors likely to increase roof loading, including snow and wind, but currently they do not consider tephra fall which can impose significant additional loading to a roof. We follow an approach similar to that taken for snow loading in the Eurocodes, where empirical equations are used to estimate the proportion of the load on the ground that is likely to be on the roof. These equations, which take account of changes due to drifting or sliding, are based on large amounts of field data that are difficult to collect for tephra loads, given the obvious hazard. We therefore used laboratory tests to investigate how tephra sliding varies with the slope and material of a roof. We measured the internal angle of friction (which affects internal sliding within a deposit) for coarse- and fine-grained tephra and conducted sliding tests at tephra depths of 10 – 30 cm, in wet and dry conditions on tiles, metal sheet and fibre cement roofing. Our results show that in all the cases we tested, the deposit was substantially shed on roofs with pitches > ~ 35 °, while there was no movement when the roof pitch was < ~ 15 °, indicating these can be treated as flat when considering sliding behaviour. We have been able to select a characteristic curve showing how tephra sliding varies with roof pitch, and derive a shape and material coefficient from this curve. We have found this to be independent of roof material, tephra density and grain size. This work can provide a first step in assessing the impact of tephra loads on roofs during the building design process.

360

From probabilistic tephra load modelling to vulnerability assessment on Ascension Island: a GIS tool to identify buildings at risk

Ms Sara Osman[1], Dr Julia Crummy[2], Dr Stephen Carver[1], Dr Mark Thomas[1]
[1]University Of Leeds, Leeds, United Kingdom, [2]British Geological Survey, Edinburgh, United Kingdom

Following an explosive eruption, buildings relatively proximal to the vent may be at risk of roof collapse under tephra loading. It is important to identify buildings at highest risk so they can be prioritised for roof clearing and this is particularly critical on islands where evacuation may be difficult. We focus on Ascension, a volcanically active island in the south Atlantic, where the most recent explosive eruptions (~ 60 ka) have produced monogenetic basaltic cones across much of the south and west of the island. To identify buildings that may be at risk in future eruptions we have created a GIS tool, available for ArcGIS and QGIS, that combines probabilistic tephra loads with the roof shape and material coefficients from laboratory tests and data on individual buildings. Tephra loads were determined using the freely available probabilistic tephra dispersion tool, tephraProb. We modelled a range of eruption scenarios (using a grid of possible vent locations to take account of vent uncertainty) to investigate how tephra loads could vary across the island's main settlements. Roof shape and material coefficients, produced from our laboratory tests, were used to identify the proportion of a deposit expected to remain on a roof, for a range of roof types and slopes. Our GIS tool combines these with data on building condition, roof material and pitch to produce maps showing buildings where tephra loading may exceed the critical roof load, and hence identify buildings at highest risk of collapse, for different eruption sizes and vent locations.

1436

Probabilistic volcanic ash dispersion modeling of the 2019 Ubinas volcano eruption

Dr Soledad Osores[1], Ms Eliana Vazquez[1], Ms Diana Rodriguez[1]
[1]*Servicio Meteorológico Nacional, Ciudad De Buenos Aires, Argentina*

Volcanic ash in the atmosphere is a hazard for civil aviation. When an eruption occurs Volcanic Ash Advisory Centers produce advisories, with information about the current and expected location and height of the ash cloud, that are delivered to pilots and decision-makers to take the necessary actions to avoid the impact of ash on aircraft.

Volcanic ash dispersion forecasts are based on numerical simulations, that depend on source term parameters (such as column height, mass vertical distribution, and mass flow rate), physical parameterizations, and meteorological data. All these inputs have uncertainties that impact to a different degree over the result. Probabilistic modeling allows us to take into account these uncertainties and help the stakeholders identify potential risks helping them in the decision-making process. In this framework, we apply a probabilistic approach to model the dispersion of volcanic ash during the Ubinas volcano eruption that occurred in July 2019. To achieve this we use the FALL3D 8.2 model that includes the capability of producing ensembles perturbing different source term parameters and meteorology. The results are compared with a satellite classification of volcanic ash based on VIIRS data and using a three thermal band method. It is expected that this system can support aeronautical decision-making during volcanic emergencies in the Buenos Aires Volcanic Ash Advisory Center area of responsibility.

546

A short magmatic reactivation before the catastrophic directed lateral blast of Bezymianny

Miss Lea Ostorero[1], Professor Hélène Balcone-Boissard[2], Professor Georges Boudon[1], Professor Alexander Belousov[3], Professor Marina Belousova[3]
[1]Université Paris Cité, Institut de physique du globe de Paris, Paris, France, [2]Institut des Sciences de la Terre de Paris (ISTeP), UMR 7193, CNRS-Sorbonne Université, Paris, France, [3]Institute of Volcanology and Seismology, Petropavlovsk-Kamchatsky, Russia

Lateral directed blasts are rare explosive events following a major sector collapse of a volcano, with the potential of devastating an area around the volcano of several hundreds of km2, due to powerful dilute and turbulent pyroclastic density currents. The eruption of 30 March 1956 of Bezymianny (in the Kurile-Kamchatka volcanic arc) was the first historical magmatic eruption of this volcano, after 1000 years of dormancy, and is at the origin of the appellation of "directed blast". Magma stored in a cryptodome was depressurized by a sector collapse generating a lateral directed blast. This event was followed by a Plinian eruptive column (35-40 km high). Deciphering the pre-eruptive dynamics is of particular interest to understand the magmatic processes prior to this major eruption and to constrain magma movements. This is of interest for future volcano monitoring, as Bezymianny is one of the most active volcanoes in the world since 1955. By combining two petrological chronometers on orthopyroxenes and magnetites from the clasts of the different phases of the eruption, we showed that the reactivation of the magma chamber located between 8-15 km is short (~1 year before but mainly in the 6 months prior to the eruption). Less than 6 months before the eruption, the magmas experienced a heating event, probably by a magma injection or degassing processes, that could have formed the dominant last reverse-zoned rims in orthopyroxenes and in magnetites. The abundance of multiple zoning in the orthopyroxenes indicates a short and complex history of the storage area before the ascent of the magma generating the different eruptive phases, that we propose to unravel in order to determine the dynamics of the storage area during this emblematic eruption.

547

Insights into volcanic unrest by correlating petrological and seismic observations at Kizimen volcano (Kamchatka, Russia)

Miss Lea Ostorero[1], Professor Hélène Balcone-Boissard[2], Professor Georges Boudon[1], Professor Nikolai M. Shapiro[3,4], Professor Alexander Belousov[5], Professor Marina Belousova[5], Professor Andreas Auer[6], Professor Sergey L. Senyukov[7], Professor Svetlana Ya. Droznina[7]

[1]Université Paris Cité, Institut de physique du globe de Paris, CNRS, Paris, France, [2]Institut des Sciences de la Terre de Paris (ISTeP), UMR 7193, CNRS-Sorbonne Université, Paris, France, [3]Institut des Sciences de la Terre (ISTerre), Université Grenoble Alpes, Grenoble, France, [4]Schmidt Institute of Physics of the Earth, Russian Academy of Sciences, Moscow, Russia, [5]Institute of Volcanology and Seismology, Petropavlovsk-Kamchatsky, Russia, [6]Department of Geoscience, Shimane University, Matsue, Japan, [7]Kamchatka Branch of the Geophysical Survey, Russian Academy of Sciences, Petropavlovsk-Kamchatsky, Russia

The increase of number and intensity of earthquakes during a pre-eruptive crisis is the main basis of seismic volcano monitoring. Deciphering the timescales of magmatic processes in the magma plumbing system leading to volcanic eruptions in the past can provide information for future crisis management, especially if a correlation between these timescales and monitoring signals can be established. Here we present a direct comparison between characteristics of a seismo-volcanic crisis recorded prior to the 2010-2013 explosive-extrusive eruption of an arc volcano (Kizimen, Kamchatka) with no previous historical magmatic activity, and the timescales of processes in the magma plumbing system. These timescales are inferred from the modelling of Fe-Mg intracrystalline interdiffusion in zoned orthopyroxene crystals from dacites and silica-rich andesites samples collected after the eruption. We show that the eruptible magmas were assembled rapidly during a magma mixing episode ~ 1.5 years before the eruption, which is well correlated with the onset of a seismic crisis. We conclude that the observed seismic re-activation marks the onset of magma mixing leading to the destabilization of the reservoir followed by the eruption after ~1.5 years. This could provide a valuable key for interpretation of the past and future eruptions on arc volcanoes.

Pre-print link: 10.21203/rs.3.rs-1140681/v1 (in revision)

214

Centimeter-Scale Mapping with a System Combining Multibeam Sonar, Lidar, and Stereo Photography of Four Hydrothermal Vent Sites at Axial Seamount

Ms Jennifer Paduan[1], Dr. David Caress[1], Mr. Eric Martin[1], Mr. Michael Risi[1], Mr. Chad Kecy[1], Dr. Giancarlo Troni[1], Dr. David Clague[1]
[1]Monterey Bay Aquarium Research Institute, Moss Landing, United States

The MBARI Low-Altitude Survey System (LASS) was deployed in September, 2021 to map at centimeter scale the Ashes, International District, Marker N3, and CASM hydrothermal vent sites at Axial Seamount. The LASS was integrated with the ROV Doc Ricketts, which was operated at a 3-m standoff to obtain 5-cm lateral resolution bathymetry using a 400 kHz multibeam sonar, 1-cm resolution bathymetry using a wide-swath lidar laser scanner, and 3 mm/pixel resolution color photography using stereo still cameras illuminated by Xenon strobe lights. The instrument package was mounted to the ROV toolsled on a frame that is actively articulated to keep the sensors and lights oriented normal to the seafloor. Surveys were planned over 0.5-m resolution AUV bathymetry to have 3-m line spacing and 0.2 m/s speed, and executed autonomously by the ROV. The steep walls at CASM and sides of the tall, multi-spired hydrothermal chimneys, with their abrupt height changes and cloudy, dangerous high-temperature fluids, were flown with a combination of hand-piloting and automated controls. Areas of 120 x 120 m can be covered in about 8 hours. In total, more than 52,000 m² were mapped in under 40 hours on bottom.

The entire Ashes and International District vent sites were mapped, including the instruments associated with the OOI Cabled Observatory, large black-smoker chimneys, and microbial mats and tufts of tubeworms indicative of diffuse flow from cracks in the lava. Also mapped were the Marker N3 vent site, notable for its recovery from burial under recent lava flows and dense blue ciliate populations, and part of the CASM vent site, with its narrow, deep fissure and tall chimneys. The LASS cm-scale mapping simultaneously measured fine scale volcanic and hydrothermal morphologies, imaged the benthic vent communities, and provided context to other observations and sampling, and can be repeated for monitoring purposes.

981

Insights into volcano degradation from analogue modelling: interactions between basin development and morphology through time

Dr Engielle Mae Paguican[1], Dr Daniel O'Hara[1], Dr Pablo Grosse[2,3], Roos M. J. van Wees[1], Dr Gareth N. Fabbro[1,4], Dr Matthieu Kervyn[1]

[1]*Vrije Universiteit Brussel, Brussels, Belgium,* [2]*Consejo National de Investigaciones Científicas y Técnicas, , Argentina,* [3]*Fundación Miguel Lillo, Tucumán, Argentina,* [4]*University of East Anglia, Norwich, United Kingdom*

Volcanoes undergo topographic changes after formation. Bare, undissected, morphologically young volcanoes transform into vegetated landscapes with deeply entrenched gullies and erosional valleys as their flanks become less permeable. This in turn alters the way water moves across the surface and through the subsurface. How this alteration and subsequent erosional degradation happens is not well understood.

Using a combination of experimental and numerical techniques, we investigate how drainage basins and the overall morphology of volcanic edifices change as they are affected by surface runoff and mass movements triggered by precipitation. We also study the interaction between basin development and morphology, to explore how these evolve through time. We designed analogue experiments that permit the observation of sediment erosion and transport processes on volcanic edifices, allowing the quantitative measurement of erosion-based degradation. A range of composite granular material was used to build analogue volcanoes, a rainfall system was used to simulate long term precipitation, and a camera system was used to record the processes and the changing landscape. Qualitative observations from timelapse photographs reveal the erosional processes that occur and the evolution of the surface throughout the experiment. Surface changes in digital elevation model timeseries derived from the analogue volcanoes are then quantitatively analysed, including numerical and statistical analyses with the MorVolc and DrainageVolc algorithms, to measure erosion, drainage basin development, and the morphological evolution of volcanoes. MorVolc generates measurements of landform-scale edifice morphology, while DrainageVolc generates quantitative descriptions of the drainage basins on each volcanic edifice. Using these data, the erosion rate and basin dynamics through the lifetime of a volcano can be described. This methodology opens new perspectives for understanding the development and evolution of drainage patterns on volcanoes, including the formation of asymmetric drainage and large valleys, and its impact on the overall morphology of edifices.

983

Drainage analysis of Philippine volcanoes: implications for their degradational evolution

Dr Engielle Mae Paguican[1], Dr Daniel O'Hara[1], Dr Gareth N Fabbro[1,2], Dr Pablo Grosse[3,4], Dr Matthieu Kervyn[1]
[1]Vrije Universiteit Brussel, Brussels, Belgium, [2]University of East Anglia, Norwich, United Kingdom, [3]Consejo National de Investigaciones Científicas y Técnicas, , Argentina, [4]Fundación Miguel Lillo, Tucumán, Argentina

Understanding the processes that drive landscape evolution on volcanoes is important for hazard assessment. Much work has been done on the formation and growth of volcanoes, including on their eruptions; however, long-term degradational processes remain less well studied, despite the fact that these processes often induce catastrophic events, including landslides, flank collapses, and lahars. Degradation alters the shape of volcanoes, leaving long-lasting signatures on their morphology. Analyzing the shapes of volcanic edifices thus can be used to interpret the erosional patterns and degradational evolution, and understand the processes that sculpt them.

The Philippines has many volcanoes at different evolutionary stages, which, taken as a whole, provide a snapshot of the whole life cycle of a volcano. We apply quantitative analysis using the DrainageVolc algorithm to 30-m resolution Shuttle Radar Topography Mission digital elevation models of ~180 volcanoes in the Philippines to generate quantitative descriptions of the drainage basins on each edifice. The results of these analyses are compiled and combined with a previously published database of volcano morphometry produced using MorVolc. This allows us to characterise the interactions between the morphometry of the edifices and the shapes of their drainage basins, and investigate the erosional processes that occur on tropical island arc volcanoes and how these shape volcanic landscapes. As volcanoes evolve, large basins develop that disrupt the symmetrical, radial arrangement of basins. This provides new insights into the degradation processes that occur during and after the development of volcanoes, offering new methods for reconstructing volcano histories and aiding hazard assessment in volcanic regions.

1116

The 1.03 Ma Yura Tuff: preliminary stratigraphy of the most recent ignimbrite of Arequipa, Peru

señorita Carla Jenifer Palacios Nuñez[1], Magister Nélida Victoria Manrique Llerena[1], Magister Rigoberto Aguilar Contreras[1,2], Bachiller David Bheenic Arteaga Utani[1]
[1]Observatorio Vulcanológico del INGEMMET, AREQUIPA, Peru, [2]Université Clermont Auvergne, Laboratoire Magmas et Volcans UMR 6524 CNRS, OPGC, IRD, Campus Universitaire des Cézeaux, Clermont - Ferrand, France

Yura Tuff outcrops in the southwest of Baquetane Hill, covering much of the valley between Nocarane edifice (Chachani Volcanic Complex edifice) to the east and Yura Group and Tacaza Group scarps to the west. The present work describes tephro - stratigraphically the exposed deposits of the Yura Tuff focused on distinguishing the units that make them up, since despite the studies carried out on the Neogene and Quaternary ignimbrites, including the Yura Tuff, they have not been characterized or differentiated its units yet, being essential for the eruptive and emplacement mechanism. Yura Tuff is the youngest ignimbrite in Arequipa, it covers an approximate area of 197 km2 with a length of 34 km. Based on its macroscopic characteristics (stratigraphy and petrology) of the deposits and the degree of compaction of the ignimbrite (nonwelded). It is possible to suggest that the Yuta Tuff is made up of at least 5 levels of pyroclastic flow, some of them with pumice accumulation lenses, two pyroclastic surges and a pyroclastic fall deposit. Each level presents similar petrographic characteristics in the juvenile fragments (pumice with a fibrous texture) and lithic fragments (black, dark gray, reddish and banded). On the other hand, according to the geological mapping where the spatial distribution of Yura Tuff is observed, it is inferred that its emission source is located under Baquetane Hill. Also, the stratigraphic position of the deposits indicates that Yura Tuff is older than the Baquetane Hill block lava flow deposits.

Keywords: Ignimbrite, Yura Tuff, Baquetane Hill

1247

Distinguishing the cause of diffusive water loss from melt inclusions using hydrogen isotopes

Ayla Pamukcu[1], Glenn Gaetani[2]
[1]Stanford University, Stanford , United States, [2]Woods Hole Oceanographic Institution, Woods Hole, United States

Melt inclusion (MI) suites that display lower water and/or higher CO_2 contents than expected from degassing are common. Experiments have also elucidated that changes in host melt water concentration can drive diffusive exchange of water with MIs in some mineral hosts. Two frequently invoked explanations for unexpected MI volatile contents are CO_2 fluxing and magma ascent, both of which can induce diffusive water loss. Distinguishing between these mechanisms from volatile concentrations alone is not possible; however, diffusive water loss can induce hydrogen isotope fractionation. It is thus conceivable that differences in the timescale and evolutionary path of water in the host melt caused by each of these processes could produce differences in the hydrogen isotope record of MIs.

We compare the effect of water loss induced by ascent and fluxing on hydrogen isotope fractionation using a 1D diffusive equilibration model, which includes the formation of a CO_2-rich vapor bubble with water loss. To inform and interpret the model, we utilize volatile, hydrogen isotope, and major element compositions from a suite of natural olivine-hosted MIs that display hydrogen isotope fractionation consistent with diffusive water loss. For ascent models, the external melt evolves along a degassing path starting at an initial pressure determined from the maximum measured water and reconstructed CO_2 (glass CO_2 + vapor bubble CO_2) of the MIs. For fluxing models, the external melt follows paths estimated from isobaric, isenthalpic ENKI models that simulate CO_2 fluxing. For the ENKI models we use the major element and maximum measured MI water content with variable CO_2 contents within the range measured from reconstructed MIs.

Initial results indicate that MI isotope equilibration after fluxing occurs in days to weeks, so fractionation is unlikely to be preserved. In contrast, magma ascent occurs over shorter timescales and is thus likely to preserve fractionation.

314

Initiating Volcanic Hazards Communication and Education in Dormant Volcano-Rich Regions - A Case Study in Southwestern British Columbia, Canada

Ms Yu Yen Pan[1], Dr Glyn Williams- Jones[1], Dr Melanie Kelman[2], Dr Eileen van der Flier-Keller[1]
[1]Department of Earth Sciences, Simon Fraser University, Burnaby, Canada, [2]Geological Survey of Canada, Vancouver, Canada

British Columbia, Canada contains 26 dormant Quaternary volcanic fields and complexes, however, studies on these volcanoes are limited and there is no dedicated monitoring. Additionally, without living memory of eruptions, many residents have a false perception that volcanic risk in Canada is minimal to negligible.

This research, part of the "Volcano Risk Reduction in Canada" project, aims to understand how to increase community resilience to volcanic hazards in a long-dormant volcanic region. The study takes place in the Squamish-Lillooet Regional District (SLRD) in southwestern BC, where the two highest threat Canadian volcanoes: Mount Meager and Nch'kay (Mount Garibaldi), are located. Preliminary interviews were conducted with stakeholders in the SLRD to understand their perceptions of and concerns about surrounding volcanic hazards. Three main findings were identified: (1) many land use planning and emergency management agencies are aware of and have a fair understanding of volcanic hazards; (2) although there is no specific emergency plan for volcanic hazards, each community has a standardized emergency response procedure that can be modified; and (3) although volcanic hazards are not currently their priority, stakeholder agencies are still interested in receiving more information, particularly about "probability of eruption", "impacted area and consequences", "reasonable protective action", and "timeframe of an event".

Since the SLRD is inhabited by diverse communities (urban, rural, remote, and indigenous), the risk perception and communication obstacles vary from place to place. As a result, our next step is to engage with the public and implement participatory approaches (e.g., volcanic eruption scenario activity) to identify knowledge gaps between experts and the public and understand how to appropriately develop and support volcanic risk management and educational programs. We believe that the outcome of this study will build a solid foundation and provide crucial guidance for future volcano risk reduction in Canada.

191

On the longevity of crustal silicic magma reservoir sourcing the Sar'akhor volcano, northeastern Iran

Dr Kwan-Nang Pang[1], Prof. Sun-Lin Chung[1,2], Dr. Mohammad Hossein Zarrinkoub[3], Dr. Ling Chen[4], Dr. Ben-Xun Su[5], Dr. Wei-Qiang Ji[4], Dr. Hao-Yang Lee[1], Dr. Han-Yi Chiu[1]

[1]Academia Sinica, , Taiwan, [2]Department of Geosciences, National Taiwan University, , Taiwan, [3]Department of Geology, University of Birjand, , Iran, [4]State Key Laboratory of Lithospheric Evolution, Institute of Geology and Geophysics, Chinese Academy of Sciences, , China, [5]Key Laboratory of Mineral Resources, Institute of Geology and Geophysics, Chinese Academy of Sciences, , China

The Sar'akhor volcano is situated in the Binalud Mountains, northeastern Iran where an inferred Paleozoic ophiolite belt and a Cretaceous ophiolite belt occur in close proximity. The composite volcano is dominated by lavas and pyroclastic rocks of intermediate-silicic compositions, but its formation in the Late Cenozoic has only been hinted by limited K-Ar ages. Here, we apply zircon U-Pb geochronology to samples from different sites of the volcano, indicating four stages of formation at ~13 Ma, ~10 Ma, ~7−8 Ma and ~2−3 Ma. The samples contain abundant inherited zircon of Neoproterozoic ages, consistent with derivation from Cadomian basement suggested to exist beneath most Iranian terranes. The samples have the following whole-rock geochemical features in common: (i) intermediate SiO2 (63−71 wt.%), (ii) negative Nb-Ta-Ti anomalies in extended trace element patterns, (iii) relatively high Sr/Y (24−108) and modest MREE/HREE fractionation (e.g., Dy/Yb = 1.7−2.1), and (iv) depleted mantle-like Sr-Nd isotopes (initial $^{87}Sr/^{86}Sr$ = 0.7040 to 0.7045, εNd = −0.3 to +3.1). These features are consistent with an amphibole-bearing zone of melting, assimilation, storage and homogenization (MASH) in the deep crust of the Iranian basement. Although the intermediate-silicic volcanic rocks are associated with minor basaltic lavas, the latter lack age data to support the two are temporally related. Thus, models involving fractionation of such basaltic lavas to form intermediate-silicic magmas remain contentious. Our results indicate that the magmatic system feeding the Sar'akhor volcano was long-lived (>10 Myr), likely developed in a crustal weak zone because of earlier Tethyan ocean closure.

192

Late Cenozoic OIB-type basalts, Thailand: a continental analog of petit-spot volcanism?

Ms. Ya-Jung Hsu[1,2], Dr Kwan-Nang Pang[1], Dr. Liekun Yang[3], Dr. Fei Wang[3], Dr. Phisit Limtrakun[4], Dr. Weerapan Srichan[4], Dr. Masatoshi Sone[5], Dr. Sandra M Barr[6], Dr. Yang Sun[7], Dr. Sun-Lin Chung[1,2], Dr. Hao-Yang Lee[1]
[1]Academia Sinica, Taipei, Taiwan, [2]Department of Geosciences, National Taiwan University, , Taiwan, [3]State Key Laboratory of Lithospheric Evolution, Institute of Geology and Geophysics, Chinese Academy of Sciences, , China, [4]Department of Geological Sciences, Chiang Mai University, , Thailand, [5]Department of Geology, University of Malaya, , Malaysia, [6]Department of Earth and Environmental Science, Acadia University, , Canada, [7]Department of Earth and Space Sciences, Southern University of Science and Technology, , China

The southeast Asian volcanic province refers to outpourings of Miocene-Quaternary basaltic lavas in scattered and diffused regions of the Indochinese Peninsula. Eruptions in southern Vietnam, Cambodia and southern Laos appear to be of larger extent than those in Thailand, but the underlying causes remain poorly known. In an attempt to address this issue, we analyze a set of lavas from different areas of Thailand for major and trace element compositions, Sr-Nd-Pb isotopic compositions and, for representative samples, $^{40}Ar/^{39}Ar$ dating. The $^{40}Ar/^{39}Ar$ age data confirm an earlier view that volcanism did not follow any systematic spatial-temporal patterns. The rocks are mainly ne-normative alkali olivine basalt and hy-normative olivine tholeiite, both of which display OIB-like geochemical signature. The lack of residual amphibole signature (e.g., low Rb/Ba and K/La) among the basalts indicates that input from metasomatized lithospheric mantle was immaterial. The Sr-Nd-Pb isotopic variations reflect largely mantle source heterogeneity with minor or negligible crustal contamination. Both types of basalts have variable Yb concentrations that are apparently location-specific; those occurring over the Khorat plateau, eastern Thailand mostly have low Yb concentrations (<1.5 ppm) relative to those elsewhere in the country, probably reflecting a greater extent of garnet fractionation. A carbonated mantle source involving both peridotite and pyroxenite explains most geochemical variations, including relatively high Zr/Hf and negative Zr-Hf anomalies in extended trace element patterns. Based on the above results, we suggest that Late Cenozoic volcanism in Thailand, and probably in the entire southeast Asian volcanic province, operated in a fashion analogous to petit-spot volcanoes. If that is correct, then the volcanic fields should mark areas of variable degrees of lithospheric flexure and extension. While the hypothesis is to be tested in future work, it generally agrees with the occurrence of widespread Cenozoic rift basins surrounding the Indochina block.

977

Integrating responsive petrology data into monitoring, forecasting, and community planning: Lessons and inspiration from the 2021 Tajogaite eruption, Canary Islands

Dr Matthew Pankhurst[1,2], Dr Katy Chamberlain[3], Dr Olivia Barbee[4], Dr James Hickey[5], Prof Jane Scarrow[6], Prof Alan Butcher[7], Prof Luca Caricchi[8], Dr Marc-Antoinne Longpre[9], Dr Nemesio Pérez[1,2]

[1]Instituto Volcanológico de Canarias (INVOLCAN), San Cristóbal de La Laguna 38320, Spain, [2]Institute of Technology and Renewable Energy (ITER), Granadilla de Abona 38600, Spain, [3]School of Health & Life Sciences, Centuria Building, Teesside University, Tees Valley, TS1 3BX, UK, [4]Geology Department, Whitman College, 345 Boyer Ave, Walla Walla, 99362, USA, [5]Department of Earth and Environmental Sciences, University of Exeter, Penryn Campus, TR10 9FE, UK, [6]Department of Mineralogy and Petrology, University of Granada, Campus Fuentenueva, Granada 18002, Spain, [7]Geological Survey of Finland GTK, PO Box 96, 02151 Espoo, Finland, [8]University of Geneva, rue des Maraîchers 13, Geneva CH-1205, Switzerland, [9]Queens College, City University of New York, Queens, NY, USA

Petrology is a window to understanding dynamic magmatic processes in detail and the key to connecting evidence from past eruptions to the management of those in the present and future. The potential value of petrology to volcano monitors and decision-makers has increased in recent decades thanks to both scientific progress and technological development. Realizing this value in the next decade will likely include: 1) referral to detailed case studies that demonstrate both causative connection and complementary insight between petrological and “traditional” monitoring data: “what is the scientific significance?”; 2) multidisciplinary discussion of best petrological practice: “what specific signals do we assign significance to in practice?” and 3) increased amounts of petrological work at observatories: “significant programs can be supported if the economic case is convincing”.

Petrological data management that is open, and interfaces in a useful way with other types of data, will support each of these points. There remain, however, several challenges to address as a community before an ideal petrology data management protocol can be realized. In this contribution we will reflect on the experience of responsive petrology that was carried out during the 2021 Tajogaite eruption of the Cumbre Vieja system, La Palma, Canary Islands, from technical, institutional, and inter-institutional/community perspectives. Inspirations as to how the challenges can be addressed will be discussed. These include a vision for responsive petrology mobile laboratories, provision of centralized sample libraries, management of integrated petrological databases, consideration of integrating petrological results with traditional monitoring signals, and suggestions for leveraging inter-sector funding for petrological programs.

994

Modeling fissure eruption localization; analogue experiments using hot wax

Dr Stephen Pansino[1], Professor Ed Llewellin[1]
[1]*Durham University, Durham, United Kingdom*

Fissure eruptions evolve with time, localizing from an elongated fissure into one or more discrete vents. Once localized, these vents can become the primary source of emitted lava, potentially constructing scoria cones and housing temporary lava lakes. A likely cause of localization is thermo-rheological feedback inside the fissure. Regions with slow ascent velocity (due to viscosity or fissure thickness) have more time for cooling, thereby increase in viscosity, and ultimately solidify. Faster regions receive more magma flux and heat supply, maintain activity, and form a vent. Vents can subsequently widen with time, due to thermal and mechanical erosion. This feedback causes initially-small perturbations in the system to grow with time, so that the final fissure geometry strongly depends on the initial conditions.

We investigate this hypothesis using scaled analogue experiments, in which we inject hot wax through a cooler, narrow slot, housed inside of an acrylic block. The acrylic conducts heat away from the slot, promoting solidification. As wax solidifies, it changes in appearance from transparent to opaque and, since acrylic is transparent, we can observe the evolution of the flow geometry. We vary the flux, the initial wax temperature, and the thickness of the slot (either uniform thickness or with a linear gradient). Localization appears to depend on the ratio of heat supply to heat loss and occurs on a time scale proportional to slot thickness. In experiments with a thickness gradient, localization is favored in the thicker region of the slot.

1020

Intraplate volcanism caused by delamination of continental lithosphere: geochemical and isotopic insight from monogenetic volcanoes on the East Antarctic craton

Kurt Panter[1], Yuyu Li[1], John Smellie[2], Jerzy Blusztajn[3], Jenna Reindel[1], Kari Odegaard[1], Michael Spicuzza[4], Stanley Hart[3]
[1]Bowling Green State University, Bowling Green, United States, [2]University of Leicester, Leicester, United Kingdom, [3]Woods Hole Oceanographic Institution, Woods Hole, United States, [4]University of Wisconsin-Madison, Madison, United States

Basalt erupted at Mount Early and Sheridan Bluff (c. 87°S, 153°W) provide a rare glimpse of mantle domains and melting conditions beneath East Antarctica and offer insight on the origins of small-volume mafic systems in intraplate continental settings worldwide. Directly beneath these volcanoes, shear wave velocity images reveal sinking lithosphere replaced by slower velocity asthenosphere at 50-80 km depth and is credited as the cause of volcanic activity [Shen et al., 2018. Geology 46, 71-74]. Here we present geochemical and isotopic evidence supporting this model. Early Miocene monogenetic activity produced alkaline (hawaiite, mugearite) lavas at Mount Early. At Sheridan Bluff, polymagmatic activity is expressed by an uninterrupted 110-m-thick sequence of lavas composed of silica-oversaturated olivine tholeiite overlain by silica-undersaturated hawaiite. All compositions are enriched in incompatible elements and have similar heavy-REE abundances but diverge with alkaline samples reaching higher concentrations for elements at increasing incompatibility (e.g., light-REE, Nb, Th). Isotopically, tholeiites have enriched Sr and Nd signatures relative to hawaiite at Sheridan Bluff but similar Pb and oxygen values. Mass balance and energy-constrained models demonstrate that neither fractional crystallization nor crustal contamination can explain the relationship between subalkaline and alkaline compositions. Their coexistence, geochemistry and isotopic signatures require a progressive ephemeral change from higher (c. 6%) to lower (c. <2%) degrees of partial melting of heterogeneous mantle (mixture of enriched and depleted sources) concurrent with decreasing reaction between melt and peridotite. We propose that initial melting within the asthenosphere occurred at a higher degree, triggered by flux from the sinking and devolatilizing lithosphere. The reaction between silica-undersaturated melts and the surrounding peridotite produced tholeiite magmas while diminished melt production and less orthopyroxene to react produced alkaline magmas. Lower melt production was concurrent with lower relative proportions of enriched to depleted materials in order to explain the change in isotopic signatures.

377

Lithospheric influence on the origins of volcanism in the southwestern Ross Sea, Antarctica

Kurt Panter[1], Adam Martin[2], Masako Tominaga[3], Philip Kyle[4], Jerzy Blusztajn[3]
[1]Bowling Green State University, Bowling Green, USA, [2]GNS Science, Dunedin, NZ, [3]Woods Hole Oceanographic Institution, Woods Hole, USA, [4]New Mexico Institute of Mining and Technology, Socorro, USA

Petrogenetic models explaining the origin of intraplate alkaline magmatism within the West Antarctic Rift System (WARS) differ on whether magmas are produced from lithospheric mantle or sub-lithospheric sources and whether melting is facilitated by 'passive' mantle flow or by active plumes. Particularly in the southwestern Ross Sea is the Erebus Volcanic Province (EVP) and the eponymous Erebus volcano, which along with volcanism comprising Ross Island is believed to be sourced by a mantle plume ('Erebus Plume'). Included in the northern EVP are other terrestrial and submarine volcanoes distributed c. 300 km oblique to and traversing across the N-S axis of the Terror Rift. Along this traverse, major-, trace-elements and radiogenic isotopes of primitive rocks display systematic variations. For example, total alkali, incompatible trace elements and ratios La/Sm, Nb/Y and Nd isotopes decrease while ratios Ba/La, Zr/Ta-Nb and Sr isotopes increase with decreasing degree east longitude from sea to coast and inland. Concurrent with geochemical variations is varying depth of the lithosphere-asthenosphere boundary (LAB) which increases from c. 60 within the rift to greater than 100 km beneath the East Antarctic craton. The topography of the LAB is favorable for craton-directed edge-driven convective flow and is a mechanism for melting. In this scenario, partial melts of peridotite within the asthenosphere beneath the coast would occur at greater depths and at lower degrees relative to melts generated oceanward. But this is opposite of what is indicated based on trace element ratios (e.g., La/Yb). Furthermore, Sr and Nd isotopic ratios show a gradational change in composition across the rift that is difficult to explain by sub-lithospheric sources. While modal (e.g., hydrous phase-bearing lithologies and eclogite) and mantle domain (e.g., HIMU, depleted and EM-types) heterogeneities are well documented in EVP samples, our findings highlight an overriding lithospheric influence on magma genesis in this region.

582

Unique Resources for the Southern Polar Volcanology Community at the Polar Rock Repository

Dr Anne Grunow[1], Dr. Erica Maletic[1], Kurt Panter
[1]Ohio State University, Polar Rock Repository, Columbus, United States

The Polar Rock Repository (PRR) is a United States National Science Foundation funded facility that provides online access to rock samples, unconsolidated deposits, terrestrial cores, and dredge samples from Antarctica and surrounding areas. More than 60,000 samples are available for research. Scientists may request samples from the website and conduct research using destructive techniques. The PRR archives supporting materials from the collector, e.g. images of the samples, annotated maps and air photos, petrographic thin sections, etc. The PRR has created a media archive (some images dating back > 60 years) that provides logistical, geological, and glaciological information.

The PRR contains ~ 5500 Cenozoic igneous rocks from Antarctica as well as samples from Southern Ocean dredges and a few samples from southern South America. The samples come from almost all Cenozoic volcanic locations in Antarctica, including many remote outcrops in West Antarctica and Peter 1st Island. Unique collections include the Erebus Volcanic Province DVDP cores 1, 2 and 3 that were drilled to a depth of 380 m, a collection of Mt. Erebus bombs and lava flows that span almost 50 years of eruptive history and tephra records from Mt. Moulton. Samples from discrete eruptive events on Deception Island plus volcanic dredges from Bransfield Strait and the Scotia Sea are in the collection. Dredge samples from the edge of the Ross Ice Shelf provide an opportunity to assess the frequency and characteristics of volcanics derived from proposed sub-glacial volcanic vents beneath the West Antarctic Ice Sheet.

Researchers may search for samples on the PRR website using multiple search criteria. Map layers (REMA, USGS topographic maps, SCAR geological map) are available to facilitate searches. Search results can be viewed as a table or thumbnail, downloaded as a spreadsheet, plotted on an interactive map and/or placed into a ‘shopping cart’ for loan requests.

1367

Insights on rift obliquity in the North Volcanic Zone in Iceland using UAV-based structural data.

Miss Elisabetta Panza[1], Dr. Joël Ruch[1]
[1]*University of Geneva, Geneva, Switzerland*

A fundamental point in volcanology research is the interaction between magma and crustal structures, expressed during volcano-tectonic events. In this study we focus on volcano-tectonic processes in the upper crust of rift systems, focusing on the role of inherited structures and rift obliquity.

The data acquisition was conducted in Iceland, which both lies on a mantle plume and is one of the two locations on Earth where a Mid-ocean Ridge is directly observable (the other being in Afar, Ethiopia). In the Icelandic active rift zone at least 15 volcano-tectonic events have been historically recorded and geodetic data indicate a ~2cm/yr opening. In the near-field, however, the opening proceeds stepwise at centuries-scale, in cycles of strain loading and release in meter-scale single events.

We performed an extensive UAV survey (~33km2) of the near-field in four areas of the active rift in the North Volcanic Zone, obtaining ~3cm/px DEMs and ~2cm/px orthomosaics. The imagery was the base for detailed structural and morphological mapping, aimed at analysing fracture orientations, sense of opening and the effect of topography on the rift segments. Focus has been put on the rift obliquity variation from North to South. While geodetic data indicate a ~N104°opening in all the examined rift segments, the overall strike of the rift structures goes from approximatively N-S in the North (Fjallagjá graben), where we observed volcanic morphologies ~10°-20° consistently oblique to the enclosing graben shoulders, to NE-SW towards the South, where the 2014-2015 Holuhraun event showed opening obliquity with a left-lateral shear component.

The observations help constraining the stress configuration and evolution during intrusions, when the orientations of rift opening and existent structures don't perfectly match.
The aim is to unveil the processes that govern magma propagation in a fractured crust at divergent plate boundaries, which exert a fundamental influence on eruptions locations.

869

Global time-size distribution of volcanic eruptions on Earth

Dr Paolo Papale[1], Prof Warner Marzocchi[2], Dr Deepak Garg[1]
[1]Istituto Nazionale di Geofisica e Vulcanologia, Pisa, Italy, [2]Università Federico II, Napoli, Italy

Understanding the global time-size distribution of volcanic eruptions on Earth is relevant for quantifying the global rates of volcanic productions, for modeling virtually any global Earth process from mantle convection to atmospheric evolution, for detecting changes in the Earth history and their relationships with other global factors such as glaciations or astronomical cycles, etc. Here we present a statistical model for the global distribution of volcanic eruptions in time and size, the latter in terms of continuous distribution of the volume of eruption discharges. Global volcanic eruptions are defined and catalogued according to global databases such as the Smithsonian GVP database (https://volcano.si.edu), and the LaMEVE database (www.bgs.ac.uk/vogripa). We show here that global volcanic eruptions from the smallest lava flows to the largest super-eruptions distribute in time according to an exponential distribution, and in size according to an initial log-normal followed by a tapered power law distribution. This allows i) the quantification of the global volcanic hazard in terms of probability of occurrence of globally impacting volcanic eruptions, ii) the quantification of the global discharge rates and their relationships with volcanic eruption sizes, iii) the evaluation of individual volcanic eruption distributions in terms of comparison with the global distribution; we report here on each of these aspects.

871

Modeling the dynamics of deep magma transfer, shallow magma chamber recharge, ground displacement, and gravity variations at volcanoes

Dr Paolo Papale[1], Dr Antonella Longo[1], Dr Deepak Garg[1], Dr Chiara Montagna[1], Dr Matteo Bagagli[1]
[1]*Istituto Nazionale di Geofisica e Vulcanologia, Pisa, Italy*

Relating deep magmatic movements to signals recorded from the surface is one major aim and challenge of volcanology, for the complex relationships between magma flow dynamics and rock elasto-dynamics, the intricate interplays between several quantities governing the processes, and the impacts on unrest interpretations and effectiveness of early warning systems. Here we report on the results from numerical simulation studies at INGV Pisa, where the multi-D, transient dynamics of magma injections at shallow crustal levels have been simulated over a spectrum of buoyancy-pressure triggers, and the associated ground displacement dynamics and gravity signals have been quantified for frequencies in the range 0.0001 – 10 Hz. The results illustrate the relative roles of buoyancy and pressure forces, and the associated deeply different dynamics, driving magmatic injections in shallow reservoirs; the occurrence of ULP (Ultra-Long-Period) ground displacements, with frequencies of order 0.01 Hz, diagnostic of magma convection at shallow levels; the decoupling between quasi-static ground displacement and gravity anomalies associated with transfer of magma from depth to shallow levels; and several other complex, often non-intuitive aspects of the plumbing system dynamics and their corresponding signals, that are being successfully compared with real signals from geophysical monitoring systems at active volcanoes.

1278

Linking surface Observables to sub-Volcanic plumbing-system:a multidisciplinary approach for Eruption forecasting at Campi Flegrei caldera (Italy).

Dr Lucia Pappalardo[1], Dr Stefano Caliro[1], Dr Anna Tramelli[1], Dr Elisa Trasatti[2]
[1]INGV sezione di Napoli Osservatorio Vesuviano, Napoli, Italia, [2]INGV sezione di Roma, Roma, Italia

The Campi Flegrei caldera (Italy) is one of the most dangerous volcanoes in Europe and is in a new phase of the unrest that has persisted intermittently for several decades. The geophysical and geochemical changes accompanying the unrest stimulated a number of scientific investigations that resulted in a remarkable production of articles over the last decade. However, large uncertainties still persist on the architecture of the caldera plumbing system and on the nature of the subsurface processes driving the current (and previous) unrest.

LOVE-CF is a 4-years project started in October 2020 and funded by INGV, with the aim of improving our ability to forecast the behavior of the caldera, through a multi-disciplinary approach based on a combination of volcanological, petrological, geochemical, seismological and geodetic observations, as well as experiments and numerical models.

We present the project objectives and methods, and show obtained preliminary results. Particularly our investigation includes:

a) the integration of structural, volcanological and petrological data from representative past eruptions with results of decompression experiments and numerical models of conduit dynamics and dyke propagation;
b) innovative geochemical, minero- petrological and seismic measurements at the crucial “Solfatara-Pisciarelli” hydrothermal site as well as geochemical characterization of submarine emissions in the area of “Secca delle Fumose” in the Gulf of Pozzuoli which has been poorly-explored so far;
c) novel multi-dimensional statistical analysis of seismic, geochemical and geophysical records collected (both on land and offshore) in the last decades and in the recent period of unrest, constrained by geological observations and advanced numerical modelling;
d) comprehensive analysis of surface deformations from historical data (since 35 BC) to modern techniques (both in-situ and remote sensing), and related modelling to disclose the active plumbing system and the relationship among the different sources of deformation throughout the decades and centuries.

1410

YOUR DATA IS IMMORTAL — YOU ARE NOT

Ms Debra Parcheta[2]
[1]Blue Marble Enterprises, Inc., Aurora, United States, [2]University of Colorado at Denver, Denver, United States of America

Imagine caring for your project data so well that a student on Mars in the year 3000 uses your work again to reliably predict geological activity. Your name and your data lived on! It was findable, accessible, interoperable and reusable and you've contributed to new advancements in your science long after your own successes.

Scientists today collect vast amounts of data for specific projects. Some professionals have tended to the digitization of the hard-won data of their heroic predecessors. But data is fading from existence as our own projects end or hard drives are replaced or excel sheets retire with their creators, never to be seen again.

We are slowly embracing open data, open software, and collaboration. New efforts have championed the standardization of professional data collection for certain disciplines. As a community, we talk of common objectives for research, discovery and analysis but do we walk the talk? Many grants require you to make a plan to store, protect and manage data well, but the effort dies with the project conclusion.

This talk focuses on what individual scientists can do to make their data immortal with practical tips on data collection standards, data rescue, meta-data, digital collaborations, data migration and your role in creating a preservation culture and the future of machine learning.

655

Eruptive fissure sequence and vigor was determined by dike propagation and reactivation processes during the Kīlauea 2018 eruption

Dr Carolyn Parcheta[1]
[1]Usgs, Hilo, United States

Basaltic fissures typically open as a multi-kilometer-long series of cracks erupting along most or all of their entire length before activity focuses at one main point. This process typically takes hours to days, however, the 2018 eruption of Kīlauea took almost a month. Initial fissuring opened downrift May 3-9, then uprift 4-km through Leilani Estates, when forward dike propagation temporarily stalled causing magma to ascend to the surface. Downrift dike propagation renewed May 10-11, likely triggering the brief pause in eruptive activity as magma moved laterally rather than ascending. New vents opened along another 3 km within Lani Puna Gardens and Halekamahina on May 12-13. Fissures 1-16 erupted sequentially instead of simultaneously. The lava was more viscous than later lavas, producing vigorous spattering instead of low lava fountains. On May 13, activity switched to textbook Hawaiian fissure fountains (< 30 m tall), accompanied by an increase in eruption rate. The next eight vents opened in a mostly uprift direction between May 14-18 after dike propagation stopped. They spanned spatial gaps between earlier fissures and some fissures erupted simultaneously. Interestingly, the 6.8-km-long fissure system never fountained along its entire length simultaneously. Instead, between May 19-27, only two-kilometer-long stretches were active at any given time, and activity slowly migrated uprift by reactivating earlier fissures as downrift fissures shut down. This reactivation pattern repeated every couple of days until activity settled at the focus point (fissure 8) for the remaining three months of the eruption. This uniquely prolonged opening of a fissure system provides insight into several volcanic processes including dike intrusion mechanisms, structure of the lower East Rift Zone, and transport processes between the middle and lower East Rift Zone.

1407

Understanding the temporal and spatial variation of magma degassing processes during the 2021 Tajogaite eruption, La Palma, from OP-FTIR spectroscopy.

Miss Ana Pardo Cofrades[1], Dr. María Asensio-Ramos[2], Prof. Mike Burton[1], Dr. José Barrancos[2,3], Dr. Alessandro La Spina[4], Dr. Patrick Allard[5], Dr. Catherine Hayer[1], Dr. Benjamin Esse[1], Dr. Pedro A. Hernández[2,3], Dr. Eleazar Padrón[2,3], Dr. Gladys V. Melián[2,3], Dr. Nemesio M. Pérez[2,3]
[1]The University Of Manchester, Manchester , United Kingdom, [2]Instituto Volcanológico de Canarias (INVOLCAN), San Cristóbal de La Laguna, Tenerife, Spain , [3]Instituto Tecnológico y de Energías Renovables (ITER), Granadilla de Abona, Tenerife, Spain, [4]Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo. Sezione di Catania., Catania, Italy, [5]Institut de Physique du Globe de Paris, Université Paris Cité, Paris, France

The 2021 Tajogaite eruption on La Palma island (Canary archipelago) lasting 85 days and 8 hours was the longest historical eruptive event on the island. It started on September 19 with lava fountains and spattering along a NW-SE opened fracture system but rapidly evolved into a cone-forming eruption, with explosive activity and lava jetting originating from summit vents while lava spattering and effusive activity (lava flows) simultaneously developed at lower flank vents.

From October 2 until the end of the eruption (mid-December) we performed nearly daily remote measurements of gas composition from different vents by using open-path Fourier transform infrared spectroscopy (OP-FTIR). Measurements were performed at a distance range of 0.6 to 5 km from the vents. Gas composition were retrieved from infrared absorption spectra of the radiation emitted by molten lava and incandescent ash. Our data set makes the 2021 Tajogaite eruption a best documented eruptive event for gas chemistry using OP-FTIR spectroscopy.

In this work, we report and discuss the main results obtained for H2O, CO2, SO2, HCl and CO during magma degassing involved in both explosive and effusing activities at the different vents. We document sharp chemical contrasts in gases from simultaneous explosive and effusive activities, a very high CO2/SO2 ratio in the main gas phase that evidence a CO2-rich alkaline magma, the influence of magma fragmentation (ash) upon the degassing extent of HCl, and the potential redox state of the 2021 erupted Tajogaite magma.

1226

Characteristics of the volcanic ash from Hunga Eruption: A tale of extreme fragmentation

Dr Joali Paredes-mariño[1], Professor James D. L. White[2], Dr. Tobias Dürig[3], Ms. Rachael Baxter[2], Professor Shane J. Cronin[1], Taaniela Kula[4], Dr. Ingrid Ukstins[1], Dr. Jie Wu[1], Dr. David Adams[1], Dr. Marco Brenna[2], Ms. Isabelle Brooks-Clarke[1]
[1]University Of Auckland, Auckland, New Zealand, [2]University of Otago, Dunedin, New Zealand, [3]University of Iceland, Reykjavik, Iceland, [4]Tonga Geological Services, Government of the Kingdom of Tonga, Nuku'alofa, Tonga

The January 2022 eruption of Hunga Volcano is likely the most explosive mafic eruption yet documented. It exhibited dynamics of ash plume expansion and atmospheric pressure waves unlike anything previously observed by satellites. It erupted crystal-poor andesitic magma (57-63 wt.% silica glass) and produced an eruptive column of at least 55 km high. Deposits were sampled from four islands across the Kingdom of Tonga within 10 days of the eruption. Textural, grainsize and morphological analyses were completed to assist local response authorities. The tephra (500-5600 µm) comprises, on average, dark pumice (43%), light pumice (21%), blocky glass (25%), banded pumice (4%), lithics (6%) and free-crystals (Pl, Cpx, Opx) (1%). Specific gravity of particles ranges from 0.4-1.0 (few and rare light pumice lapilli) to ~2.1-2.8 (ash-sized material). All inhabited islands reported ashfall, except the northern Nuia group, >300 km from the volcano, with measured thicknesses from 4 (at ~60 km distance) to less than 0.1 cm. Scanning electron images show that pumices have variable vesicularity, from dense glassy blocky particles; glassy particles with isolated and weakly deformed vesicles; and a lower percentage of microvesicular and reticular pumices. The general characteristics imply that magmatic vesiculation, as well as deformation and collapse, must have occurred prior to magma-water interaction, i.e. a primary fragmentation process. This could be a combination of rapid decompression and explosive magmatic gas release, along with highly-efficient crack-confined phreatomagmatism, accelerated by stress waves and thermal contraction rapidly increasing magma surface area for interaction. The ash is fine-grained and poorly sorted overall, with 8 wt.% finer than 10 µm and <0.05 wt.% finer than 1 µm. Variations in the mode and sorting of ash fall at different locations and angles from the vent show that there was potentially complex dispersal of ash from different phases of the 11-hour-long eruption.

1320

Where did all the ash go? 15 January 2022 Hunga Eruption.

Dr Joali Paredes-mariño[1], Professor Shane J. Cronin[1], Dr. Sung-Hyun Park[2], Dr. Jihyuk Kim[2], Dr. Kyu-Chul Yoo[2], Mr. Marcus Chaknova[3], Professor James D. L. White[4], Mr. Folauhola Latu'ila[5], Mr. Taaniela Kula[5], Dr. Ingrid Ukstins[1], Dr. Jie Wu[1], Dr. David Adams[1]

[1]University Of Auckland, Auckland, New Zealand, [2]Korean Polar Research Institute, Incheon, Republic of South Korea, [3]Department of Earth Sciences & Oregon Institute of Marine Biology-University of Oregon, Oregon, United States of America, [4]University of Otago, Dunedin, New Zealand, [5]Tonga Geological Services-Government of the Kingdom of Tonga, Nuku'alofa, Tonga

After the Hunga Volcano eruption of 15 January 2022, the ash volume estimated by on-land fall thickness appeared anomalously small for the explosive magnitude. The eruptive column from this event reached at least 55 km high. Ash dusting (<1 mm) was reported on islands as far as 200 km NE from the volcano in the Vava'u group. Ashfall in the Ha'apai group and Tongatapu Islands, ~70 km NE and SE from the volcano, respectively, did not exceed 40 mm in thicknesses. Deep-water sampling campaigns, carried out by both the Korean Polar Research Institute and the University of Washington with the Woods Hole Oceanographic Institution, shed light on deposits located up to 100 km W and S of the volcano. Gravity- and box-cores were collected at ~2000-3200 m depth, returning deposits rich in juvenile volcanic ash. At 100 km NW of Hunga, deposits reached a thickness of ~1 cm, while 40 km from the eruptive centre (location of a deep basin), deposits were a minimum of 22 cm thick. Subaerial (sa) and submarine (sm) samples were studied, and preliminary results show that both are fine-grained and poorly sorted, with 36.1 ± 4.8wt.% of fine ash (<63 µm), for sa samples, and 37.7 ± 16.6wt.% of fine ash for sm. Unusually, both sa and sm samples contain few particles of very fine range (<0.01 wt.% finer than 1 µm). In general sm samples are unimodal, and those to the W exhibit a mean size decreasing with increasing distance to the source. However, an anomalously fine-grained sm sample 32 km SSW from the volcano, points to a different emplacement mechanism compared to those to the west. Work is in progress to unravel the deposition mechanism of the sm deposits, which could be via fall and/or turbidity currents generated by PDCs entering the ocean.

951

Seismoacoustic observations of the January 2022 Hunga eruption in the southern Korean Peninsula

Dr Iseul Park[1], Dr Il-Young Che[1]
[1]*Korea Institute Of Geoscience And Mineral Resources, Daejeon, South Korea*

The January 2022 Hunga eruption in Tonga was recorded at a dense network of geophysical instruments in South Korea, ~8,500–9,000 km from the volcano. The network comprises barometric, infrasonic, and seismic stations operated by the Korea Institute of Geoscience and Mineral Resources and the Korea Meteorological Administration. The seismoacoustic observations carry information about the eruption processes and atmospheric propagation effects for the given distances.

The infrasound network used for this study consists of nine arrays. Each array comprises 4–13 elements with different apertures (0.15–10 km) and operational environments. The average inter-array spacing is ~100 km, which dense distribution facilitates the increase of detection capability for atmospheric waves. We have detected coherent infrasound signals, the first minor-arc passage of atmospheric waves, by the PMCC method. The signals lasted for ~3 hours with consistent variations of back azimuth in a frequency band of 0.01–2 Hz. The surface-guided Lamb waves are dominant prior to observation of the infrasound waves. These waves are distinctly identified at more than 300 barometers, and celerity with an average of 314 m/s tends to decrease as the distance from the volcano increases. This deceleration can be partly explained as due to a decrease in lower atmospheric temperature at the continental-ocean boundary.

Seismometers also registered ground motion and air-to-ground coupled waves. The ground waves by the initial explosion arrived with ~3.9 km/s and lasted for ~70 minutes. The coupled waves coincide with the atmospheric waves (< 0.01 Hz) and particularly have a peak frequency of ~3.7 mHz, similar to the Lamb mode.

As active volcano monitoring is still challenging in Korea, this study might be helpful in understanding seismoacoustic wave fields from significant volcanic eruptions and invigorating volcano studies using the Korean network.

952

Seismoacoustic observations at Ambae volcano, Vanuatu

Dr Iseul Park[1], Dr Arthur Jolly[2], Dr Robin Matoza[3], Prof Ben Kennedy[4], Dr Geoff Kilgour[5], Richard Johnson[5], Esline Garaebiti[6], Sandrine Cevuard[6]

[1]Volcano Research Group, Korea Institute Of Geoscience And Mineral Resources, Daejeon, South Korea, [2]U.S. Geological Survey, Hawaii Volcano Observatory, Hilo, United States, [3]Department of Earth Science and Earth Research Institute, University of California, Santa Barbara, United States, [4]School of Earth and Environment, University of Canterbury, Christchurch, New Zealand, [5]GNS Science, Wairakei Research Centre, Taupo, New Zealand, [6]Vanuatu Meteorology and Geohazards Department, Port Vila, Vanuatu

The 2017–2018 Ambae eruption in Vanuatu produced various volcanic activities which can be observed by the geophysical monitoring system. Seismoacoustic signals associated with the eruption were recorded at a temporary network around the volcano from July 2018. The local network comprises seven broadband seismic stations and four acoustic arrays, 8–18 km from the summit. The observed seismic signals mostly consist of explosion quakes in the tremor frequency band, while these in a very long period band are characterized as air-to-ground coupled waves. Based on seismic amplitude decay, seismic source locations might be estimated as an ascent to the near-surface and descent into 15 km depth during the distinct explosions. These variations are open to interpretation in the propagation of a pressure front, bubble activity, and two superimposed source locations. The infrasound arrays each having three sensors recorded eruptive pulses at relatively low frequency (< 1 Hz). These signals are coherent over all arrays at each eruption, which allows to detect previously unreported volcanic explosions based on a reverse-time-migration method. The detected coherent events may be small-scale distinct or sustained volcanic fluid emissions. Joint seismoacoutic observations at this volcano are unreleased prior to this study. Although this temporary network withdrew, I suggest improving the local monitoring system to detect seismoacoustic activity at Ambae volcano by the observed data in this study.

1139

From bubble nucleation to conduit size during Plinian eruptions

Mr Jonggil Park[1], Sahand Hajimirza[1], Professor Helge Gonnermann[1]
[1]Rice University, Houston, United States

Magma ascent during explosive volcanic eruptions is inaccessible to direct observations. The subsurface conditions and processes that result in explosive eruptions can in part be inferred from measurements made on the erupted pyroclastic material and numerical models of magma ascent. In pyroclasts, the abundance of vesicles is thought to bear a direct relation to eruptive conditions, such as decompression rates, which in turn are related to magma ascent velocities. Eruption models, in turn, facilitate the integration of observations by simulating the underlying physical processes that occur during ascent. In essence such models match pressure boundary conditions within the magma chamber and at the volcanic vent by adjusting conduit size, or magma discharge rate, or both. We present the first such model that incorporates bubble nucleation during Plinian eruptions of rhyolitic magma, capable of using the vesicle size distribution (VSD) of pyrcolasts as a new constraint on combined eruption rate, conduit size, and exit pressure at the vent. We find that VSDs from a number of different rhyolitic Sub-Plinian and Plinian eruptions can be reproduced. Our results are consistent with the following conditions: (1) bubbles nucleate heterogeneously on abundant nanolites; (2) bubble nucleation is more or less continuous at variable rates throughout magma ascent; (3) coalescence is not of primary importance; (4) conduit size becomes smaller going from chamber toward the level of fragmentation; and (5) conduit shapes may either be broad cupolas atop the chamber that narrow upward into cylindrical conduits or dikes that emanate from the chamber and gradually become more equant and conduit-like in shape toward the surface.

949

Deformation, seismicity and monitoring response preceding and during the 2022 Fagradalsfjall eruption, Iceland

Michelle Parks[1], Freysteinn Sigmundsson[2], Kristín Vogfjörd[1], Benedikt Ófeigsson[1], Ásta R Hjartardóttir[2], Vincent Drouin[1], Andrew Hooper[3], Sigrún Hreinsdóttir[4], Halldór Geirsson[2], Hildur Fridriksdóttir[1], Sara Barsotti[1], Esther Jensen[1], Páll Einarsson[2]

[1]Icelandic Meteorological Office, Reykjavík, Iceland, [2]Nordic Volcanological Center, Institute of Earth Sciences, University of Iceland, Reykjavík, Iceland, [3]COMET, School of Earth and Environment, University of Leeds, Leeds, United Kingdom, [4]GNS Science, Lower Hutt, New Zealand

Following two periods of dike intrusion in 2021, one which led to an eruption at Fagradalsfjall, Iceland, in 2021, a third dike intrusion commenced on 30 July 2022. A sudden increase in seismicity occurred in the area, with approximately 1000 automatically detected earthquakes within 12 hours. Strong earthquakes were felt over several days (largest MW 5.3). Based on activity in 2021 and experience from previous unrest (Krafla and Bárðarbunga volcanoes), the timeline and spatial distribution of seismicity suggested it was resulting from diking, together with triggered seismicity in nearby areas releasing stored tectonic stress. Continuous GNSS observations revealed outward displacements consistent with a dike intrusion. A Sentinel-1 image was acquired on Track 16, at 18:59 on 1 August 2022 and an interferogram formed with the previous image from the same orbit. Line-of-sight changes up to 16 cm were observed with the main signal consistent with a dike intrusion, confirming the prior interpretation. Geodetic modeling was undertaken on 2 August utilizing the new GNSS and InSAR data. A best-fit model indicated the top depth of the dike was shallow (median depth of 1.1 km), and magma inflow rate was high (median value of ~ 50 m^3/sec). Considering also a decline in seismicity, a warning was issued that the likelihood of a new eruption in the coming days was high. An effusive eruption started the next day (3 August) on a 375 m long fissure, with an initial measured extrusion rate of 32 m^3/s. The projected surface location of the dike (from the optimal model) was within 49 m at the northern end and 110 m at the southern end of the fissure opening. We compare the details of the activity that occurred prior to this diking and eruption to the previous events at Fagradalsfjall to improve understanding of unrest preceding eruptions.

1095

Field results from testing of the Wee-g MEMS-based gravity sensor on volcanic complexes in British Columbia, Canada.

Miss Elizabeth Passey[1], Mr Kristian Anastasiou[1], Dr Abhinav Prasad[1], Dr Karl Toland[1], Professor Giles Hammond[1], Professor Glyn Williams-Jones[2]
[1]University Of Glasgow, Glasgow, United Kingdom, [2]Simon Fraser University, Burnaby, Canada

Gravity surveys are an important geophysical method for understanding subsurface geological features in a wide variety of applications including volcanology. Currently, the high cost and ability to safely transport sensitive gravity sensors are significant limitations to deployments in arduous volcanic terrain. "Wee-g" is a new MEMS-based (Micro-Electromechanical System) sensor which offers a low-cost, robust, and highly portable solution in comparison to the industry gold standard. The Wee-g field prototype has been used for small scale surveys within various regions of the United Kingdom by both academic and industrial end users. More recently, a small-scale gravimeter array has been installed on Mount Etna, Italy. In summer 2022, the Wee-g was deployed in the Garibaldi Volcanic Belt of southwestern British Columbia (Canada), specifically on the volcanic complexes of Mount Cayley, Mount Garibaldi and Mount Meager. These glacier-clad volcanic complexes offer an excellent field laboratory in which to test the Wee-g to characterise its performance in challenging, yet accessible, mountainous environments where station altitudes and temperatures can vary greatly. Comparison with industry standard gravimeters is important to assess the performance and robustness of a prototype gravimeter's control system (temperature, tilt, pressure, power consumption) to ensure optimal performance. This study shows that how the Wee-g performance compares to LaCoste & Romberg gravimeters in various challenging environmental conditions via foot, vehicle and helicopter surveys. This work is part of ongoing spatial and temporal gravity surveys in support of volcanological and geothermal energy studies in Western Canada.

627

Constructing geologically-based fluid flow models of hydrothermal systems at the Okataina Volcanic Centre and White Island Volcano, New Zealand

Dr Sophie Pearson-Grant[1], Dr Edward Bertrand[1], Lucy Carson[2], Dr Craig Miller[2]
[1]GNS Science, Lower Hutt, New Zealand, [2]GNS Science, Wairakei, New Zealand

Hydrothermal systems are the source of surface features (e.g. geysers), phreatic volcanic eruptions, and geothermal energy for electricity generation and direct use. In the Taupo Volcanic Zone, pathways of hydrothermal fluid circulation from the underlying heat source to the surface can be complex and difficult to image in detail. However, numerical models of heat and fluid flow allow us to individually explore factors that influence these pathways and investigate what controls the near-surface locations of hydrothermal systems. Here, we use two examples from New Zealand: the Okataina Volcanic Centre (OVC) and White Island (Whakaari) Volcano.

The OVC is New Zealand's most recently active caldera complex and hosts numerous hydrothermal systems and surface features predominantly around its margins. Successive caldera collapses over the past ~ 550 kyr have created a complex crustal structure through which fluid migrates to supply heat to the hydrothermal systems. We have created a suite of TOUGH2 models from Leapfrog Geothermal geological models and compared resulting temperatures with shallow DC resistivity soundings and with MT resistivity models at 3 km depth. Model results suggest that localised basal heat sources (as inferred by MT models) are the largest influence on the locations of geothermal upflow. Near the surface, topographic loading effects also have a strong influence. Models are relatively insensitive to structural permeability variations, suggesting that deep fluid circulation is dominated by flow in fracture networks rather than individual large-scale fault structures.

At White Island, an active andesite cone volcano prone to phreatic eruptions, geological models of the shallow hydrothermal system in the crater floor are used to constrain numerical models. These models aim to explore how fluid pathways change prior to phreatic eruptions, providing valuable insight into the processes that lead to phreatic eruptions.

1438

Analysis of surface dynamics changes without evident precursors: The case of (2016 – present) Nevados de Chillán Volcanic Complex eruption

Miss Gabriela Pedreros[1], Miss María Angélica Contreras[1], Mr Juan Jose San Martin[1], Miss Loreto Córdova[1], Miss Claudia Bucarey[1], Miss Maira Figueroa[1]
[1]*Southern Andean Volcano Observatory, National Geology and Mining Service, Temuco, Chile*

In January 2016, NChVC started a new eruptive cycle which has been thoroughly monitored through a robust and multiparametric monitoring network showing explosive, effusive, mixed and resting phases of different magnitude. Columns up to 3.5 km high with a high pyroclastic content, 8 lava flows and 4 domes ranging in composition from 63.72% to 67.34% SiO_2; and pyroclastic density currents reaching 1.9 km long have been observed. Although this activity has posed a low hazard level, volcanic monitoring has been challenged by the high variability of processes and the overlap of possible precursors with ongoing activity. In this way, the level of effusive and explosive activity has been parameterized for a period of 6 years. We identified 4 turning points and have detected the major eruptive events. These turning points were preceded by changes in SO_2 content; however, they show an oscillating behavior of emission rates during the different extrusive periods. Two occurred during uplift cycles, and the others were associated with transitions from inflation to subsidence and a variation of seismic energy. The ascent of some lavas did not generate unequivocal changes in the instrumental parameters until they were observed on surface. Hence, to understand the origin of the ascent of Sebastian (2008), L1 (2019) and L5 (2020) lava flows as well as Domo 1 (2017), their dynamic on surface and their link to instrumental data and volumetric variations, a reconstruction of their magmatic differentiation is carried out using MELTs. Which period of instrumental anomaly does each effusive body corresponds to? How long did it take for them to show up? Our work shows the advantages of complementing instrumental data with magma ascent modelling, in order to improve the procedures that aim to detect volcanic activity lacking evident instrumental signals.

434

Experimental insight into the generation of pore fluid pressure in pyroclastic density currents resulting from eruptive fountain collapse

Mr Baptiste Penlou[1], Olivier Roche[1], Siet van den Wildenberg[1,2]
[1]Laboratoire Magmas et Volcans, University Clermont Auvergne, Clermont-Ferrand, France, [2]Laboratoire de Physique de Clermont, University Clermont Auvergne, Clermont-Ferrand, France

Pyroclastic density currents formed through collapse of eruptive fountains commonly have long runout distances. A possible cause of this high flow mobility is elevated gas pore pressure, which may have various origins. We investigated experimentally the generation of pore pressure at the impact zone of eruptive fountains where pyroclastic density currents emergence from compaction of free falling gas-particle mixtures. Pyroclastic fountain collapse was simulated by releasing nearly monodisperse glass beads of mean sizes of 29-240 µm from a hopper at height of 3.5 m above a 5.5 m-long horizontal channel. In the impact zone, we used two pressure transducers and a force sensor to measure the pore fluid pressure and the impact force, respectively. The experiments were filmed with a high-speed camera in order to study the flow kinematics. During free fall, the granular mixtures expanded and accelerated to reach particle concentrations of 5-10 vol.% and velocities of 6.6-7.8 m/s before they impacted the base of the channel. Upon impact, the particles accumulated to form concentrated granular flows with particle concentrations of 45-50 vol.% and high pore fluid pressures, which indicated full bed weight support for particle sizes smaller than 180 µm. Both the degree of fluidization in the impact zone and the flow runout distance increased as we decreased the particle size and hence the hydraulic permeability of the concentrated granular mixtures. Our results suggest that pore fluid pressure in concentrated pyroclastic density currents can be generated at the impact zone of collapsing fountains and that small particle size conferring low permeability and long pore pressure diffusion timescale is one of the causes of long flow runout distances.

435

Enhanced and hindered particle settling in experimental turbulent gas-particle suspensions and volcanological implications

Mr Baptiste Penlou[1], Siet van den Wildenberg[1,2], Olivier Roche[1], Michael Manga[3]
[1]Laboratoire Magmas et Volcans, University Clermont Auvergne, Clermont-Ferrand, France, [2]Laboratoire de Physique de Clermont, University Clermont Auvergne, Clermont-Ferrand, France, [3]Department of Earth and Planetary Science, University of California, Berkeley, USA

The dynamics of dilute turbulent gas-particles mixtures generated by volcanic eruptions depends to a large extent on particle concentration, which in turn depends particle settling velocity. We investigated turbulent air-particle suspensions in a 1 m-long and 4 cm-diameter vertical pipe by pouring glass beads of diameter 78 µm or 467 µm into the pipe and then injecting an air flow through a basal porous plate to create suspensions. We increased gradually the air flow velocity to match the particle fall velocity and obtain turbulent but quasi-static suspensions. The latter had bulk particle concentrations between 0.1 and 3 vol.% and were optically opaque. We measured local particle concentrations in the mixtures by acoustic probing and local air pressure measurements and found that these independent techniques yield similar results. We observed that in suspensions of small particles (78 µm) the settling velocity increased with the local particle concentration. This was likely due to the formation of particle clusters, which enhanced particle settling. In contrast, in suspensions of larger particles (467 µm), the settling velocity decreased with increasing particle concentration. Although in this case particle clusters were also present, the dependence of the settling velocity on the particle concentration is captured by a hindered settling model. These results suggest an interplay between hindered settling and cluster formation, which in our experiments decrease and increase particle settling speeds by a few tens of percent relative to the terminal velocity of single particles. Our study has implications for volcanic plumes and pyroclastic density currents. It suggests that clustering and related enhanced or hindered particle settling velocity should be considered in models and that drag law corrections are needed for reliable predictions.

1384

The 2021 Tajogaite eruption at La Palma (Canary Islands): an overview of the geochemical monitoring program

Dr Nemesio M. Pérez[1,2], Dr. Pedro Hernández[1,2], Dr. Gladys Melián[1,2], Dr. Eleazar Padrón[1,2], Dr. María Asensio-Ramos[1], Dr. José Barrancos[1,2], Dr. Germán Padilla[1,2], Dr. Fátima Rodríguez[1], Dr. Luca D'Auria[1,2], Ms. Cecilia Amonte[1,2], Dr. Mar Alonso[1], Ms. Alba Martín-Lorenzo[1,2], Mr. David Calvo[1], Ms. Claudia Rodríguez[1,2], Mr. William Hernández[1], Dr. Beverley Coldwell[1,2], Dr. Matthew Pankhurst[1,2], Tajogaite International Collaborative Research TEAM[3]

[1]Instituto Volcanológico de Canarias (INVOLCAN), San Cristóbal de La Laguna, Spain, [2]Instituto Tecnológico y de Energías Renovables (ITER), Granadilla de Abona, España, [3]Manchester Univ, Palermo Univ., UCL, INGV, IPGP, Azores Univ., New Mexico Univ., Durham Univ., Tokyo Univ., Tokyo Institute of Technology, ,

Cumbre Vieja is the most active volcano in the Canary Islands. The establishment of a geochemical monitoring program by our research group for the volcanic surveillance of Cumbre Vieja started in 1997. This program was mainly focused on diffuse degassing monitoring because of the absence of visible volcanic degassing manifestations (fumaroles, plumes, etc.) as well as other obvious geothermal features at Cumbre Vieja up to the 2021 eruption.

The INVOLCAN's soil degassing monitoring at Cumbre Vieja is carried out by means of a geochemical permanent network and regular geochemical surveys at Cumbre Vieja. Soil degassing anomalies have been observed and some of them years before the Tajogaite eruption. Regular helium-3 emission monitoring has been carried out since 1991 and provided an early warning of the 2021 Tajogaite eruption. Regular sampling of groundwater for chemical and isotopic analysis were also in perfoemed.

Since the 2021 eruption onset, INVOLCAN performed daily observations of SO2 emissions using a miniDOAS in traverse mode, on terrestrial (car), sea (ship) and air (helicopter) mobile position recording relatively high SO2 emissions (> 50.000 t/d). Static scanners and satellite instruments were used also to monitoring the SO2 emission; a task lead by Manchester University. Additional plume geochemical monitoring was carried out using OP-FTIR spectrometers and UAV, helicopter and ground-base MultiGas units to characterize the chemical composition of the plume degassing in collaboration with scientists from Manchester Univ., Palermo Univ., UCL, INGV, IPGP and Azores Univ. Carbon isotope analysis of the CO2 gas plume was also undertaken in collaboration with New Mexico Univ. Analysis of pristine ash leachates has been also performed in collaboration with Durham Univ. and Tokyo Institute of Technology since provides important information on the eruption processes was also performed.

The results have been tremendously useful to understand the recent magmatic reactivation of Cumbre Vieja volcano.

1396

Gas hazard assessment at inhabited areas of La Palma (Canary Islands) related to the 2021 Tajogaite eruption

Dr. Pedro Hernández[1,2], Dr Nemesio M. Pérez[1], Dr. Eleazar Padrón[1,2], Dr. Gladys Melián[1,2], Dr. Germán Padilla[1,2], Dr. María Asensio-Ramos[1,2], Mr. Jon Vilches-Sarasate[4], Dr. José Barrancos[1,2], Dr. José Pacheco[3], Ms. Daniel Di Nardo[1]

[1]Instituto Volcanológico de Canarias (INVOLCAN), San Cristóbal de La Laguna, Spain, [2]Instituto Tecnológico y de Energías Renovables (ITER), Granadilla de Abona, Spain, [3]Instituto de Investigação em Vulcanologia e Avaliação de Riscos (IVAR), Ponta Delgada, Portugal, [4]Viceconsejería de Lucha contra el Cambio Climático y Transición Ecológica (GOBCAN), Las Palmas de Gran Canaria, Spain

The 2021 Tajogaite eruption at Cumbre Vieja (La Palma, Canary Islands) has been considered the most important eruption in Europe during the last 75 years. Some urban areas, such as La Bombilla and Puerto Naos, were not directly damaged by lava flows but are affected by strong carbon dioxide (CO2) emissions. In order to assess this gas hazard, several geochemical monitoring tools are being applied. A diffuse degassing survey is performed weekly at La Bombilla (0.033 km2), and the average diffuse CO2 degassing per square kilometer yields a remarkable value of ~ 500 (t·km-2·d-1). The daily average concentration of CO2 in the outdoor ambient air recorded by monitoring stations located in La Bombilla shows a wide range of concentration values from <5.000 ppm to 100.000 ppm. In the case of Puerto Naos, the daily average concentration of CO2 in the outdoor ambient air recorded also shows a wide range of values from <5.000 ppm to 10.000 ppm, with values exceeding 45.000 ppm in some of the monitoring stations. The daily average concentration of CO2 in indoor ambient air (ground floors = street level) recorded at Puerto Naos also shows a wide range of values from <5.000 ppm to 200.000 ppm. In the case of basements, these average values must be higher than those registered. Most of the stations that monitor the content of CO2 in ambient air, both outside and inside, reflect that the daily averages of CO2 concentrations from fifteen-minute data during the night tend to be higher than during the day, generating that the danger associated with these anomalous CO2 concentrations is greater at night than during the day. The results obtained from the Alkaline Trap Network during the last four months have helped delimit those areas (ground floors) most affected by anomalous CO2 emissions in Puerto Naos.

632

Constraining volcano-seismic source locations using the amplitude ratio and delay time information from unnormalized cross-correlation functions

Dr Theodorus Permana[1], Dr Hiroshi Aoyama[1]
[1]Institute of Seismology and Volcanology, Faculty of Science, Hokkaido University, Sapporo, Japan

Seismic activity at volcanoes consists of different types of volcanic earthquakes and tremors characterized by high variations in amplitude, duration, and frequency contents. However, accurate localization of their sources is still a challenge in volcano monitoring. Well-known methods to locate seismic sources rely on the onset time of seismic phases, which is often difficult to observe, especially during heightened seismic activity that may lead to eruptions. Among the alternative location methods that avoid reading the onset times, we consider two classes of methods based on the information they extracted from the seismic data: the “amplitude method” that measures the seismic amplitude level regardless of the seismic phases and assumes a simple spatial amplitude decay model, and the “cross-correlation method” that uses cross-correlation to measure phase similarity regardless of the amplitudes and extracts the delay time at the maximum correlation. We explore the idea to combine both classes of methods, providing more constraints to the source locations, and study the changes in location accuracy as compared to using each method individually. We employ the unnormalized cross-correlation, where we use seismic data at two pairs of observation stations to extract the amplitude ratio and delay time information. We develop a method that integrates both information to find an optimum source location that minimizes the residual between the theoretical and observed values, assuming the isotropic radiation of seismic waves due to seismic scattering. We present the application at Tokachidake volcano, Japan, using volcanic earthquakes with known hypocenters and an episode of volcanic earthquakes and tremors accompanied by tilt changes, indicating the movement of volcanic fluids driven by the hydrothermal system beneath the volcano. The new method reveals an improvement in location accuracy and observes changes in the source locations related to volcanic fluid movements, revealing the potential of the method for volcano monitoring.

1125

Decoding pyroclastic density current infrasound in the field and lab

Ms Anna Perttu[1], Dr Gert Lube[1], Dr Ermanno Brosch[1], Dr Mie Ichihara[2]
[1]Massey University, Palmerston North, New Zealand, [2]Earthquake Research Institute, University of Tokyo, Tokyo, Japan

While infrasound (sound below human hearing < 20Hz) has been established to identify and monitor volcanic eruptions, much of the focus has been on the explosive signals and signals related eruption columns. This project is aimed at another phenomenon during eruptions: pyroclastic density currents (PDC). PDCs are among the deadliest, and most destructive aspects of volcanic eruptions, and thus also difficult to study in situ. Infrasound offers a remote tool for studying these phenomena in the field. This project combines a database of known recorded events in the New Zealand catalog, events published in the literature, with large scale analog experiments. While there have been several high profile studies detailing observations of infrasonic recordings of PDCs, they remain limited within the literature. This project presents preliminary results from the literature, field, and lab experiments to characterize the acoustic signature of PDCs, and understand their generation and relationship to physical parameters of the flows.

1132

Remote characterization of the 12 January 2020 eruption of Taal Volcano, Philippines, using seismo-acoustic, volcanic lightning, and satellite observations

Ms Anna Perttu[1], Jelle Assink[2], Kathleen McKee[3], Alexa Van Eaton[4], Chris Vagasky[5], Silvio De Angelis[6], Corentin Caudron[7], Brian Perttu[1], Janine Krippner[8], Benoit Taisne[9], Gert Lube[1]

[1]Massey University, Palmerston North, New Zealand, [2]R&D Seismology and Acoustics Department, Royal Netherlands Meteorological Institute (KNMI), De Bilt, Netherlands, [3]NASA Goddard Space Flight Center, Greenbelt, USA, [4]U.S. Geological Survey, Cascades Volcano Observatory, Vancouver, USA, [5]Vaisala Inc, Louisville, USA, [6]University of Liverpool, Liverpool, UK, [7]Université Libre de Bruxelles, Bruxelles, Belgium, [8]University of Waikato, Hamilton, New Zealand, [9]Earth Observatory of Singapore, Nanyang Technological University, Singapore, Singapore

On 12 January 2020 an eruption began on the shores of the Main Crater Lake of Taal Volcano, a caldera system located about 30 km south of the major metropolitan area of Manila, Philippines. Throughout the day the eruption intensified, creating a sustained plume reaching 16–17 km altitude with prolific lightning and ashfall over a large region. The thorough reporting and response by the Philippine Institute of Volcanology and Seismology (PHIVOLCS) during the eruption provide an opportunity to study how remote monitoring may complement local observations. A key factor is that remote systems are less likely to be compromised by the eruption itself, providing a continuous, albeit lower-resolution, record of eruptive processes. We report a post-event analysis of the activity on 12 January that includes long-range data from lightning, infrasound, and seismic arrays up to several thousands of kilometers away. In particular, this study takes advantage of both the infrasound and seismic components of the International Monitoring System (IMS) network, which is a worldwide network associated with the Comprehensive Nuclear Test-Ban Treaty. Using these systems, we infer a major shift in eruption behavior during the night (around 12:00 UTC on 12 January) that may be consistent with the observed shift from an intense, ash-rich plume to lava fountaining reported by PHIVOLCS several hours later. We speculate that the shift to higher frequency infrasound, decreasing lightning rates, and pulsatory behavior of the plume in Himawari-8 satellite images may represent a shift from intense phreatomagmatic to more magmatic activity due to drying of the crater lake or tephra buildup that blocked water access to the vent. Overall, these remote observations suggest ways to add detail to an eruptive timeline in near-real time. We consider future opportunities to support and augment local monitoring data during ongoing volcanic eruptions in other regions.

917

Advances in lahar hazard analysis: a case study from Mt. Ruapehu

Dr Stuart Mead[1], Professor Jonathan Procter[1], Professor Mark Bebbington[1], Mr Brian Perttu[1]
[1]*Massey University, Palmerston North, New Zealand*

Lahars, rapidly flowing mixtures of water and volcanic debris, are a frequent and destructive hazard at Mt. Ruapehu. Mt. Ruapehu's ring plain preserves a record of lahar formations spanning 22,600 years ago to the present day, with the youngest Onetapu Formation encompassing events from 2000 years to present day (roughly coeval with the present Crater Lake). The Onetapu Formation includes deposits that represent events showing volume, stage, and discharge measures that are orders of magnitude greater than the laharic events observed in the last 160 years.

To analyse the associated hazards, events represented in the Onetapu Formation have been grouped into 36 lahar sequences based on key lithological, textural, and grainsize changes. The volume, stage (at 40km from source) and four main triggering mechanisms: flank collapse, Crater Lake collapses, meltwater/rainfall remobilizing debris, and phreatic tephras mobilizing ice/meltwater have also been identified. This record was ordered and characterized by volume allowing for simple statistical analysis to determine the annual return period of different volumes for the first time. Lahar sequences with volumes >0.5x106 m3 have a 100-year annual recurrence interval, and lahar sequences with volumes >103 m3 have a 6.67-year annual recurrence interval, however changes to lahar typology would affect probabilities and require updated models. These data allow, for the first time, quantitative hazard determination for risk analysis from lahars at Mt. Ruapehu.

Events over the last 160 years provide a more robust and more detailed record of events due to direct observations allowing for the identification of each lahar event during a sequence. In contrast the pre-historic events recorded in the depositional sequences over the last 2000 years are not as detailed but sedimentological units do provide insights into the ability to increase event resolution to develop more robust hazard models however new statistical models need to be applied.

589

The effects of unsteady vent conditions on lava flow propagation, morphology, and surface texture

Dr Sean Peters[1,2], Dr Amanda Clarke[2,3], Dr Erika Rader[1]
[1]University of Idaho, Moscow, United States, [2]Arizona State University, Tempe, United States, [3]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Pisa, Pisa, Italy

The emplacement of lava, a multiphase fluid, is complicated by variables both intrinsic (e.g., rheology) and extrinsic (e.g., effusion rate) to the flow. Lava flows represent a hazard to populations and infrastructure proximal to volcanoes. Knowing the emplacement conditions of lava flows is important for understanding historical eruptions on Earth as well as the surface evolution of other planets (e.g., Mars or Venus) where evidence of volcanism is extensive but historical context is nonexistent. Laboratory analog experiments allow for the observation of complex flow dynamics and phenomenology observed in active flows. Here, we utilized analog experiments to investigate how changes in flow rate (via unsteady vent conditions) impact flow propagation with respect to breakouts, inflation, and tube formation.

We performed 150 experiments using 2 different eruption rate patterns to address the following controls on lava flow emplacement: single step-wise decrease or increase of eruption rates on a flat slope (n = 120) and double step-wise decrease-increase and increase-decrease on a flat slope (n = 30). We controlled wax and ambient temperature, pulse duration, and eruption rate. Results indicate that the likelihood and magnitude of breakouts, inflation, and tubes increases with longer durations of decreasing and/or increasing eruption rates. Prolonged increases in eruption rate favor widespread marginal breakouts, surface breakouts (resurfacing), inflation, and some tube formation. Prolonged decreases in eruption rate promotes localized marginal breakouts, inflation, and tube formation. Similar observations were made during the early stages of the 2021 Fagradalsfjall eruption in Iceland. Morphologies observed in the lab were controlled by the existence, or lack of, of a coherent crust. Complex effusion rate patterns created more complex flow morphologies and surface textures not unlike those observed in nature. Post-emplacement morphologies are modified by a variety of factors (e.g., deflation), which may not preserve the finer surface textures.

1295

Primary and reworked tephra support land use reconstruction in the Sarno river plain (Campania-Italy) over the last 5000 years

Professor Paola Petrosino[1], Dr Chiara Comengna[1,2], PhD Halinka Di Lorenzo[1], Prof. Nicoletta Santangelo[1], Prof. Antonio Santo[3], Prof. Elda Russo Ermolli[1]

[1]DiSTAR - University of Napoli Federico II, Napoli, Italy, [2]DICEM, Università degli Studi della Basilicata, Matera, Italy, [3]DiCEA - University of Napoli Federico II, Napoli, Italy

A very precise age model was achieved by applying tephrochronological techniques to the primary and reworked tephra of the infilling succession of the Fossa San Vito sinkhole, a depression located at the foot of the carbonate slopes bounding the Sarno Plain towards NE. B24 borehole intercepted 45m of infilling deposits consisting in laminated lacustrine silts interbedded with primary tephra layers, reworked volcanic material and alluvial debris. The base of the succession is ^{14}C dated to ca. 5500 cal yr BP. Primary tephra were characterized by a sharp basal contact, good sorting and homogeneous lithological composition, reworked volcanic deposits mainly contained pumice fragments embedded in a sandy volcanoclastic matrix, whereas alluvial layers were made up of limestone pebbles with a minor fine component. A standard sampling methodology was set to analyse glasses of juvenile component of 12 samples from the three categories. At least 50 individual point analyses were carried out on different clasts of volcanic reworked deposits and on fragments extracted from the matrix of alluvial deposits. The results of these analyses clustered to identify different sourcing eruptions starting from Campanian Ignimbrite. On these clusters we used a “first appearance” approach, considering a terminus post quem age for the layer in which we found for the first time the juvenile fragments of a specific Campi Flegrei or Somma Vesuvius eruption. These results, integrated with those on primary tephra layers and ^{14}C dating, allowed a precise timing of the succession whose closure occurred in the Late Medieval Age. Land use data obtained through a detailed palynological investigation identify a closed environment in the basal part of the borehole. From the Greek-Roman age, anthropogenic indicators increase indicating the exploitation of the area for grazing and crop activities, whose entity can be successfully time constrained thanks to the achieved high-resolution age model.

1150

Melt extraction from a magma mush at Cordón Caulle, Chile

Mr Patrick Phelps[1], Dr. Helge M. Gonnermann[1], Ms. Heather Winslow[2], Dr. Philipp Ruprecht[2], Dr. Yang Liao[3], Dr. Francisco Delgado[4], Dr. Matthew E. Pritchard[5]

[1]Rice University, Houston, United States, [2]University of Nevada, Reno, Reno, United States, [3]Woods Hole Oceanographic Institute, Falmouth, United States, [4]Universidad de Chile, Santiago, Chile, [5]Cornell University, Ithica, United States

The temporal persistence and growth of transcrustal magmatic systems are thought to lead to elevated geotherms, which favors forming shallow bodies of high-silica rhyolite-melt by extraction from crystal mush magma bodies. We test the hypothesis that the inflation at Cordón Caulle during the past decade may be due to such a melt extraction event. Although transcrustal magma transport tends to be viewed as an upward propagating cascade of events, here we show how shallow events, such as eruptions, can dynamically affect the upper-most parts of transcrustal systems, perhaps setting in motion a downward cascade of magma transport. In 2011-12, Cordón Caulle erupted crystal poor rhyolitic magma containing crystal-rich mafic enclaves with intergranular glass of identical composition as the erupted rhyolite. This suggests the existence of a crystal-rich magma mush overlain by rhyolite melt that segregated from the mush, with enclaves representing entrained pieces of the mush. We model the mush as an elastically deformable crystal matrix with interstitial compressible rhyolite melt. The pressure decrease, from eruptive withdrawal of the rhyolite layer in 2011-12, resulted in melt extraction from the mush. Because of the rigidity of the crystal matrix, a net increase in volume occurs of the combined mush and extracted rhyolite, producing the observed uplift. We estimate a mush storativity (amount of melt released per unit drop in pressure) of 0.02±0.015, as well as lower bound estimates for the volume of the mush and overlying rhyolite of ~4 km^3 and ~2 km^3, respectively. These values are contingent upon sample-scale mush permeabilities based on porosity and grain size of the enclaves. We conduct independent validations of these estimates using micro-computed tomography (CT) imaging of the enclaves' pore structure in conjunction with pore-scale modeling of melt flow. Larger mush and rhyolite thicknesses result if field-scale permeabilities are significantly larger than sample-scale permeabilities.

814

Determining eruption ages from non-gaussian feldspar 40Ar/39Ar age distributions: insights from paleoanthropologically significant tuffs in the Turkana Basin, Kenya

Professor David Phillips[1], Dr Erin Matchan
[1]*The University of Melbourne, Parkville, Australia*

Determining silicic tuff eruption ages via 40Ar*/39Ar dating of feldspar crystals relies on the assumption that grains either crystallised immediately prior to eruption or retain negligible pre-eruptive 40Ar*. There is increasing evidence from high precision geochronology studies that feldspar populations from at least some tuffs are characterised by a spectrum of older apparent ages extending from the time of eruption. Previous studies of pumice-hosted feldspars from the Turkana Basin have assigned stratigraphic integrity to reported 40Ar/39Ar eruption ages, although uncertainties of 20–50 ka hindered finer scale resolution of ages and produced apparent gaussian age distributions. Consequently, eruption ages were calculated from arithmetic means of the most concordant values. Outlier identification involved first excluding grains with low gas yields, then using an iterative approach to exclude those ages greater than 2σ from the arithmetic mean. As per convention, young outliers were attributed to 40Ar*-loss, whereas old outliers were ascribed to extraneous 40Ar* (inherited/excess 40Ar*).

The order of magnitude improvement in analytical precision afforded by modern noble gas multi-collector mass spectrometry reveals 40Ar*/39Ar age distributions of unprecedented definition, necessitating a re-evaluation of best practise for determining tuff eruption ages. In this study, we carried out 40Ar/39Ar experiments on pumice feldspar crystals from the paleoanthropologically important KBS, Malbe, Chari and Gele tuffs in the Turkana Basin. We compared various statistical approaches to constrain tuff eruption ages: normalised median absolute deviation (nMAD), normal distribution/MSWD filters and Bayesian age estimation methods. Feldspar populations from KBS pumice samples exhibit restricted compositional and age ranges. The remaining tuffs show both wider feldspar compositional and apparent age variations. The Bayesian estimation approach produced the most consistent results, I most cases providing millennial scale resolution of eruption ages.

1098

A 74,000-year Record of Explosive Eruptions Along the Western Sunda Volcanic Arc: Tephra Correlations, Ages, Volumes, Magnitudes and Tephrochronological Markers

Marcus Phua[1,2], Dr Caroline Bouvet de Maissoneuve[1,2], Dr Steffen Eisele[1,2], Dr Francesca Forni[3], Dr Hamdi Rifai[4], Dr Andreas Lückge[5], Dr Mahyar Mohtadi[6]
[1]Earth Observatory of Singapore, Nanyang Technological University, Singapore, Singapore, [2]Asian School of the Environment, Nanyang Technological University, Singapore, Singapore, [3]Department of Earth Sciences "Ardito Desio", University of Milan, Milano, Italy, [4]Faculty of Math and Science, Universitas Negari Padang, , Indonesia, [5]Marine Geology, Federal Institute for Geosciences and Natural Resources (BGR), Hannover, Germany, [6]Center for Marine Environmental Sciences (MARUM), University of Bremen, Bremen, Germany

Sumatra is host to over 113 morphologically explosive edifices that have or are likely to have produced eruptions in the geological past. Despite a likely frequent and explosive eruptive history, little is known about the history and behaviour of Sumatran edifices. This study presents an expanded tephrochronological record of explosive eruptions in the last 74,000 years from the Sumatran segment of the Sunda Volcanic Arc through the geochemical investigation of proximal eruptives and distal tephrostratigraphic work on 39 deep-sea cores collected by various research cruises. We compiled and utilised a comprehensive volcanic glass geochemical dataset of 106 primary distal tephra-bearing horizons and 21 proximal eruptives to establish tephra correlations, which identified 52 volcanic eruptions. Only eight of these correlated eruptions were known prior to the study and are associated with the Singkut, Toba, Malintang, Maninjau, Tandikat, Ranau and Krakatau eruptive centres, whilst 44 of these eruptions are entirely new to the Sumatran explosive eruption record. We correlated 13 of these 44 identified eruptions to three known eruptive centres — Marapi, Ranau and Krakatau; five were correlated to four probable volcanic sources — Ranau, Tandikat, Talang and Toba; and the remaining 26 eruptions were assigned probable eruptive source regions throughout Sumatra. 80% of the identified eruptions are Upper Pleistocene in age: 15-35 ka (21); 35-55 ka (12); and 55-74 ka (8). Whilst the remaining 20% are Holocene in age: 0-5 ka (4); and 5-12 ka (7). Erupted tephra volumes for the 52 eruptions range from < 1 to 158 km³. Two-thirds of these 52 eruptions are between 3.0-8.8 in magnitude (M), whilst the other one-third are 2.1 ≤ M ≤ 2.9 eruptions. We also define a new 37 ka tephrochronological marker for the Sumatran region. This study broadens our knowledge on the temporal and spatial distribution of explosive eruptions throughout Sumatra.

1101

A Quaternary Tephrochronological Record of Highly Explosive Eruptions Along the Sumatran Segment of the Sunda Volcanic Arc

Marcus Phua[1,2], Dr Caroline Bouvet de Maisonneuve[1,2], Dr Francesca Forni[3], Dr Steffen Eisele[1,2], Dr Hamdi Rifai[4], Dr Andreas Lückge[5], Dr Mahyar Mohtadi[6], Dr Satish Singh[7], Dr Rina Zuraida[8]
[1]Earth Observatory of Singapore, Nanyang Technological University, Singapore, Singapore, [2]Asian School of the Environment, Nanyang Technological University , Singapore, Singapore, [3]Department of Earth Sciences "Ardito Desio", University of Milan, Milano, Italy, [4]Faculty of Math and Science, Universitas Negari Padang, , Indonesia, [5]Marine Geology, Federal Institute for Geosciences and Natural Resources (BGR), Hannover, Germany, [6]Center for Marine Environmental Sciences (MARUM), University of Bremen, Bremen, Germany, [7]Marine Geosciences, Institut de Physique du Globe de Paris, Paris, France, [8]Center for Geological Survey, Geological Agency, , Indonesia

Indonesia is host to over 459 active or potentially active volcanic edifices of varying morphologies – making up about two-thirds of edifices throughout Southeast Asia. Sumatra in particular, accounts for around one-third of these edifices. Among these edifices, there are at least 13 large calderas and 28 well-plugged stratovolcanoes that have or are likely to have produced highly explosive eruptions between 5-8 in magnitude (M). And yet, only 9 highly explosive eruptions in Sumatra have known ages, spanning from 1.4 Ma to 1883 AD and fewer have geochemical or volcanological constraints. This study presents an extensive tephrochronological record of highly explosive eruptions post-YTT eruption (74 ka) to the end of the Quaternary (2.58 Ma) along the western Sunda Volcanic Arc through the distal tephrostratigraphic work on 37 deep-sea cores collected by research cruises in the past half-century. We assembled and utilised a comprehensive volcanic glass geochemical dataset of 97 primary distal tephra layers to establish correlations, with which 41 volcanic eruptions that are likely to or have originated from Sumatra were identified. Out of the 41 eruptions, four of these correlated eruptions were known prior to the study and are associated with the Toba caldera (YTT, MTT, OTT and HDT), whilst the remaining 37 eruptions are new to the Quaternary explosive eruption record for the Sumatran region. We correlated four of these 37 newly identified eruptions to three probable volcanic sources – Toba, Koto Petai and Pasomah, whilst the remaining 33 eruptions were assigned probable eruptive source regions throughout Sumatra – North Sumatra-West Sumatra; West Sumatra-Jambi; and Lampung-South Sumatra. This study highlights the significant knowledge gap that exists for the older (post-YTT) and highly explosive eruptions (M ≥ 5) in Sumatra where the preservation of tephra is severely hindered by humid tropical conditions, high precipitation rate and dense vegetation cover.

779

Melts from the Low Velocity Zone as a Source for Mt Etna

Professor Sebastien Pilet[1], Dr Rosa Anna Corsaro[2], Dr Massimo Chiaradia[3], Professor Luca Caricchi[3], Professor Othmar Müntener[1]
[1]University of Lausanne, Lausanne, Switzerland, [2]Istituto Nazionale di Geofisica e Vulcanologia (INGV-OE), Catania, Italy, [3]University of Geneva, Geneva, Switzerland

Flux or decompression melting of the mantle are the two main mechanisms to explain the generation of magma beneath large stratovolcanoes. Mt Etna differs from other giant active volcanoes in subduction zones or oceanic islands by the emission of large volumes of alkaline lavas. Volcanism at Mt Etna has been associated with a slab window caused by the roll back of the Ionian slab producing mantle upwelling and melting. However, the opening of a slab window does not explain how large volumes of highly enriched alkaline magmas are generated, neither why Mt Etna activity starts by the emission of small volume of tholeiitic lavas. We propose that magma erupted at Mt Etna pre-exist in the low seismic velocity zone and was extracted to the surface in response to the differential stress linked to the asymmetric subduction of the African and Ionian plates below Eurasia. The presence of low degree melt at the base of the lithosphere is supported by various geophysical studies to explain the seismic and electric properties of this critical zone which decouples rigid lithospheric plate from the weak asthenosphere. We use geochemical data and modelling to show that extraction of such melts coupled with melt-peridotite reaction satisfies the temporal, compositional, volatile, and volumetric constraints of lavas from Mt Etna and the associated Hyblean plateau emitted few million years prior to Mt Etna on the northern margin of the African plate. We suggest that the extraction of low degree melts from the Low Velocity Zone is an alternative way to produce alkaline volcanoes, whose magmatic composition, in most cases, has been modify by interaction with the lithosphere. Mt Etna may be a unique place on Earth where melt from the Low Velocity Zone is presently extracted to the surface.

1096

Temporal variations of ambient noise polarization on Piton de La Fournaise (La Réunion, France) and on Volcano island (Italy)

Dr Marta Pischiutta[1], Dr Rodolfo Puglia[2], Dr Valérie Ferrazzini[3], Prof Martha Savage[4], Dr Zacharie Duputel[3], Dr Cyril Journeau[5], Dr Andrea Di Muro[3], Dr Aline Peltier[3], Dr Antonio Paonita[6], Dr Tullio Ricci[1]

[1]INGV - Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy, [2]INGV - Istituto Nazionale di Geofisica e Vulcanologia, Milan, Italy, [3]Observatoire Volcanologique du Piton de la Fournaise, Institut de Physique du Globe de Paris , France, [4]Victoria University of Wellington, Wellington, New Zealand, [5]Université Grenoble Alpes, Grenoble, France, [6]INGV - Istituto Nazionale di Geofisica e Vulcanologia, Palermo, Italy

In the last decade, many studies performed on fault zones using both ambient noise and earthquake recordings have suggested that ground motion tends to be amplified and polarized perpendicularly to the pervasive fracture fields (e.g. Pischiutta et al., 2012). Several works involving direct comparisons with measured faults/fracture orientations investigated in the field, as well as other seismological constraints, have confirmed this interpretation. Polarization is determined in the time domain through the covariance matrix analysis, allowing us to define the polarization ellipsoid shape as a function of time. The resultant vector length R (exploited by Petrosino & Di Siena, 2021) is used to statistically quantify the circular spread of the azimuth distribution.

We have exploited this approach in the volcanic environment where magma and fluids rise and can induce strong variations in the local stress field, thus influencing fracture opening and, potentially causing temporal variation of ground motion polarization.

On Piton de la Fournaise volcano we employ continuous recordings acquired by stations belonging to the permanent monitoring network during three periods: 2011, 2013-2014, 2018-2022. We found that polarization azimuth tends to be stable through time, and is independent of the seismic source (ambient noise, volcanic tremor, volcano/tectonic earthquakes). However, polarization strength given by the resultant vector length R, is sensitive to the eruptive activity, starting a few days before an eruption. Similarly, on Vulcano Island we investigate ground motion polarization during the last unrest phase (2021-2022) when a significant increase of degassing was observed. We used the 8 permanent stations of the INGV seismic network operating on the Island. At station IVGP, located in one of the areas mainly affected by such gas emission increases (Grotte Palizzi), we found that the resultant length parameter seems to be well correlated to GPS variations, degassing, and seismicity.

900

Rapid assembly of eruptible magma bodies leading to the Aira caldera-forming eruption, Southern Japan

Dr Bradley Pitcher[1], Dr. Guilherme Gualda, Dr. Nobuo Geshi
[1]*Columbia University, New York, United States*

The 400 km³ caldera-forming eruption (CFE) of Aira (Japan) was preceded by three smaller pyroclastic eruptions that occurred within 3,000 years of the 30 ka CFE. Thus, this system provides a unique opportunity to investigate the timescales and processes that lead to a CFE; either a large volume of eruptible magma was left untapped during the prior three events, or 400 km³ of magma was amassed in less than 1,000 years. To address this question, we compare major and trace element compositions of glass and crystals from pre-CFE and CFE pumice, constrain temperatures and storage pressures, and estimate timescales using plagioclase and quartz diffusion chronometry.

All eruptions are high-silica rhyolites (77.0 ±0.5 wt.% SiO_2) and pre-CFE glass and plagioclase compositions, rhyolite-MELTS storage pressures (75-125 MPa), and zircon saturation and Fe-Ti oxide temperatures (730-800°C) are similar. CFE pumice, however, differ slightly in composition and range to higher pressures (100-175 MPa) and temperatures (730-850°C). Additionally, plagioclase from the CFE ignimbrite have distinctly higher Lithium abundance (60 ppm vs. 15 ppm) and Li/albite ratio within interiors than pre-CFE magmas, suggesting compositionally distinct magmas.

Textures suggest that only one major resorption event is recorded by most plagioclase crystals from all eruptions. Diffusion timescales in both plagioclase and quartz suggest short residence times of hundreds of years (< 800 years) for the CFE and pre-CFE eruptions, and a lack of systematic increase over the 3 ka span of the four eruptions suggests that each batch of eruptible, crystal-poor magma began crystallizing only after the previous eruption. Thus, we suggest that the pre-CFE eruptions do not represent a gradual 3 ka ramp-up to the catastrophic eruption. Rather, each pre-CFE tapped a rapidly-assembled, independent magma body, and that the 400 km³ of crystal-poor rhyolite magma body that fed the CFE was assembled in less than 1 ka.

1248

Volcanic glass from the 232 ± 10 CE Taupō eruption, New Zealand in Antarctic ice: implications for ice core chronologies

Mr Stephen Piva[1], Simon Barker[1], Colin Wilson[1], Bruce Charlier[1], Rewi Newnham[1], Lionel Carter[2], Nancy Bertler[2], Holly Winton[2], Nels Iverson[3], Nelia Dunbar[3]

[1]School of Geography, Environment and Earth Sciences, Victoria University Of Wellington, Wellington, New Zealand, [2]Antarctic Research Centre, Victoria University of Wellington, Wellington, New Zealand, [3]New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, Socorro, United States of America

Due to their widespread dispersal and typically distinctive geochemical fingerprints, tephra deposits preserved in terrestrial, marine and glacial archives are valuable time-stratigraphic markers. Tephras not only provide high-precision chronological constraints and links between sedimentary settings but can be integrated with proximal-medial eruptive successions and used to better understand the scale and tempo of past eruptions, the long-term behaviour of volcanoes, and effects of volcanism on climate and the environment. In Antarctic ice cores, chemical anomalies (particularly non-sea-salt sulfur) have been linked to major global eruptions, but tephra records are almost entirely limited to local sources. In part this reflects the scarcity of tephra particles derived from non-Antarctic sources and in part uncertainties in the ages of (pre-historic) candidate eruptions. Geochemical analyses of microscopic volcanic glass shards extracted from an interval of the Roosevelt Island ice core (RICEcore) associated with increased non-sea-salt conductivity and particle count measurements at 230 ± 32 CE indicate that two chemically distinct populations of trachytic and rhyolitic glass are derived from explosive eruptions from Mt. Melbourne, Northern Victoria Land, Antarctica and Taupō volcano, New Zealand, respectively. Unpolished scanning electron microscopy analysis using energy dispersive spectrometry (SEM-EDS) and polished electron microprobe analysis using wavelength dispersive spectrometry (EMPA-WDS) were conducted due to the low number and small size of analysable particles. Recognition of material from the 232 ± 10 CE Taupō eruption for the first time in Antarctica provides valuable links to mid-latitude terrestrial and marine palaeoenvironmental and palaeoclimatic records in widely different geographic areas and depositional environments. These links can aid reconstructions of volcanic impacts, offer insights into the ash cloud extent, dispersal and long-distance transport of tephra in the Southern Hemisphere, and will help to correlate between and constrain the age of existing ice core and blue ice chronologies in Antarctica.

590

AVERT: Anticipating Volcanic Eruptions in Real-Time

Professor Terry Plank[1], Dr. Einat Lev[1], Nicolas Frearson[1], Dr. Conor Bacon[1], Jasper Bauer[1], Dr. John Power[2], Dr. Társilo Girona[3], Skye Kushner[3], Prof. Ronni Grapenthin[3], Dr. Allan Lerner[4], Dr. Christoph Kern[4], Dr. Diana Roman[5]

[1]Columbia University/LDEO, Palisades, United States, [2]Alaska Volcano Observatory, USGS, Anchorage, USA, [3]University of Alaska, Fairbanks, USA, [4]Cascades Volcano Observatory, USGS, Vancouver, USA, [5]Carnegie Instution for Science, Washington, USA

The development of physics- and machine learning-based eruption forecast models requires multi-parameter, real-time, open data collected on active volcanoes. Unfortunately, all these conditions are seldom met for most volcanic systems displaying unrest. This is due to the significant logistical challenges and costs of installing and maintaining equipment in harsh environments and of establishing a continuous path to open data repositories. Here we report the development and deployment of multi-parameter, real-time, open data volcano sensor arrays through our collaborative project AVERT: Anticipating Volcanic Eruptions in Real-Time. A partnership between LDEO and the Alaska Volcano Observatory (AVO), AVERT is targeting Cleveland and Okmok volcanoes in the Aleutians. Cleveland is an open vent volcano that is one of the most active in the US, having experienced explosive eruptions in most years since 2001. Okmok is a closed system volcano that has been inflating episodically since its VEI 4, 2008 eruption. Building on AVO's decades of experience in establishing and maintaining autonomous seismic, GNSS and infrasound stations, AVERT is adding novel instrumentation such as continuous, real-time fluxgate magnetometers, synchronized visual and thermal cameras, scanning spectrometers measuring SO2 emission rates, and probes for soil temperature and CO2 flux. Wind generators are being tested along-side solar panels to provide power during dark periods and reduce dependence on batteries. Data is telemetered via satellite, thus eliminating the requirement for multiple line-of-sight radio repeaters for data delivery. On-site single board computers allow edge processing of imagery and seismic events to optimize bandwidth utilization. Data will be available in open portals with less than one hour latency. The design, data and lessons learned from the AVERT pilot arrays will be openly shared, will guide the development of community experiments such as SZ4D, and will encourage more cross-agency and cross-disciplinary collaborations to produce the next generation of volcano sensor data.

339

Gravity change at Kīlauea Volcano, Hawaiʻi, during 2019–2022 due to accumulation of lava and magma

Dr Mike Poland[1], Dr. Elske de Zeeuw-van Dalfsen[2]
[1]U.S. Geological Survey, Vancouver, United States, [2]Royal Netherlands Meteorological Institute (KNMI), De Bilt, Netherlands

From 2019 through 2022, Kīlauea Volcano, on the Island of Hawaiʻi, experienced a series of significant changes as it recovered from its major 2018 summit collapse and flank eruption. Uplift began in early 2019 as magma refilled the summit reservoir. A water lake appeared as groundwater flowed into the area of the pre-2018 summit eruptive vent in July 2019. Following a magmatic intrusion beneath the summit caldera in early December 2020, an eruption began on December 20, and lava began to accumulate in the 2018 collapse crater, vaporizing the water lake. The eruption ended in May 2021, but an intrusion in late August 2021 was followed by another eruption, which began on September 29 and continued to fill the summit collapse caldera with lava. By summer 2022 the overall lava depth was over 350 meters.

In March 2019 and April 2022, microgravity surveys using Scintrex CG-5 gravimeters were completed across a network of about 40 benchmarks in Kīlauea's summit region. Each survey utilized a double-loop procedure to account for instrument drift, and data were corrected for tares and solid Earth tides. Vertical deformation to correct for free-air effects was determined from ascending and descending InSAR data spanning the same period as the gravity data and supported by continuous GNSS measurements. The maximum residual gravity change after free-air adjustment was 800–1000 microgals. Forward modeling suggests that as much as two thirds of the residual gravity signal is due to the emplacement of new lava in the 2018 collapse pit, with the remainder related to subsurface magmatic activity associated with both gradual magma accumulation and rapid intrusive events.

340

Proactive, timely, and diverse: The communication strategy of the Yellowstone Volcano Observatory

Dr Mike Poland[1], Elizabeth Westby[1], Dr. Wendy Stovall[1]
[1]*U.S. Geological Survey, Vancouver, United States*

Yellowstone attracts international attention thanks to iconic landscapes, charismatic megafauna, and spectacular geology. Public interest in Yellowstone's volcanic character is especially enthusiastic. Unfortunately, this interest provides fertile ground for misinformation and widespread misconceptions, which propagate on social media and in exaggerated documentary films.

The communications strategy of the Yellowstone Volcano Observatory (YVO) emphasizes proactive, timely, and diverse messaging to provide public information about volcanic activity and to combat misconceptions and misinformation. YVO publishes a weekly essay, Yellowstone Caldera Chronicles (YCC), which addresses geology, research, and current events (like earthquake swarms). YCC is available online and via social media and is reproduced by regional news outlets. This proactive approach allows YVO to be a primary source of information rather than having to respond to incomplete, misleading, or incompetent external reporting. As a companion to formal monthly status updates, YVO also issues video updates that review activity and discuss a new aspect of Yellowstone geology each month. The video format is vital, given the growing popularity and reach of videos over written content, and the prevalence of misinformation on video-sharing platforms. Each year, YVO summarizes recent activity, status and results of the monitoring network, and current research in an annual report that is published online and in print. Finally, throughout the year, YVO uses social media to answer questions and address misconceptions in a timely manner. This is particularly important in response to significant events—for example, the March 31, 2020, central Idaho M6.5 earthquake that was believed by some of the public to be associated with Yellowstone volcanism, and June 2022 flooding that sparked concerns of hydrothermal explosions. This coordinated strategy of diverse, timely, and proactive communication is critical for quashing rumors before they take root, allowing YVO to drive the narrative instead of the opposite.

1487

The 2022 Mauna Loa Eruption: Collaborative Interagency Hazard/Risk Planning and Public Communication

Ken Hon[1], Katherine Muliken[2], Frank Trusdell[1], Natalia I Deligne[1], Jefferson Chang[1], Hannah Dietterich[3], Peter J. Dotray[1], Andria P Ellis[1], William William Hanson[4], David Hyman[5], Ingrid A Johanson[1], Jim Kauahikaua[1], Talmadge Magno[4], David Phillips[1], Dr Mike Poland[6], Wendy Stovall[6], Mike Zoeller[1]

[1]U.S. Geological Survey Hawaiian Volcano Observatory, , , [2]Research Corporation of the University of Hawaiʻi, , , [3]U.S. Geological Survey Alaska Volcano Observatory, , , [4]Hawaii County Civil Defense Agency, , , [5]Center for the Study of Active Volcanoes, University of Hawaiʻi at Hilo, ,

Lava erupted from Mauna Loa in 2022 for the first time in 38 years. Strong interagency collaboration was key to delivering hazard and risk messaging that resonated within potentially exposed communities.

Significantly elevated unrest began in mid-September, and the U.S. Geological Survey Hawaiian Volcano Observatory (HVO) concluded there was a high probability of an eruption within weeks to months. HVO worked closely with the Hawaiʻi County Civil Defense Agency (HCCDA) to communicate to residents that a Mauna Loa eruption was likely in the coming months with little advanced warning immediately prior to eruption. We stressed what we would be unable to tell the community: the exact time of the eruption and which communities lava flows might inundate. However, we established a clear sequence of probable Mauna Loa events based on previous eruptions.

Residents were encouraged to prepare and identify their lava inundation zone and many people self-evacuated the night of the eruption. Throughout the crisis, timely information was provided by HVO, HCCDA, and other emergency and land managers to the public via several platforms, including formal alert messages, websites, and social media.

Lava flow locations, advance rates, and behaviors were described and contextualized, particularly as fast-moving flows approached flatter ground, causing them to slow dramatically. Geospatial information on lava flow locations was updated in near real-time and shared with partners, who provided maps directly to the public.

We were careful in messaging that a Mauna Loa eruption could be large in volume but would likely cover only a small part of the volcano. Public viewing areas were established so residents and visitors could witness and be included in the event.

Fortunately, the 2022 Mauna Loa eruption had a minimal impact to infrastructure, however, significant impacts are inevitable in the future. Continued community engagement is necessary for future eruption responses.

760

The efficacy of high-resolution petrological monitoring at open-conduit volcanoes: A case study from Stromboli volcano (Italy).

Dr Alessio Pontesilli[1], Dr Elisabetta Del Bello[1], Dr Piergiorgio Scarlato[1], Prof Silvio Mollo[1,2], Dr Ben Ellis[3], Dr Daniele Andronico[4], Dr Jacopo Taddeucci[1], Dr Manuela Nazzari[1]

[1]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Roma 1, Via di Vigna Murata 605, 00143 Roma (RM), Italy, Italy, [2]Dipartimento di Scienze della Terra, Sapienza Università di Roma, P.le Aldo Moro 5, 00185 Roma (RM), Italy, Italy, [3]Institute of Geochemistry and Petrology, ETH Zurich, Zurich (8092), Switzerland, [4]4Istituto Nazionale di Geofisica e Vulcanologia-Osservatorio Etneo, Sezione di Catania, Catania, Italy

Typically, petrological monitoring matches eruptive phenomena and textural and compositional features of eruptive products over time scales of days to years, potentially missing key moments in fast-changing eruptions. Here, we present a high spatial (individual vents) and high temporal (minutes to hours) resolution petrological and volcanological investigation using as test site Stromboli volcano. On May 11 2019, we had the opportunity to collect individually ash fallout samples from eighteen consecutive explosions from two vents that were also recorded by continuous, high frequency (50 Hz) infrared thermal videos. Explosions were more frequent and ash-dominated at the southwestern crater area (SCA, 8–10 events/hour) than at the northeastern crater area (NCA, 3–5 events/hour), where coarser material was ejected. The statistical analysis of glass and plagioclase compositions reveals differences in the products erupted from the two crater areas. SCA explosions erupted less differentiated magmas in equilibrium with more anorthitic plagioclase cores (An_{72-88}), whereas NCA area explosions are more differentiated and in equilibrium with less anorthitic plagioclase cores (An_{68-82}). Thermometric calculations based on clinopyroxene-plagioclase-melt equilibria highlight that NCA eruptions were fed by a colder magma relative to that feeding SCA eruptions. Diffusion modeling of Li concentration profiles in plagioclase also indicates longer timescales of magma degassing and ascent for NCA eruptions, leading to preferential groundmass crystallization at the conduit walls and explaining the observed transition from dominantly sideromelane to tachylite textures. The final emerging picture is that concurrent eruptions from distinct vent areas at Stromboli are heralds of distinct magma differentiation conditions within the uppermost part of the storage region, in close agreement with observed eruptive phenomena. This high-resolution approach has the potential to unequivocally constrain the processes driving transient, rapid, explosive eruptions in active volcanoes, thus offering new insights on the complex interplay between magma dynamics, magma ascent rate, and eruptive behavior.

1373

The Late Cretaceous volcanism in Bolnisi district: lithological, structural and stratigraphic control on ore deposits, Lesser Caucasus, Georgia

Mrs Nino Popkhadze[1], Mr Robert Moritz[2], Mr Şafak Sönmez[2], Mr Tornike Lipartia[3], Mr Malkhaz Natsvlishvili[3], Mr Shota Tagviashvili[3], Mr Badri Gogia[3]

[1]A.Janelidze Institute of Geology of Iv.Javakhishvili Tbilisi State University, Tbilisi, Georgia, [2]University of Geneva, Department of Earth Sciences, Geneva, Switzerland, [3]RMG Rich Metals Group company , Tbilisi, Georgia

The Bolnisi district is a part of the Lesser Caucasus and is located at its northern extremity. To the west, this ore district continues into the Eastern Pontides, Turkey. This favourable geotectonic location of the Late Cretaceous Bolnisi ore district (which is also part of the Arvin-Bolnisi Belt) between the Lesser Caucasus and the Eastern Pontides is reflected by its geological diversity, volcanism type and mineral deposit distribution. The Late Cretaceous (~87–71 Ma) bimodal volcanism in this region resulted in mafic and felsic rock types, the latter being a major host of the ore deposits and prospects, and being defined locally as the felsic Mashavera and Gasandami suites. A stratigraphic control recognized on the distribution of Upper Cretaceous ore deposits and prospects in the Bolnisi district (Gugushvili, 2004). The presently producing late Turonian to early Santonian Madneuli deposit and the Tsiteli Sopeli, Kvemo Bolnisi, Mushevani and David Gareji prospects from the eastern part of the district are hosted by the stratigraphically older volcanic and volcano-sedimentary rocks of the Mashavera suite. A second group of Campanian ore occurrences, including the currently producing Sakdrisi and Beqtakari deposits, also the Darbazi, Imedi, Beqtakari, Bnelikhevi and Samgreti prospects, in the western district, are hosted by volcanic and VS rocks of a stratigraphically younger suite named the Gasandami suite. All above mentioned ore deposits are connecting to the Upper cretaceous explosive volcanic event in different stratigraphic levels and there is lithological structural control on mineralization. Explosive breccia and pumice bearing rocks (including different type of ignimbrites and pumice tuffs), are good permeable rocks for fluid, where mineralization is mostly localized. Even non-mineralized explosive breccia in the system creates a fracture system sometimes together with the regional faults where gold/copper gold bearing quartz and quartz-sulphide veins and stockworks are developing.

918

Multi-hazard assessment in volcanic environments applied to Santorini Volcano (Greece)

Professor Modesto Portilla Gamboa[1]
[1]*Universidad Nacional de Colombia, Bogota, Colombia*

Volcanic eruptions and earthquakes are the hazards usually studied in volcanic environments. However, the most frequent and most active events are the mass movements resulting from the destabilization of volcanic deposits by hydrometeorological agents. These geodynamic processes, such as volcanism, seismicity, and terrain slides, coincide within the same specific geographic area. Therefore, they must be analysed spatiotemporally as multi-hazards for proper assessment and integrated risk management.

Portilla (2022) presented the Theoretical Risk Framework at the Cities on Volcanoes 11 Congress (Heraklion, Greece), which defines: hazard as the probable event occurrence detonated in a specific place (source), which has its own traits (life, rate, and magnitude), interacting with the environment components along its pathway (intensity); ontologicity, which is related only to the entities' characteristics, entities being all living beings and thinks in existence (ecosystems, services, infrastructure, economic, social and cultural assets, etc.); and risk as the expected consequences for the entities due to their interaction with the event's intensity.

In the IAVCEI 2023 Scientific Assembly (Rotorua, New Zealand), a multi-hazard analysis for the islands of the Santorini Volcano (Greece) due to volcanism, seismicity, and mass movements, will be presented. After the 3.6ka Minoan volcanic eruption, andesitic to dacitic pyroclastic fall deposits of the Santorini Volcano's first and second explosive cycles covering the steep cliffs of Therasia, Aspronisi, Palaea Kameni, Nea Kameni, and Santorini islands, have been destabilized. Volcanic activity, seismicity, rainfall, and anthropogenic activity, besides being concurrent hazards in the Santorini caldera, act as triggers of mass movements, which can cause damage to roads leading from the ports to the upper parts of the islands (Oia, Fira, Pyrgos, Akrotiri, Thirasia); and, during heavy rainfalls, to sightseeing boats, with the consequent risk to the main socioeconomic and cultural activity of Santorini, tourism.

Done

797

Receiver function imaging of the complex plumbing system feeding Mount St. Helens, Washington

Dr Daniel Portner[1], Dr Jonathan Delph[2], Dr Eric Kiser[3], Dr Geoffrey Abers[4], Dr Alan Levander[5]
[1]Arizona State University, Tempe, United States, [2]Purdue University, West Lafayette, United States, [3]University of Arizona, Tucson, United States, [4]Cornell University, Ithaca, United States, [5]Rice University, Houston, United States

Mount St. Helens in Washington state, the most active volcano in the Cascade arc, was recently instrumented with a dense, expansive network of seismometers through the imaging Magma Under Mount St. Helens (iMUSH) Seismic Experiment, providing a unique opportunity to characterize the lithospheric structure of a magmatic system at an active volcano. With data collected from this experiment, the magmatic plumbing system feeding Mount St. Helens has been characterized by a variety of independent seismic imaging studies. These have identified an upper crustal (~4-15 km depth) low velocity zone interpreted as the primary magma reservoir containing up to an estimated 10-12% of partial melt and large lower crustal high velocity zones interpreted variably as magmatic cumulates or accreted high velocity terrane. Here, we attempt to further constrain the seismic properties of this system through a comprehensive analysis of receiver functions at the volcano. Among our analyses, we perform adaptive common conversion-point (ACCP) stacking of receiver functions to reveal a three-dimensional model of seismic impedance contrasts within the crust and across the crust-mantle transition. We identify clear variations in the amplitude of the Moho correlated with the presence of previously interpreted lower crustal cumulates as well as upper-crustal velocity contrasts associated with the shallow magma reservoir. This ongoing work allows us to integrate constraints from the varied multi-scale seismic imaging studies of the Mount St. Helens plumbing system.

930

The Future of Forecasts and Warnings

Dr Sally Potter

The communication of volcano-related information has advanced remarkably over the past few decades. Instead of focussing only on the science and monitoring indicators as the subject of messages, produced in a silo by a science agency, we are now fostering partnerships and communicating meaningful information with stakeholders to the public.

Recent events in New Zealand have taught us a lot about how to effectively communicate geohazard information. Our team of social scientists have spent a decade researching effective communication of earthquake forecasts following the Canterbury and Kaikoura earthquakes. We have applied those findings iteratively and within multi-disciplinary teams as subsequent earthquakes occurred. These findings were also translated to a volcano context and applied during the tragic Whakaari 2019 eruption to support decisions to return to the island. Our learnings have evolved as Ruapehu and Taupo volcanoes underwent unrest in 2022, in a context of high uncertainty. We have strengthened partnerships with response agencies through Volcanic Advisory Groups and co-location. We are also leaning towards people-centred communications as we build our crowdsourced hazard and impact observation capabilities.

The communication of impact-based warnings is becoming increasingly popular and encouraged, particularly in the world of weather warnings. What are these, how effective are they, and what does it mean for volcanic eruption forecasting and communication? Why do people respond in different ways to forecasts and warnings, and how can we make our messaging more effective at prompting a response?

The environment is changing due to global warming, and people's experiences with the COVID-19 pandemic have demonstrated different appetites for risk. There is exponential growth in technology and access to social media, allowing information sharing to reach unprecedented levels. In this evolving context, we must look to the future and forecast how and what we will need to communicate 5, 10, 20 years from now. In this way we can design our science and volcano monitoring capabilities, our partnerships and priorities, to meet the needs of society.

931

The communication and management of caldera unrest at Taupō Volcano 2022

Dr Danielle Charlton, Dr Sally Potter[1], Dr Graham Leonard, Nico Fournier, Mr Brad Scott
[1]*GNS Science, Tauranga, New Zealand*

Prior to eruptions, volcanoes show signs of unrest, including seismicity, geodetic, degassing and/or geothermal phenomena. Low levels of unrest are often recorded at active volcanoes, causing difficulties in deciding whether the volcano is in a state of normal background activity, or unrest. Unrest tends to be used as the first step on volcanic alert level systems and as a trigger to communicate to decision-makers, as well as appearing on forecasting tools such as Bayesian Event Trees. The Volcanic Unrest Index (VUI) was developed to help define unrest at volcanoes, and to communicate the relative intensities of unrest episodes.

Taupō volcano in New Zealand showed signs of activity in 2022. Due to the most recent eruptive episode in 232 AD being a catastrophic caldera-forming eruption, there was concern that communicating about its unrest would in itself cause adverse impacts. GNS Science raised the volcanic alert level to 1 (minor unrest) for the first time. The Emergency Management sector requested scenario information to help support their decision-making, which GNS Science and Universities around New Zealand worked together to produce.

This successful management of caldera unrest built on previous research from the last decade, as well as established relationships across the sectors. A historical catalogue of unrest and its impacts at Taupō was coupled with the VUI and New Zealand's Volcanic Alert Level system, to produce effective messages. Forecasts were co-produced and drew on multi-disciplinary research and experiences in effectively communicating science advice since the Canterbury Earthquake sequence started in 2010.

This presentation outlines these different strands of research and how they came together to support the communication and management of caldera unrest at Taupō volcano in 2022.

545

Uncertainty-bounded estimates of ash cloud properties using the ORAC algorithm: Application to the 2019 Raikoke eruption

Dr Andrew Prata[1], Professor Roy G. Grainger[1], Dr Isabelle Taylor[2], Dr Adam Povey[3], Dr Simon Proud[3,4], Dr Caroline Poulsen[5]

[1]Atmospheric, Oceanic and Planetary Physics, University of Oxford, Oxford OX1 3PU, United Kingdom, [2]COMET, Atmospheric, Oceanic and Planetary Physics, University of Oxford, Oxford OX1 3PU, United Kingdom, [3]National Centre for Earth Observation, Atmospheric, Oceanic and Planetary Physics, University of Oxford, Oxford OX1 3PU, United Kingdom, [4]RAL Space, STFC Rutherford Appleton Laboratory, Harwell Campus, Didcot OX11 0QX, United Kingdom, [5]Australian Bureau of Meteorology, Melbourne, Australia

Uncertainty-bounded satellite retrievals of volcanic ash cloud properties such as ash cloud-top height, effective radius, optical depth and mass loading are needed for the robust quantitative assessment required to warn aviation of potential hazards. Moreover, there is an imperative to improve quantitative ash cloud estimation due to the planned move towards quantitative ash concentration forecasts by the Volcanic Ash Advisory Centers. Here we present the Optimal Retrieval of Aerosol and Cloud (ORAC) algorithm applied to Advanced Himawari Imager (AHI) measurements of the ash clouds produced by the June 2019 Raikoke (Russia) eruption. The ORAC algorithm is open source and uses optimal estimation to consolidate a priori information, satellite measurements and associated uncertainties into uncertainty bounded estimates of ash cloud-top height, effective radius and optical depth. Using ORAC, we demonstrate several improvements in thermal infrared volcanic ash retrievals applied to broadband imagers. These include: an improved treatment of measurement noise, accounting for multi-layer cloud scenarios, distinguishing between heights in the troposphere and stratosphere, and the retrieval of a wider range of effective radii sizes than existing techniques by exploiting information from the new channels available from next generation geostationary satellite instruments. The dataset presented here provides uncertainties at the pixel level for all retrieved variables and could potentially be used for dispersion model validation or implemented in data assimilation schemes.

897

Over 14 years of sulphur dioxide (SO2) measurements made with the Infrared Atmospheric Sounding Interferometer (IASI)

Dr Isabelle A. Taylor[1], Professor Roy G. Grainger[1], Professor Tamsin A. Mather[2], Dr Andrew Prata[3]
[1]COMET, Atmospheric, Oceanic and Planetary Physics, University of Oxford, Oxford, United Kingdom, [2]COMET, Department of Earth Sciences, University of Oxford, Oxford, United Kingdom, [3]Atmospheric, Oceanic and Planetary Physics, University of Oxford, Oxford, United Kingdom

Satellite data offers a global view on sulphur dioxide (SO_2) emissions from volcanoes over extended time periods. Compilations of these observations allow us to assess long term patterns in volcanic SO_2 emissions: important for assessing their impacts on the atmosphere and for identifying patterns in volcanic activity. The Infrared Atmospheric Sounding Interferometer (IASI), onboard the Metop platforms, has been successfully used to study SO_2 from individual volcanoes and specific eruptions. The instruments were launched in 2006, 2012 and 2018 and each instrument obtains near global coverage twice a day. The Earth Observation Data Group (EODG) at the University of Oxford has multiple tools for studying volcanic plumes. The first tool, a linear retrieval, can be applied in near real time to detect elevated amounts of SO_2. We then run a full iterative retrieval to quantify information about SO_2. This includes the column amount, height and a comprehensive error matrix.

We have applied the EODG SO_2 retrievals to the IASI data going back to June 2007. This has created a detailed dataset on SO_2 in the atmosphere. Using this dataset, it is possible to estimate total daily atmospheric burdens of volcanic SO_2. This peaks in 2011 after the eruption of Nabro in Eritrea. It is also possible to identify emissions from smaller eruptions and ongoing volcanic emissions (e.g. Popocatepetl in Mexico and Etna in Italy). Additionally, we identified anthropogenic emissions (e.g. in South Africa, Russia and China). We were able to explore the distribution of SO_2 with latitude and height: important for investigating factors such as the SO_2 lifetime, dispersion and atmospheric impacts. This dataset will be archived at the Centre for Environmental Data Analysis (CEDA) to make it available to other researchers. In the meantime, the dataset can be made available by contacting the lead author.

901

Observations of the Hunga Tonga-Hunga Ha'apai plumes with the Infrared Atmospheric Sounding Interferometer (IASI)

Dr Isabelle A. Taylor[1], Professor Roy G. Grainger[1], Dr Andrew Prata[2], Dr Elisa Carboni[3], Dr Richard Siddans[3], Professor Tamsin A. Mather[4]
[1]COMET, Atmospheric, Oceanic and Planetary Physics, University of Oxford, Oxford, United Kingdom, [2]Atmospheric, Oceanic and Planetary Physics, University of Oxford, Oxford, United Kingdom, [3]STFC RAL Space / NCEO, Harwell Campus, United Kingdom, [4]COMET, Department of Earth Sciences, University of Oxford, Oxford, United Kingdom

The 2022 Hunga Tonga-Hunga Ha'apai (HT-HH) eruption was the largest eruption to have occurred since the 1991 Pinatubo eruption. The eruption was widely observed with satellite instruments including the Infrared Atmospheric Sounding Interferometer (IASI): a hyperspectral instrument on-board the Metop platforms. Within the IASI spectral range there is sensitivity to ash, sulphur dioxide (SO_2) and sulphate aerosol which can be utilised to study these plumes.

The Earth Observation Data Group (EODG) at the University of Oxford has tools for studying SO_2. The first is a linear retrieval: a rapid tool for the detection of SO_2 which can be applied in near real time. An iterative retrieval is then applied which quantifies the SO_2 column amounts and heights. The Remote Sensing Group (RSG) at the Rutherford Appleton Laboratory (RAL) has an Infrared Microwave Sounder (IMS) retrieval which obtains information about sulphate aerosol. The RAL sulphate product does not include height information but the results have been adjusted using the EODG IASI SO_2 heights. The EODG SO_2 product and RAL sulphate product are studied together to estimate the total SO_2 mass and to show the conversion of SO_2 to sulphate.

The IASI SO_2 retrievals were able to detect small emissions from HT-HH in December 2021 and in early January 2022. A stratospheric SO_2 plume (17-18 km) was then identified from the 13th January eruption. This was followed by the explosive event on 15th January. The results from the IASI iterative retrieval showed a small emission of SO_2: a peak atmospheric burden of 0.2 Tg. The retrieved heights show a complex structure to the plume with layers at 25-27, 20-23 and 17-19 km. The plume is then tracked as it travels away from the source. This eruption is unusual both for the plume height and the small quantity of SO_2 measured.

618

Transient ice ring observed during Hunga Tonga-Hunga Ha'apai eruption

Dr Andrew Prata[1], Professor Roy G. Grainger[1], Dr Isabelle Taylor[2], Dr Alyn Lambert[3]
[1]Atmospheric, Oceanic and Planetary Physics, University of Oxford, Oxford, United Kingdom, [2]COMET, Atmospheric, Oceanic and Planetary Physics, University of Oxford, Oxford, United Kingdom, [3]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, USA

The Hunga Tonga-Hunga Ha'apai (HTHH) eruption on 15 January 2022 was an exceptional event for many reasons; record breaking heights have been reported, a significant amount of water was injected into the stratosphere and wave disturbances from the surface to the ionosphere have been detected. A peculiar, yet significant aspect of the 15 January eruption was a distinctive, transient "ring" of extremely small ice particles (~2 micron), observable for ~2 h before dissipating. The small ice particles led to record positive brightness temperature differences (exceeding 50 K) in the thermal infrared channels. We present quantitative observations of the ice ring cloud's radial extent, height, particle sizes, optical depth, total mass and lifetime. We hypothesise that the ice was generated due to the passage of an atmospheric pressure wave, the Lamb wave, triggered by the violent explosion of the eruption. The passage of the Lamb wave produced a reduction in temperature that cooled water vapour in the upper troposphere-lower stratosphere (UTLS) below frost point, leading to rapid vapour-ice deposition. Due to eruptive activity on 13 January, the atmosphere was likely primed with ice nucleating particles, which may explain how ice was able to form. Our modelling suggests that a temperature drop of the order of 1 K from frost point and water vapour concentrations from ~5-10 ppmv near 100 hPa would be required to explain the formation of small ice particles indicated by the satellite observations. We also find that if the departures from frost point are modelled as a damped oscillator, the growth of ice particles by vapour deposition is consistent with our observations of small ice particles oscillating in size with time. This phenomenon serves as an important natural experiment revealing the timescales upon which ice particles grow via vapour diffusion at temperatures from 190-210 K.

343

Eruption of a large-volume, monotonous intermediate ignimbrite at the dawn of Taupō Volcanic Zone activity, New Zealand

Mrs Marlena Prentice[1], Dr Adrian Pittari[1], Dr Geoff Kilgour[2], Professor David Lowe[1]
[1]University Of Waikato, Hamilton, New Zealand, [2]GNS Science, Taupo, New Zealand

Voluminous (> 100 km^3) silicic volcanism within New Zealand has been a prominent feature during the >2 Ma history of the Taupō Volcanic Zone (TVZ). During this time, there have been numerous eruptions of crystal-poor (< c. 10 vol.%) rhyolites that are compositionally variable, but often not systematically zoned, whereas the eruption of voluminous crystal-rich (> c. 20 vol.%) ignimbrites has been rare (e.g., Ongatiti, Whakamaru and Rotoiti ignimbrites). The Waiteariki Ignimbrite, erupted from the Omanawa caldera in the Tauranga Volcanic Centre (TgaVC) c. 2 Ma, does not conform with these typical endmember ignimbrites. This large-volume (870 ± 44 km^3 DRE; magnitude, M, 8.3), dacitic (67.27–71.13 wt. % SiO_2) ignimbrite is crystal-rich (c. 30-50 vol.%, ave. 41 vol.%), and has a consistent mineral assemblage of plagioclase, hornblende, orthopyroxene, quartz, with accessory Fe-Ti oxides, zircon and apatite. Additionally, whole-rock and glass major and trace element compositions vary minimally within a narrow range throughout the < 150 m vertical thickness, analogous to typical monotonous intermediate-type ignimbrites (cf. Fish Canyon Tuff). Despite this apparent homogeneity, the Waiteariki Ignimbrite is highly heterogenous at the microscopic level and demonstrates textural evidence of the syn-eruption of coexisting magma bodies and subsequent mixing of magmas. Plagioclase crystals span a broad compositional range (An_{22}-An_{78}) with both normal and reverse zoning juxtaposed, and many crystals display complex textural features. Similar compositional and textural variations are observed in orthopyroxene (En_{28}-En_{79}, Wo_1-Wo_4) and hornblende (Al(t)=1.15-2.11 apfu), all reflective of remobilisation of the underlying mush zone with a complex evolutionary history. Estimates of magmatic conditions are modelled using multiple independent crystal-melt (plag-liq, opx-liq) or crystal-only (cpx; Al-in-hornblende) thermo-geobarometers to give pre-eruptive temperature ranges between 740-840°C and 900-990°C (ave. 790°C and 950°C, respectively) and pressures between < 50-150 MPa that are indicative of multiple extraction zones with shallow, upper-crustal storage.

305

Using text corpora for volcanic eruption forecasting, impact assessment and resilience planning: The first steps of the CorVo project

Mrs Claudia Principe[1], Costanza Marini[2]
[1]*Istituto di Geoscienze e Georisorse, Pisa, Italy,* [2]*University of Bergamo, Bergamo, Italy*

The CorVo project* (Corpora for Volcanoes) aims at building an innovative tool for volcanic risk forecasting, impact assessment, and resilience planning. Exploiting technologies coming from the digital humanities and computational linguistics, a flexible digital interface will be developed to query a body of documents (the CorVo corpus) containing extensive descriptions of the past activity of one of Italy's most high-risk volcanoes: the Vesuvius. The methodology proposed is an innovative type of approach and the resulting prototype is likely to be extended to other volcanoes in multi-hazard settings.

By querying the linguistically annotated corpus, end users (such as Civil Protection units and other stakeholders) will be able to quickly obtain important information from past eruptive scenarios, such as precursors, phenomenology, deposit distribution, and damages, as well as their social impact and the reactions they provoked in the institutions. In this way, they will be able to tackle future emergency scenarios, assess area vulnerability, and plan their response strategies in the best way.

In order for the CorVo tool to return useful information, the CorVo corpus linked to it needs to contain a balanced selection of documents that describe the different types of eruptions the volcano may experience: Plinian-type, fissural or mixed (explosive-effusive). Therefore, the first three eruptions that are going to be included in the pilot are going to be the Plinian-type eruption of 1631, the fissural eruption of 1794, and the most recent mixed eruption of 1944. The bulk of the documents to be included in the corpus is going to be selected from the BIBV Database (http://libero.area.pi.cnr.it/libbiv/aboutBIV.html). The testing phase of the tool will be carried out in cooperation with other units of the PNRR EPOS MEET project.

*The CorVo project is funded as Operating Unit 12 CNR-IGG, WP11 of the PNRR EPOS MEET project, starting September, 1st 2022.

1491

Advancing volcano science and hazard mitigation with multi-parameter satellite datasets: Vision for a global volcano satellite observatory

Professor Matthew Pritchard

There are more than 60 satellites in orbit that are routinely observing volcanic activity. Satellites have detected activity at more than 411 volcanoes between 1978 and 2021 manifest as ash, thermal, and gas emissions, ground displacement, and surface and topographic change. Satellite data has greatly increased the number of volcanoes with known activity—for example, the number of volcanoes known to be deforming increased five-fold between 1997 and 2017. Satellite data are being used by volcano observatories operationally and synergistically with ground sensors to fill gaps in ground networks, evaluate noise in the ground observations, and decide alert levels. Remote sensing data complement ground monitoring but won't replace it. Technological developments are making satellite data ever more useful for volcanology, including higher spatial resolutions (less than 0.5 m/pixel), constellations of satellites and geostationary satellites reducing revisit times to hours (or even minutes), and automated processing and detection of anomalies from petabytes of data using machine learning and artificial intelligence. Yet, satellites are still not always collecting the optimal types of data at the relevant volcanoes with sufficiently high temporal an spatial sampling to facilitate eruption forecasting. We propose a vision for how the volcano remote sensing community could work together with volcano observatories, space agencies, and companies to improve the utility and uptake of satellite data by 2030. Specifically, we need (1) global coordination of background satellite observations (as done for polar regions) and eruption response, (2) open data being rapidly distributed during crises, (3) communication tools and forums for discussion of satellite data, (4) integrated ground and satellite databases of unrest, and (5) global capacity building. This contributes to the development of an integrated, international, global remote sensing geohazard monitoring effort for disaster risk management as part of the Committee on Earth Observation Satellites (CEOS) Volcano Demonstrator project.

1197

Developing and presenting multi-hazard volcanic hazard assessments; A case study from Mt. Taranaki, New Zealand.

Professor Jonathan Procter[1], Dr Stuart Mead, Professor Mark Bebbington
[1]*Massey University, Palmerston North, New Zealand*

Volcanic hazard assessments are typically presented as spatial maps displaying hazard zones. Hazard maps are limited in providing data for risk assessments due to the lack of probabilistic data. A case study from Taranaki is presented where probabilistic hazard information is applied to determine hazard (impact) at points (or key infrastructure) locations providing for more robust spatial hazard information for risk assessment. Current probabilistic estimates of eruption likelihood indicate a moderate (0.35-0.38) probability of one or more eruptions of Taranaki occurring within the next 50 years. Expert elicitation suggests medium sized eruptions are more likely than very large and very small eruptions; most likely VEI 3 with a probability of 0.85. Smaller (>VEI 2) and larger (VEI 4 or greater) eruptions are less likely, with probabilities of 0.07 and 0.08 respectively. The scale of impact to locations around the volcano is dependent on the eruption size. Ashfall impacts are likely to be minor (probability of 0.1 to exceed 9 cm of ash at 5 km from the vent). Volcano ballistic impacts form a highly localised. The chance of more than 10 cm of ashfall is estimated at between 0.5 and 0.95. In addition to these hazards, very large eruptions (VEI 4 or greater) may also trigger debris avalanches (0.15 to 0.015 probability) affecting the eastern sector of Taranaki. Simulations of 200,000 to 1,000,000 m3 pyroclastic flows indicated maximum flow heights of between 5 and 15 m, at key infrastructure locations around the volcano. Lahars, simulated with ~100,000 m3 of water in addition to the pyroclastic flow volume, are estimated to reach maximum flow heights between 11 and 22 m, however superelevation (inclination of flow towards the outer bend) may result in lahar flow for very large flows (~900,000 m3) reaching bridges.

699

Insights into the evolution of mass-flow dynamics from the seismic analysis of the 18 March 2007 Mt. Ruapehu, New Zealand.

Dr Braden Walsh[2], Professor Jonathan Procter[1], Dr Charline Lormand[3], Dr Glyn Williams-Jones[2]
[1]Massey University, Palmerston North, New Zealand, [2]Simon Fraser University, Burnaby, Canada, [3]University of Durham, Durham, United Kingdom

At 23:18 UTC on 18 March 2007 Mt. Ruapehu produced the biggest lahar in New Zealand in over 100 years when a tephra dam holding crater lake water back collapsed causing 1.3x106 m3 of water to flow out and rush down the Whangaehu channel. The outburst of water transformed into a lahar. Here, we describe the seismic signature of the lake-breakout lahar over the course of 83 km along the Whangaehu river system using three 3-component broadband seismometers installed <10 m from the channel at distances of 7.4, 28, and 83 km from the crater lake source. Examination of 3-component seismic amplitudes, frequency content, and directionality combined with video imagery and sediment concentration data depicts the evolution of an ever transforming lahar from a highly turbulent out-burst flood (high peak frequency throughout), to a fully bulked up multi-phase hyperconcentrated flow (varying frequency patterns depending on the lahar phase) to a slurry flow (bedload dominant). Estimated directionality ratios show the elongation of the lahar with distance from source and extraordinary promise for mass flow monitoring and detection systems where streamflow is already present. Ultimately, the 3-component broadband seismic data for the 18 March 2007 lahar at Mt. Ruapehu may lead to more accurate and advanced real-time waring systems for mass flows through the use of seismic frequency and directionality analysis worldwide.

1312

Data and service management of the European volcanological community by the Volcano Observations Thematic Core Service (EPOS-ERIC)

Dr Giuseppe Puglisi[1], Dr. Lucia Cacciola[1], Dr. Adelina Geyer[2], Eng. Davíð Steinar Guðjónsson[3], Eng. Yannick Guehenneux[4], Prof. Jean-Christophe Komorowski[5], Dr. Philippe Labazuy[4], Dr. Arnaud Lemarchand[5], Dr Rosella Nave[6], Dr Jean-Marie Saurel[4], Eng. Danilo Reitano[1], Dr. Letizia Spampinato[1], Dr. Kristín Vogfjörd[3]
[1]Istituto Nazionale di Geofisica e Vulcanologia (INGV), Catania, Italy, [2]Geosciences Barcelona, CSIC, Barcelona, Spain, [3]Icelandic Meteorological Office (IMO), Reykjavík, Iceland, [4]Université Clermont Auvergne (UCA), CNRS, OPGC, Clermont-Ferrand, France, [5]Université Paris Cité, Institut the Physique du Globe, CNRS, Paris, France, [6]Istituto Nazionale di Geofisica e Vulcanologia (INGV), Naples, Italy

The Volcano Observations Thematic Core Service (VOLC-TCS) is one of the TCSs forming the EPOS European Research Infrastructure Consortium (EPOS-ERIC). The overarching objective of the VOLC-TCS is the implementation of the technical and legal framework consistent with EPOS infrastructure for both coordinating the European volcanology community and giving access to data and services relevant to the volcanoes located in the European countries and their overseas territories, provided by Volcano Observatories (VOs) and Research Institutions (VRIs).

To ensure a long-term sustainable operational infrastructure it was necessary to define a clear financial, legal, political and governance framework, alongside the solution of technical issues. One of the main challenges of the management of volcanological data consists in their great heterogeneity, regarding technical characteristics, and also legal aspects (e.g., different data policies among the data providers, different purposes for the use of data from science to monitoring, early-warning, information, etc.). Another challenge derives from the consistency of the VO-TCS with the service provision of EPOS, which characteristic is to merge different Earth Science communities (seismology, GNSS, geomagnetic, geochemistry, geology, etc.). Indeed, some of the services used in volcanology are in common with other communities, thus the implementation work was also devoted to harmonize the provision of data and products standardized by other TCS with the provision of volcanological services. Another important task is the implementation of the community Gateway which is aimed at allowing services not fully compliant with EPOS or implemented by institutions outside the EPOS perimeter, to be visible in EPOS and creating the conditions to interface the VOLC-TCS with data infrastructures operating at global level (e.g., WOVOdat).

950

Spatiotemporal Low-Temperature Thermal Anomalies at Okmok Caldera

Claire Puleio[1], Társilo Girona[1], Jasper Baur[2], Einat Lev[2]
[1]*University of Alaska Fairbanks, Fairbanks, United States,* [2]*Lamont-Doherty Earth Observatory, Columbia University, Palisades, United States*

The risk to human life and infrastructure presented by volcanic eruptions can be minimized by improving eruption forecasts. Better eruption forecasting tools require increasing our capabilities to detect volcanic unrest and a better understanding of the subsurface processes that drive the observations we see at the surface of volcanoes. Girona et al. (2021) showed how large-scale (several km2), long-term (~years), and subtle increases in radiant heat flux along the flanks of volcanoes can predate their eruptions. Here we further explore how these pre-eruptive, low-temperature (low-T) thermal anomalies vary both spatially and temporally around volcanoes, and work to understand the subsurface processes driving these anomalies. In particular, we present a preliminary spatiotemporal map of the low-T thermal anomalies at Okmok Caldera between July 2002 and November 2021, obtained using radiance data from the Moderate Resolution Imaging Spectroradiometers (MODIS) on board NASA's Terra and Aqua satellites. Our results are integrated with Forward Looking InfraRed (FLIR) imagery and ~1.5-year measurements taken with two in-situ ground temperature probes to explore to what extent low-T thermal anomalies are related to fumaroles or hydrothermal features. This work provides further insight into the complex eruption dynamics at volcanoes and supplies additional information needed to connect the low-T thermal anomalies at the surface with their subsurface drivers, which can aid in eruption forecasting and active volcano monitoring. This research is supported by a NASA NIP award (80NSSC21K2074) and a NASA FINNEST award (80NSSC21K1599).

Girona, T., Realmuto, V. & Lundgren, P. Large-scale thermal unrest of volcanoes for years prior to eruption. Nat. Geosci. 14, 238–241 (2021). https://doi.org/10.1038/s41561-021-00705-4

955

Spatiotemporal Low-Temperature Thermal Anomalies and Diffuse CO2 Degassing at Mount Edgecumbe Volcano

Claire Puleio[1], Társilo Girona[1], Carlo Cardellini[2], Taryn Lopez[1]
[1]*University of Alaska Fairbanks, Fairbanks, United States,* [2] *Università degli Studi di Perugia, Perugia, Italy*

Volcanic eruptions can cause severe damage to human life and infrastructure and may occur with little to no warning because of the difficulty to detect precursory activity. Recently, Girona et al. (2021) found that both magmatic and phreatic eruptions can be preceded by low-temperature (low-T) thermal anomalies along volcanic flanks; these anomalies are large-scale (several km2), long-term (~years), and subtle increases in radiant heat flux. However, it remains unclear what the subsurface driver of these anomalies is. We hypothesize that these low-T thermal anomalies are linked to the subsurface release of latent heat during the condensation of magmatic and/or hydrothermal water vapor. In such a case, water vapor does not reach the surface, but other volcanic gases, such as CO2, may. We test this hypothesis by comparing the spatial patterns of low-temperature thermal anomalies with diffuse CO2 degassing measurements collected in large areas of a volcanic edifice. In particular, we present our preliminary spatiotemporal map of low-T thermal anomalies at Mount Edgecumbe between July of 2002 and April of 2021 (obtained using radiance data from the Moderate Resolution Imaging Spectroradiometers -MODIS- on board NASA's Terra and Aqua satellites); and diffuse CO2 degassing measurements collected along a transect in a 2-day campaign in August of 2022. This work adds to our understanding of how volcanic hydrothermal subsurface processes may present as thermal anomalies on the surface of volcanoes, and how the detection of these anomalies may be used to identify volcanic unrest. Future work aims to constrain diffuse CO2 degassing over Mount Edgecumbe's summit crater and the area surrounding the volcano's flanks. This research is supported by a NASA NIP award (80NSSC21K2074) and a NASA FINNEST award (80NSSC21K1599).

Girona, T., Realmuto, V. & Lundgren, P. Large-scale thermal unrest of volcanoes for years prior to eruption. Nat. Geosci. 14, 238–241 (2021). https://doi.org/10.1038/s41561-021-00705-4

324

Oriented attachment of magnetite nanoparticles in natural silicate melts

Dr Marija Putak Juricek[1,3], Mayumi Mujin[2], Nobuyoshi Miyajima[3], Michihiko Nakamura[2]
[1]Georg-August University of Göttingen, Göttingen, Germany, [2]Tohoku University, Sendai, Japan, [3]Bavarian Geoinstitute, Bayreuth, Germany

We investigated late-stage crystallization in alkaline eruptive products of volcanic centers from the West Eifel, Germany. Residual volcanic glasses in foidite samples contained peculiar elongated magnetite crystals. Subsequent TEM study revealed that these crystals formed by repeated aggregation of magnetite nanoparticles along one specific crystallographic direction, most likely [111]. These features are consistent with a rare non-classical crystal growth mechanism called oriented attachment, which was mostly associated with low temperature and hydrothermal environments until now. This is the first report of oriented attachment in a natural magmatic system. Our observations raise numerous questions, relevant to the emerging field of nanolite research. It was recently proposed that precipitation of a small volume of nanoparticles in silicate melts may cause a disproportionately high increase in the effective viscosity of magma, as well as promote heterogeneous bubble nucleation. However, the proposed mechanisms critically depend on understanding temporal and morphological evolution of nanocrystals, as they coarsen into the microlite size range. As we show, this crucial step may not be straightforward at all. Non-classical crystallization pathways will influence the timescales of nanocrystal stability in the melt, and alter their morphological development.

1338

Petrological study on the magmatic processes involved in the formation of Parker Volcano, South-Central Mindanao, Philippines

Ms Marie Thess Quilalang-Gemal[2], Dr. Michihiko Nakamura[2], Dr. Takeshi Kuritani[3]
[1]Department Of Science And Technology - Philippine Institute Of Volcanology And Seismology, Quezon City, Philippines, [2]Volcano and Geofluids Research Group, Department of Earth Science, Graduate School of Science, Tohoku University, Sendai, Japan, [3]Department of Earth and Planetary Sciences, Graduate School of Science, Hokkaido University, Sapporo, Japan

Parker Volcano is a Quaternary volcano located at South Cotabato, Philippines. With an elevation of 1,784 meters above sea level, its summit is occupied by Lake Maughan, a ~2-3-km diameter caldera that have formed during the paroxysmal 1641 eruption. Since Pliocene, it has produced andesitic (52% - 63% SiO_2) to dacitic (63% - 68% SiO_2) calc-alkaline lavas. Parker lavas are mostly porphyritic with ~30 to 65% and ~40-50% phenocryst volume content for andesite and dacite, respectively. Major phenocryst phases are plagioclase and amphibole with pyroxene, biotite, and magnetite at a lesser proportion.

Whole-rock geochemistry suggests that Parker volcanism was a result of magma mixing process between a basaltic and dacitic end-member magmas having two different sources. Presence of two magmatic reservoir groups - the low P-T and high P-T groups is also supported by calcic amphibole thermobarometry. The low P-T group is a chemically- zoned reservoir found in shallower depth with the following physico-chemical parameter range: 738 -872 °C, 40-236 MPa, 4-7.6 wt% H_2O melt, and log fO_2 values of -10.6 to -14.4. This is associated with a dacitic melt containing Al-poor amphiboles. The high P-T group, stored at a deeper reservoir, is confined in these condition range: 911—1,044 °C, 607 – 1292 MPa, 5.3-10.5 wt% H_2O melt and log fO_2 values of -5 to -9. The andesitic magma carrying the Al-rich amphiboles was possibly supplied from the latter group.

REE composition shows an enrichment in LILE and a depletion in LREE and HREE. This geochemical trend indicates a typical arc signature similar to Central Mindanao and southwest Japan arc volcanoes. Strong positive anomalies for Pb and Sr and negative anomalies of Nb and Ta also suggest a subduction fluid-related magmatic process. Sr, Nd, and Pb isotope data reveal that eruptive products from Parker Volcano are adakitic in nature.

448

Emissivity of flowing basalt in the visible to near-infrared range: Multispectral imaging of Halema'uma'u lava lake, HI

Dr Erika Rader[1], Emily Forsberg[1], Dr. Leslie Baker[1]
[1]*University Of Idaho, Moscow, United States*

The amount of energy emitted from basalt at high temperatures has been measured by collecting simultaneous thermal and multispectral images of an active lava lake at night. In this study, we attempt to constrain the component of the VNIR (visible to near-infrared ~475-842nm) spectrum is due to thermal emission to evaluate the usefulness of multispectral data for detecting changes in crystallinity. Reflectance in the VNIR has proven to increase with increasing crystal abundance in solidified basalt. However, the high temperatures of molten basalt can cause glowing in the visible range which influences the absolute reflectance as well. In this study, we present side-by-side thermal and VNIR imagery of the Halema'uma'u lava lake in the evening of February 22nd, 2021 to evaluate the effect of temperatures ranging from ~400-1100oC on the brightness of the reflectance in the five bands, blue, green, red, red edge, and near-IR. Radiance values ranged from 0.001-0.008. We present emissivity values of these five bands over a range of temperatures for molten and recently solidified basalt. These values will provide greater accuracy when interpreting VNIR satellite images of hot volcanic deposits, a necessary step towards potentially providing constraints on crystal content, glass content, proportion of altered material, and chemical compositional data for dangerous or difficult to access eruptions.

1216

The Isotopic Nature of the Magmas and Crystals Involved in the 2021-22 Hunga Volcano Eruption

Dr Frank Ramos[1], Professor Phil A. Shane[2], Dr. Ingrid Ukstins[2], Dr. David Adams[2], Dr. Jui Wu[2], Dr. Joali Paredes Marino[2], Dr. Shane Cronin[2], Dr. Marco Brenna[3], Dr. Folauhola Helina Latu'ila[4], Dr. Taaniela Kula[4]
[1]New Mexico State University, Las Cruces, New Zealand, [2]University of Auckland, Auckland, New Zealand, [3]University of Otago, Dunedin, New Zealand, [4]Ministry of Lands and Natural Resources, Nuka'alofa, Kingdom of Tonga

The eruption of Hunga volcano on January 15th, 2022 emanated from an active caldera system that produces highly trace-element-depleted magmas, typical of the wider Tonga-Kermadec island arc. Tephra deposits, sampled on Tongatapu and surrounding islands, are andesitic and composed of light pumice, dark pumice, and dark vesicle-poor glass. Plagioclase, clinopyroxene, orthopyroxene, and rare olivine phenocrysts also occur. The pumices and non-vesicular glass have similar highly depleted major and trace element compositions (e.g., K2O=~0.5 wt%, Ba= ~140 ppm, Sr= ~160 ppm). They also share similar 87Sr/86Sr ratios (~0.7038) but the 143Nd/144Nd ratio of the dark pumice is significantly less radiogenic (0.5128 vs ~0.5130). This pumice also retains different (230Th)/(232Th), confirming involvement of two magmas. All glass types are highly U-enriched (i.e., (238U)/(232Th) = ~1.85) typical of those resulting from subduction-related, slab fluid additions. The two magma types also retain high (226Ra)/(230Th) ratios (≥3.0) confirming rapid extraction, differentiation, and transit to the surface. In contrast to pumice and glass (i.e., melts), elemental compositions and isotope ratios of accompanying plagioclase and clinopyroxene crystals are variable. Most plagioclase crystals (~An88-93), analyzed as single crystals, have 87Sr/86Sr ratios that are generally similar to pumices and glass (~0.7037) despite variable An contents. Glasses however, are heterogeneous but have a distinct mode at Mg# ~45, which would be in equilibrium with cpx of Mg# ~75. The mode of cpx compositions is however more mafic (Mg# ~80-90). Thus, cpx crystals are likely to originate from more mafic magma and could be relics from a deeper root zone of the magmatic system. Variable cpx Mg#s are accompanied by a range of 87Sr/86Sr ratios (~0.7035 to 0.7039). Overall, magmas and crystals reflect highly variable signatures that support the presence of at least two andesitic magmas consistent with tapping diverse parts of the system not observed in earlier Hunga eruptions.

1192

New instrumentation, approaches, and future concepts for thermal and compositional imaging of volcanic plumes

Professor Michael Ramsey[1], Professor Matthew Watson[2], Dr. James Thompson[1,3], Dr. Daniel Williams[1]
[1]University Of Pittsburgh, Pittsburgh, United States, [2]University of Bristol, Bristol, United Kingdom, [3]Baylor University, Waco, United States

The measurement and analysis of volcanic point-source emissions can, for example, indicate a potential eruption, determine the impact on the local environment, and quantify the contribution to the global atmosphere. However, gas flux measurements require knowledge of local wind fields and are therefore generally confined to ground or airborne retrieval methods. These measurements rely on the absorption properties of a particular gas to identify that species and quantify its mass. The most notable species is SO_2, which is measured using Fourier Transform Infrared (FTIR) spectroscopy and Differential Optical Absorption Spectroscopy (DOAS). These approaches are quite successful, but not always practical nor affordable everywhere. In contrast, spaceborne gas retrievals are limited by the technical specifications of current orbital sensors, with none being designed specifically to detect and measure the smaller scales of passively degassing plumes. The temporal, spatial, and spectral resolution of these instruments is simply not adequate; and at best, the data provide a snapshot in time of the mass loading in the largest of plumes. The derivation of true gas flux rates from orbit remains elusive. Therefore, a step-change in spaceborne volcanology can only be achieved through a dedicated mission focused specifically on point-source emission science: an orbital plume observatory. If we are to move forward, such a system needs to acquire hypertemporal data (sub-minute) with much-improved spectral and spatial resolutions, coupled with the ability to derive gas flux directly from the data. Such a mission is currently being proposed and, if successful, would see these data and science advancements returned before the end of the decade. We will report on this mission concept as well as new ground-based thermal infrared, multi-spectral cameras designed to measure SO_2 (and other gas) flux rates in the field. In addition to the science, these data provide calibration/validation for the proposed orbital mission.

1389

High-resolution sensitivity analysis with application to interpreting volcanic unrest observations

Dr Ludovic Räss[1,2], Dr Ivan Utkin[1,2]
[1]*ETH Zürich, Zürich, Switzerland,* [2]*Swiss Federal Institute WSL, Zürich, Switzerland*

Continuum-based numerical modelling is a useful tool for interpreting field observations and geological or geotechical data. In order to match the available data and the results of numerical simulations, it is necessary to estimate the sensitivity of a particular model to changes in its parameters. Recent advances in hardware design, such as the development of massively parallel graphical processing units (GPUs), make it possible to run simulations at unprecedented resolution close to that of the original data. Thus, automated methods of calculating the sensitivity in a high-dimensional space of parameters are in demand.

The adjoint method of computing sensitivities, i.e., gradients of the forward model solution with respect to the parameters of interest, gains more attention in the scientific and engineering communities. This method allows for computing the sensitivities for every point of computational domain using the results of only one forward solve, in contrast to the direct method that would require runninng the forward simulation for each point of the domain. This property of adjoint method significantly reduces the amount of computational resources required for sensitivity analysis and inverse modelling.

In this work, we calculate the point-wise sensitivity of ground deformations during volcanic unrest to the values of various model parameters such as elastic moduli of rock. We apply the adjoint method to infer the values of sensitivity in a whole computational domain. We present the massively parallel numerical code leveraging the GPU technology to solve both forward problem and adjoint problem to compute sensitivities. We present an application of our method to esitmate the sensitivity of observed ground deformations to the thermophysical properties of rock at Campi Flegrei hydrothermal system.

1194

Insights into off-axis volcanism at Mt Taranaki from plagioclase zoning

Miss Lena Ray[1], Dr. Shane Cronin[1], Dr. Ingrid Ukstins[1], Dr. Phil Shane[1]
[1]*University Of Auckland, Auckland, New Zealand*

Mt Taranaki, New Zealand, has a 50 % chance of erupting in the next 50 years and will likely inflict significant damage and disruption to the entire country when this happens. The edifice is dominated by the main summit vent, with one prominent off-axis vent (Fanthams Peak/Panitahi) (~3 ka – 1.4 ka BP), five lava domes (<7 ka BP), and one recent monogenetic mafic vent (~1.2 ka BP). Many prior studies have focused on eruption products from the summit vent, but off-axis volcanism remains relatively poorly understood. Here, we use detailed textural and chemical data of plagioclase phenocrysts from proximal lava and pyroclastic material to understand the magmatic system feeding the secondary vents at Mt Taranaki. Plagioclase and clinopyroxene are the dominant phenocrysts (20-40%), with subsidiary Fe-Ti oxides, amphibole, and olivine (<5%). All amphiboles show some degree of disequilibrium, from symplectite reaction rims to total replacement of the primary mineral, and olivine commonly shows rim growth of amphibole and/or clinopyroxene. Clinopyroxene phenocrysts (Mg# = 64-90, avg. = 76) commonly have oscillatory zoning or overgrowth rims. Plagioclase cores display systematic compositional variation between the polygenetic Mt Taranaki summit (An# = 30-95,) and Panitahi (An# 47-95, avg. = 76) vents, the mafic Curtis Ridge Vent (An# = 74-93, avg. = 86), and the five lava domes (An# = 46-69, avg = 57). The Curtis Ridge Vent has high-An cores, lava domes low-An cores, and Panitahi and summit vents the whole range of observed compositions. Compositional profiles of the outermost rims of plagioclase suggest that the off-axis vents have variable pre-eruptive conditions. In addition, near-simultaneous eruptions from the summit vent and Panitahi do not appear connected. These findings support the idea that the Mt Taranaki magma system is dispersed, with possible interchange between magma storage chambers.

559

Advancement in the knowledge of the volcanism in the northern Victoria Land (Antartica) using marine and continental tephra deposits

Dr Paola Del Carlo[1], Dr Alessio Di Roberto[1], Dr Massimo Pompilio[1], Dr Giuseppe Re[1], Bianca Scateni[1,2]
[1]*Istituto Nazionale Di Geofisica E Vulcanologia - Sezione di Pisa, Pisa, Italy,* [2]*Dipartimento di Scienze della Terra - Università di Pisa, Pisa, Italy*

In the last decade, within the framework of TEFRAROSS, TRACERS, ICEVOLC and CHIMERA projects funded by PNRA (Programma Nazionale di Ricerche in Antartide), tephrostratigraphic studies have been carried out in the northern Victoria Land, Antarctica, allowing to get new important data on the volcanic history of the area, dispersal of volcanic products and eruptions dynamics.

We present here relevant results obtained by studying marine sequences of the Ross Sea, proximal pyroclastic sequences exposed on volcanoes summit areas and tephra layers preserved within the ice records. Main findings indicate that Mount Rittmann and Mount Melbourne volcanoes were extremely active during the late Pleistocene to historical times and are the sources of several markers beds. We identified at least two phonolite to phono-trachyte caldera-forming eruptions from Mount Ritmann occurred at c. 11 ka and in 1254 C.E. and eight trachybasaltic to trachytic, Strombolian/Vulcanian to sub-Plinian/Plinian eruptions from Mount Melbourne, the most intense of which yielded an age of 13.5 ± 4.3 ka. Results have provided significant advancement in the knowledge of the eruptive activity of these volcanoes during the Late Pleistocene and Holocene also for a better assessment of the volcanic risk connected to possible future eruptions.

557

How long has the Recent Stromboli's feeding system been so steady? Information from tephrostratigraphy.

Dr Massimo Pompilio[1], Dr Giuseppe Re[1], Dr Paola Del Carlo[1], Dr Alessio Di Roberto[1]
[1]*Istituto Nazionale Di Geofisica E Vulcanologia - Sezione di Pisa, Pisa, Italy*

Stromboli is known for its persistent activity and for the steadiness of its feeding system over the time. On the upper part of the volcano, two different sequences separated by a paleosoil, are recognisable: the Upper Sequence (U-Seq), younger than 8th century CE, consisting of coarse ash deposits associated with discrete layers of lapilli fallout, and the Lower Sequence (L-Seq), containing cm to dm-thick lapilli beds, alternated with massive slightly-reworked ash. Textures and compositions of the U-Seq volcanics match with those of the present-day activity, dominated by quasi-persistent mild explosions, periodically disrupted by more energetic paroxysms. Occurrence and intensity of paroxysms are modulated by the interaction between the deep, gas-rich and crystal-poor magma (LP), and the shallow degassed and crystal-rich magma (HP). By contrast, the L-Seq volcanics are compatible with repeated episodes of lava fountains separated by periods of quiescence; features of the plumbing system that fed such eruptive style are yet poorly known. To overcome this gap, we carried out several hand-dug trenches, on the upper NE flank of the volcano, and detailed tephrostratigraphic investigations. This study has produced new dating and the physical characterization of L-Seq deposits to deduce eruptive parameters. Petrology of the L-Seq volcanics provided insights on the plumbing system active before the 8th century CE and on its evolution back in times. Our findings highlight that L-Seq activity began more than 3 ka BP, being much older than previously thought. Moreover, L-Seq exhibits a compositional variability (Shoshonitic-HKCA series) much larger than that observed in U-Seq products. It is also worth to note that L-Seq was fed by two distinct magmas with different crystal content, mixed together during the eruptions; such dynamic indicates a substantial persistence of the magmatic processes that control the eruptions of this volcano over the time.

962

In situ observation of aggregates in volcanic ash clouds

Madeleine Reader[1], Professor I. Matthew Watson[1], Rob Clarke[1], Tom David[1], Liam Fletcher[1], Alex McConville[1], Duncan Hine[1], Professor Tom Richardson[1], Dr Kieran Wood[2], Gustavo Chigna[3], Roberto Merida[3], Josh Lucas[1], Dr Emma Liu[4]

[1]University Of Bristol, Bristol, United Kingdom, [2]The University of Manchester, Manchester, United Kingdom, [3]Instituto Nacional de Sismología, Vulcanología, Meteorología e Hidrología (INSIVUMEH), Guatemala City, Guatemala, [4]University College London, London, United Kingdom

In-situ aggregates have been found on scanning electron microscope (SEM) stubs flown through an ash cloud on an unoccupied aerial system (UAS) at Volcan de Fuego, Guatemala. During January 2022 fixed-wing UAS flights were carried out over the volcano, carrying multiple SEM stubs. The stubs were deployed as the drone entered an ash cloud and returned to the fuselage on exit. One particular flight on the 13th of January exposed two SEM stubs, released simultaneously, with captured aggregates visible upon inspection. The full stubs were imaged at low magnification using a Hitachi S-3500N SEM and the individual aggregates which range in size from ~500-1100 microns, were imaged at various magnifications up to 1000x. These images were then stitched and analysed further to calculate individual particle sizes within the aggregate. They all show the trend of having larger particles in the centre (~50-70 microns) grading out to finer particles around the rim (~5-15 microns). One possibility as to why these aggregates formed is the presence of water, as on the day of the drone flights there was significant mixing of the ash cloud and meteorological cloud which was present above the volcano. They are also forming extremely quickly as these stubs were released approximately less than five minutes after an eruption and about 100 metres from the summit. No other stubs flown on subsequent days or previous campaigns have shown the presence of these aggregates because ingress into meteorological cloud is typically avoided. Rapid aggregate formation is important to understand and explore further due to its potential influence on ash dispersion.

807

Investigating aerosols from passively degassing volcanoes with unmanned aerial systems (UAS/drones): First insights from cascade impactors and filter packs

Mr Marco Rebecchi[1], Dr. Cynthia Werner[2], Dr. Celine Mandon[3], Dr. Bruce L. A. Charlier[1], Dr. C. Ian Schipper[1]
[1]Victoria University of Wellington - Te Herenga Waka, Wellington, New Zealand, [2]Private contractor, New Plymouth, New Zealand, [3]University of Iceland, Reykjavik, Iceland

Passively degassing volcanoes dominate volcanic gas emissions to the atmosphere over decadal timescales. While field measurement techniques for volcanic gases are already well established and frequently used at volcanoes around the world, field measurement techniques for volcanic aerosols suspended within those gases are not as regularly implemented. This study aims to develop a precise and consistent volcanic aerosol sampling methodology by adopting UAS/drone technology combined with classical aerosol sampling devices such as filter-based cascade impactors and filter-packs. By doing so, we attempt to overcome commonly encountered issues of not being close enough to the volcanic aerosol source (e.g., vent, fumarole) due to hazardous volcanic environments, which often leads to the sampling of atmospherically diluted aerosols at distance (e.g., crater rim, downwind). With these systems we thus aim to obtain more concentrated aerosol samples from closer to source, and along the plume trajectory. The drone fleet, consisting of two quadcopters and two hexacopters, as well as a bespoke aerosol sampling setup have been designed and assembled in a low-cost, light and portable format including gas sensors (SO_2, CO_2) and radio transmitters for real-time data visualisation in the field. First insights on the efficiency of this new aerosol sampling method are highlighted by first datasets collected from test deployments in urban and geothermal environments (downtown Wellington City and Tauhara geothermal field in Taupo, New Zealand). They showcase chemical results from solution ICP-MS analyses as well as investigations of aerosol textural morphologies and their distributions from SEM imaging and image analysis. These initial analyses will inform technique development before field deployment at passively degassing volcanoes of the South Pacific. Ultimately, this methodology will contribute to a more precise understanding of volcanic emissions and volcanic contributions to atmospheric aerosol concentrations.

1361

Effusive–explosive transition on eruptions at Quizapu volcano: Re-analysis of the 1846-1847 and 1932 eruptions and conduit flow modeling

Alejandro Rebolledo[1], Angelo Castruccio[1], Álvaro Aravena[2]
[1]Departamento de Geología, Universidad De Chile, Plaza Ercilla 803, Casilla 13518, Santiago, Chile, [2]Facultad de Ciencias Básicas, Universidad Cátolica del Maule, Talca, Chile

Quizapu volcano is an active volcano located on the Southern Volcanic Zone of the Chilean Andes, whose recent eruptive record includes two large eruptions: 1846-1847 and 1932. Both events emitted > 3 km³, but the 1846-1847 event was essentially effusive, while the 1932 was one of the largest Plinian eruptions of the XX century on a global scale. Although previous studies suggested some mechanisms to explain this different behavior, such as different viscosities and exsolution dynamics of volatiles in the magma chamber, we propose an alternative explanation based on observation of eruptive parameters and numerical modelling of magma ascent.

We re-assessed the erupted volume of the 1846-1847 event, with a value of ~3 km³ which is considerably less than previous estimations (5 km³). In contrast, our new estimation of the 1932 event suggest that the erupted volume was in the range of 14-20 km³ (7-10 km³ DRE) which is larger than the previous value (5 km³ DRE).

Our 1-D model of magma ascent includes a method to estimate the conduit radius based in thermal considerations, rheology of magma and wall-stability analysis. Our results suggest that the 1846-1847 event was preceded by a slow injection of magma into a shallow magma chamber, that favored large amounts of magma mingling. The mafic inclusions associated with this mingling increased the viscosity of magma, which in turn, reduced ascent velocity and favored gas scape and the development of effusive volcanism with a relatively narrow volcanic conduit. On the other side, the 1932 event was triggered by a fast magma injection, low degree of mingling which favored an explosive eruption. Due to the instability of conduit walls, the conduit radius increased to > 30 m, producing a Plinian eruption.

580

Snow suppresses seismic signals from Steamboat Geyser

Mara Reed[1], Michael Manga[1]
[1]Department of Earth and Planetary Science, University Of California, Berkeley, Berkeley, United States

Much like volcano monitoring, geyser monitoring suffers from temporal, geographic, and instrumental biases. We present a bias identified in seismic monitoring of Steamboat Geyser in Yellowstone National Park, USA. Eruptions of Steamboat are the tallest of any active geyser in the world and they produce broadband signals at two nearby stations in the Yellowstone National Park Seismic Network. In winter, we observe lower signal amplitudes from major eruptions of the geyser at frequencies >22 Hz. Instead of a source effect, we find that environmental conditions affect the recorded signals, which we interpret as a mixture of direct seismic and ground-coupled airwave arrivals. Lower amplitudes are correlated with greater snow depths, and we calculate that vertical ground velocity from airwave arrivals is attenuated by 0.04 dB per cm of snow. More long-term monitoring is needed at geysers to track changes over time and identify recording biases that may be missed during short, sporadic studies.

812

Geyser gazing: engaging with the geyser enthusiast community in Yellowstone

Mara Reed[1,4], M A Bellingham[2], Tara Cross[3], Alan Glennon[4]
[1]Department of Earth and Planetary Science, University of California, Berkeley, , United States, [2]Retired, , United States, [3]Geyser Observation and Study Association, , United States, [4]GeyserTimes, , United States

As energetic displays of crustal fluid processes and promising analogs of volcanoes, geysers attract researchers across diverse disciplines. They also fascinate non-scientists drawn to the beauty and puzzle of their eruptions. Most geysers in Yellowstone National Park, USA are not continuously monitored by managing agencies. Geyser enthusiasts in Yellowstone (often called "geyser gazers") have a wealth of collective knowledge about past and present geyser activity which can fill in the gaps. Two enthusiast-led nonprofit organizations centralize this information: the Geyser Observation and Study Association (GOSA), which publishes a newsletter and a peer-reviewed journal, and GeyserTimes, a crowdsourced database of geyser observations. However, knowledge does not easily flow outside of this community because geyser gazers are few in number compared to most hobbyist groups, circulation of GOSA publications is low, and visual observations (especially those by non-scientists) are often undervalued. We describe three joint scientist-enthusiast efforts that integrate geyser gazer knowledge into research: (1) consultation with geyser gazers to maximize safety when working in thermal areas, (2) development of a researcher-friendly section of GeyserTimes to make robust datasets more visible and accessible, and (3) ongoing research related to the understudied disturbance phenomenon in Norris Geyser Basin, which relies on visual observations from geyser gazers recorded since 2013. Disturbances are events characterized by widespread boiling, turbidity, and abrupt activity changes in thermal features.

1422

Storage and Eruption of an Extreme Magmatic Differentiate: Sugarloaf Mountain, USA

Ms Allison Huisa[1], Professor Mary Reid[1], Dr. Jorge Vazquez[2]
[1]Northern Arizona University, Flagstaff, United States, [2]Stanford University/USGS, Palo Alto, United States

Sugarloaf Mountain, located on the flanks of the San Francisco Mountain stratovolcano in northern Arizona, is the youngest silicic monogenetic eruption in the San Francisco Volcanic Field. It comprises an ~0.1 km3 lava dome and associated tephra, and is composed of sanidine-bearing high silica rhyolite (>75 wt.% SiO2), with accessory zircon, allanite, and possibly chevkinite. Precise 238U-230Th disequilibrium dating was permitted by exceptionally high UO2 concentrations (0.7-2.3 wt.%) in Sugarloaf zircons. Most zircon surfaces yield a weighted mean model age of ~75 ka (n =28; MSWD= 1.8 to 2.0), assuming initial ratios within 15% of secular equilibrium of the whole rock U/Th, and a zircon isochron date of 76.5 ± 7.3 ka (2σ). The allanite surfaces (n=61) yield weighted mean model ages from 72.6 ± 0.3 ka (MSWD= 1.7) and 79.7 ± 0.2 ka (MSWD= 1.4) for the same range in initial ratios. The zircon-allanite surfaces isochron date is 75.4 ± 1.0 ka. Allanite interiors and four hornblende-hosted zircons, in contrast, give dates that average ~10 kyr older than the surfaces.

The allanite surfaces are compositionally uniform, using MnO/FeO as a proxy for differentiation. This homogeneity, along with the largely uniform zircon and allanite surface dates, indicate accessory phase co-crystallization and delimit the timing of final rim growth. The resulting maximum eruption age is ~15 kyr younger than a 91±2 ka sanidine 40Ar/39Ar date reported by Morgan et al. (2010). Judging by zircon and allanite growth rates, the grains were immersed in a compositionally uniform melt for at least 1 kyr prior to eruption, and results for the allanite interiors and zircon inclusions imply magma storage for ~10 kyr. Remobilization and eruption of the 75 ka Sugarloaf rhyolite may have been associated with a magmatic flare-up recorded as similarly aged eruptions within an ~250 km2 area.

288

An interconnected plumbing system in a complex volcanic rift setting

Dr Miriam Christina Reiss[1], Dr James Muirhead[2], Dr Luca De Siena[3], Dr Georg Rümpker[1]
[1]*Goethe University Frankfurt, Frankfurt, Germany,* [2]*University of Auckland, Auckland, New Zealand,* [3]*Gutenberg University Mainz, Mainz, Germany*

Understanding the plumbing system of rift volcanoes is essential when examining the interplay between tectonic and magmatic forces. Recent seismicity, volcanic activity, magma emplacement, and volatile release make the Natron basin the ideal location to study these processes in the East African Rift System. Here, we present detailed seismicity patterns, focal mechanisms and the first high-resolution tomographic attenuation imaging of Oldoinyo Lengai volcano and surrounding volcanic systems from a temporary seismic network.

Between March 2019 and May 2020, we locate ~10 000 earthquakes with ML -0.85 to 3.6. We observe seismicity down to ~20 km depth beneath Naibor Soito volcanic field and Oldoinyo Lengai. Shallower seismicity down to ~10 km occurs beneath the inactive shield volcano Gelai, including two fluid driven swarms. Focal mechanisms vary spatially and are a strong indicator for differences between magmatic and tectonic forces. To study the plumbing system in more detail, we apply attenuation imaging. Areas of high scattering and absorption reveal fluid-filled fracture networks below regions of magmatic volatile release at the surface and seismic swarms at depth. Eruptions at Oldoinyo Lengai may be fed via different pathways with different melt compositions. While the deeply-penetrating, highly fractured fluid-filled Natron border fault may support the production and ascent of carbonatite melt, a high absorption body at 8-14 km depth, interpreted as a sill complex, may supply silicic melt to Oldoinyo Lengai and other rift volcanoes.
Our results indicate that the Natron basin is a segmented rift system, in which fluids preferentially percolate in a region where strain transfers from a border fault to a developing magmatic rift segment. This affects the shape of the melt reservoir and supports lateral and vertical connections between shallow- and deep-seated magmas, where fluid and melt transport to the surface is facilitated by intrusion of dikes and sills.

289

Volcanic Tremor at Oldoinyo Lengai volcano

Dr Miriam Christina Reiss[1], Dr Georg Rümpker[1]
[1]*Goethe University Frankfurt, Frankfurt, Germany*

Oldoinyo Lengai is the only active natrocarbonatite volcano world-wide and presents an important endmember magmatic system in a young rift segment of the East African Rift System. This volcano typically experiences long-duration episodes of natrocarbonatitic effusions with intermittent short-duration explosive eruptions. Previous seismicity and imaging studies have illustrated that a complex, rift-wide interconnected magmatic plumbing system feeds this volcano (Reiss et al., 2021; 2022). Here, we show the first observations of persistent seismic and infrasound tremor from February 2019-2020 captured by the temporary SEISVOL network (Reiss & Rümpker, 2020).

We use data from a seismometer and co-located infrasound station at the summit of Oldoinyo Lengai to characterize the tremor. Seismic tremor is nearly constantly present throughout the year but changes significantly in amplitude, form and dominant frequency content while acoustic tremor occurs less frequently and me be hampered by wind. Seismic tremor displays wide-spectra frequency content between 5-25 Hz, but dominant frequencies may alter between 5 and 20 Hz. We observe (1) days-long tremor episodes with either spasmodic or harmonic characteristics, (2) week-long episodes of strongly banded tremor with recurrences of minutes, (3) pulsating tremor, (4) partially strong coupling between seismic and infrasound tremor, (5) frequency gliding.

We relate episodes with strong coupling between seismic and infrasound tremor to shallow eruption processes within the crater. Episodes of strong banded tremor seem to roughly correlate with thermal anomalies detected by satellites and may therefore be related to larger volume melt transport and eruptions. We use seismic stations of the network that were closest to the edifice to further constrain the location of the seismic tremor which is located in the shallower part of the edifice.

313

The Solubility of Quartz in Supercritical Water from 375 to 600˚C and 200 to 270 bar

Dr Peter Rendel[1], Dr Bruce Mountain[1]
[1]*GNS Science, Wairakei, Taupo, New Zealand*

The solubility of quartz in deionized water has been determined experimentally from 375 to 550˚C and 200 to 270 bar. The experiments were performed using a unique flow-through reactor capable of reaching supercritical conditions for pure water. The results cover the approximate range of temperature and pressure expected to be found in deep geothermal systems where supercritical conditions are expected. Quartz solubility has not been previously well-defined in this region. The new experimental data are used to refine the empirical parameters in the original Fournier and Potter equation for quartz solubility.

995

Regional mapping and volcanic risk ranking of the Central Volcanic Zone of the Andes

María-Paz Reyes-Hardy[1], Luigia Sara Di Maio[1], Lucia Dominguez[1], Corine Frischknecht[1], Sébastien Biass[1], Leticia Freitas Guimarães[2], Amiel Nieto-Torres[3], Manuela Elissondo[4], Maira Figueroa[5], Sebastián García[4], Álvaro Amigo[5], Costanza Bonadonna[1]

[1]Department of Earth Sciences, University of Geneva, 1205 Geneva, Switzerland, , , [2]Department of Geology - Geosciences Institute, Federal University of Bahia, Salvador, Brazil, , , [3]Escuela Nacional de Ciencias de la Tierra, Universidad Nacional Autónoma de México, Ciudad de México, Mexico., , , [4]Servicio Geológico Minero Argentino, SEGEMAR, Argentina, , , [5]Servicio Nacional de Geología y Minería, Red Nacional de Vigilancia Volcánica, Temuco, Chile, ,

The Central Volcanic Zone of the Andes (CVZA) is located along southern Peru, the altiplano of Bolivia and Puna of northern Chile and Argentina, between latitudes 14-28°S of the Andean cordillera. A large part of this zone is over 4000 m in altitude constituting a high, arid, and exceptionally remote region. As a result, detailed descriptions of volcanic eruptions and their deposits remain largely incomplete. In fact, the recent effort undertaken to characterize the volcanoes of the CVZA and their activity is revealing some significant uncertainty in the identification of active volcanoes. Given limited resources and the large number of volcanoes in the CVZA, among which some are surrounded by densely populated areas with critical infrastructures, it is critical to prioritize the implementation of risk-reduction strategies for the volcanoes identified as presenting the highest risk levels.

To do so, this work presents a renewed list of 62 active and potentially active volcanoes of the CVZA; including volcanoes dominantly active during the Holocene but also some Pleistocene volcanic centers showing fresh morphology and/or signs of unrest. Considering the elements at risk, we have analyzed the use of hazard-exposure regional mapping and the application of the recently developed Volcanic Risk Ranking (VRR) strategy. Both strategies help identify the volcanoes that can potentially impact this region based on a different use of the data. As the VRR integrates not only hazard and exposure, but also vulnerability and resilience, we have estimated the highest risk levels in the CVZA. Our results demonstrate how objective risk-ranking methodologies can help relevant institutions to identify and prioritize the implementation of risk-mitigation actions at a regional scale.

996

Volcanic hazards and their physical impacts on the built environment during the 2021 eruption of Cumbre Vieja volcano, La Palma

Ms María-Paz Reyes Hardy[1], Lucia Dominguez[1], Luigia Sara Di Maio[1], Corine Frischknecht[1], Sebastien Biass[1], Giulio Zuccaro[2], Costanza Bonadonna[1], Nemesio Pérez[3,4]
[1]Department of Earth Sciences, University of Geneva, 1205 Geneva, Switzerland, , , [2]Department of Structures for Engineering and Architecture, University of Naples "Federico II", Naples, Italy, , , [3]Instituto Tecnológico y de Energías Renovables (ITER), Granadilla de Abona, Tenerife, Canary Islands, , , [4]Instituto Volcanológico de Canarias (INVOLCAN), San Cristóbal de La Laguna, Tenerife, Canary Islands, ,

The recent volcanic activity on La Palma, one of the youngest islands of the Canarian Archipelago (Spain), has been characterised by simultaneous explosive and effusive activity associated with monogenetic volcanism. Vent areas are distributed along fissures with higher vents producing predominantly tephra plumes and lower vents producing predominantly lava flows. Historical eruptions of the last 500 years have generated scoria cones, tephra deposits and extensive lava flow fields that often reached the sea. The 2021 eruption started in the northern part of the Cumbre Vieja Ridge on 19 September 2021 and lasted 85 days. A rapid evolution of vents along a ~0.5 km long fissure was followed by simultaneous lava flows and tephra plumes of 3.2 km a.s.l in average. The resulting tephra deposit is elongated SW-NE with a cumulative volume of about 2.3x107 m3. The lava flows covered a total area of 12.19 km2, directly affecting three municipalities and burying more than 1600 buildings. We have studied the evolution of compound hazards (tephra and lava) and their physical impact on the built environment based on field observations and satellite images. The physical impacts assessment on buildings includes i) the spatio-temporal evolution of tephra deposits and lava flows (i.e., extension and thickness progression over time), ii) the syn- and post-eruption field impact assessment of buildings, and iii) the timing of tephra cleaning-up operations of building roofs. We discuss the distribution and diversity of impacts due to both lava flow and tephra fallout and the influence of roof cleaning during the eruption. Our results are useful inputs to improve existing tephra fragility curves for building roofs and to better understand the impacts of compound hazards in multi-hazard volcanic environments.

1305

Dynamic cap-rock formation above a silicic magma reservoir, Reyðarártindur pluton, Iceland

Dr Emma Rhodes[1,2], Dr Steffi Burchardt[1,2], Dr Hugh Tuffen[3], Dr Mike Heap[4,5], Dr Fabian Wadsworth[6], Dr Abigail Barker[1,2], Mr. Hei Ho Chun[1], Dr Dave McGarvie[3], Ms Taylor Witcher[1], Dr Holly Unwin[3], Dr Tobias Schmiedel[7]

[1]Department of Earth Sciences, Uppsala University, Uppsala, Sweden, [2]Centre of Natural Hazards and Disaster Science, Uppsala, Sweden, [3]Lancaster Environment Centre, Lancaster University, Lancaster, United Kingdom, [4]Institut Terre et Environnement de Strasbourg, Université de Strasbourg, Strasbourg, France, [5]Institut Universitaire de France , Paris, France, [6]Department of Earth Sciences, Durham University, Durham, United Kingdom, [7]Department Geoscience & Engineering, TU Delft, Delft, The Netherlands

The rates of heat and fluid transfer from magma bodies, and hence the development of geothermal reservoirs, are primarily influenced by the properties of the surrounding host rock. However, exploration of geothermal systems related to shallow-crustal magma bodies via geophysical methods and drilling often miss 3D features that exert controls on the geothermal system development. This study uses field mapping, sampling, laboratory rock strength testing, and geochemical modelling to detail the dynamic interactions between a fossil granitic magma body and its host rock.

The granitic Reyðarártindur pluton intruded into zeolite facies meta-basalts at approximately 2 km depth. Notably, the geological setting and composition mirrors that of the IDDP-1 and future KMT drilling projects. At Reyðarártindur, exposure to the heat from the pluton caused a 10 m-thick zone of the host rock above the pluton to be altered to a hornfels, which lacks primary basaltic structures, such as cooling joints and auto-breccias. The hornfels is extremely strong and is essentially impermeable as a result of recrystallization and sintering that eliminated all porosity in the rock and healed fractures. Partial melting of the meta-basalt produced felsic magma, now exposed as a thin layer of granite withenriched rare earth element concentrations. At a later stage of pluton development, overpressure buildup associated with magma recharge, facilitated by the low-permeability cap-rock, resulted in the formation of systematic fracture sets within the cap-rock.

The hornfels cap-rock acted as a 'lid' to the magma body, restricting the loss of heat and fluids from the magma reservoir. Convective transfer of heat and fluids would have only developed once faults and fractures penetrated the cap-rock. This study highlights the importance of the processes occurring at the magma-host rock interface, in particular the timing and 3D geometry, for the development of the associated magmatic-hydrothermal system (i.e. the geothermal resource).

1462

Detailed morphology of the Hunga Tonga–Hunga Haʻapai caldera: evolution of the submarine volcano after the explosive eruption

Dr Marta Ribó[1], Professor Shane Cronin[2], Sönke Stern[2], Sung-Hyun Park[3], Dr James Garvin[4], Taaniela Kula[5], Folauhola Helina Latu'ila[5], Pupunu Tukafu[5], Nikolasi Heni[5]

[1]Auckland University Of Technology (AUT), Auckland, New Zealand, [2]The University of Auckland, Auckland, New Zealand, [3]Korea Polar Research Institute, Seoul, South Korea, [4]National Aeronautics and Space Administration (NASA), Greenbelt, Maryland, United States, [5]Tonga Geology Services, , Tonga

Submarine eruptions dominate volcanism on Earth, but the recent eruption of Hunga Tonga–Hunga Haʻapai volcano in January 2022 was one of the most explosive eruptions ever recorded. Many large calderas collapse during eruptions and the resulting morphology provides unvaluable information for understanding the processes during highly unpredictable eruptions.

Here we present a detailed analyses of the post-eruption morphology of the caldera of the Hunga Tonga–Hunga Haʻapai submarine volcano. We use the first multibeam bathymetry of the caldera, acquired only 5 months after the eruption on the MV Pacific Horizon, in May 2022.

The multibeam data shows landslides with 0.5-1 km wide scars, mainly on the southern rim, with the deposits extending to the central part of the caldera. However, the flat inner caldera suggests that most of the material was deposited simultaneously to the caldera drop following the eruption, on the order of 800 m. Sediment cores collected inside the caldera show repeated turbidity current sedimentation pointing to ongoing mass wasting, which could have potentially led to eventual breaching of the rim on the north and east side. Submarine ridges were preserved on these sites, separating the inner caldera and two erosional channels on the outer part, which point to the main debris transport paths during the eruption. More than 50 active gas plumes are observed on the eastern side, located following a straight W-E transect, and on the northern side, where the vents are covering the collapse walls close to the eastern Hunga Tonga–Hunga Haʻapai island. The presence of these vents and their distribution related to the morphology of the caldera, indicate the most energetic parts of the volcano, which can potentially still be hazardous. Our morphological analyses provide new insights of transport and depositional processes following highly energetic submarine eruptions.

759

Increased volcanic risk to nautical activities following morphological changes at Stromboli's crater terrace since 2019

Dr Tullio Ricci[1], Riccardo Civico[1], Piergiorgio Scarlato[1], Daniele Andronico[2], Massimo Cantarero[2], Emanuela De Beni[2], Elisabetta Del Bello[1], Ulrich Kueppers[3], Markus Schmid[3], Jacopo Taddeucci[1]
[1]Istituto Nazionale di Geofisica e Vulcanologia, Roma, Italy, [2]Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo, Catania, Italy, [3]Department of Earth and Environmental Sciences, Ludwig-Maximilians-Universität (LMU), Munich, Germany

Volcanic hazard assessment at active volcanoes requires repeated surveys to establish a robust baseline and reveal status variations. At Stromboli (Italy), ground-based morphological surveys have been aided by Uncrewed Aircraft Systems (UASs) since 2013 revealing a plethora of new details. Until 2019, in periods of ordinary Strombolian activity, slope collapse events did not pose a significant hazard for the sea sector offshore Sciara del Fuoco (SdF). The occurrence of two paroxysmal eruptions on 3 July and 28 August 2019 abruptly changed the morphology of the entire crater terrace. Notably, the dismantling of the outer rim of the north crater area (NCA) resulted in the modification of its shallow plumbing system, the lowering of the new NCA rim, and the northward shift of the vents located in its eastern sector, towards the steep slope of SdF. This facilitated the opening of new vents at the border between the crater terrace and SdF, the piling-up of loose pyroclastic debris on SdF, lava overflows and local collapse of those unstable vents. As a consequence, ordinary activity can now result in pyroclastic density currents (PDCs) propagating offshore for several hundred meters. Previously, these hazardous events were typically associated with the opening of effusive vents along the SdF (as in 2002) or the occurrence of paroxysmal eruptions (as in 2019). Since the end of March 2020, five episodes of PDCs have been observed associated with both ordinary Strombolian activity (28-31 March 2020, 19 May 2021, 25 July 2022) and a major explosion (16 November 2020). The relatively high temporal frequency of UASs surveys after the 3 July 2019 paroxysmal eruption (17 surveys) allowed us to investigate the temporal and spatial evolution of the NCA of Stromboli's crater terrace, involved in all the collapse episodes, and to quantify the propensity for recurrent mass wasting events.

1089

Remembering to Forget: How memories of the Teneguía (1971) eruption shaped the response to the 2021 Tajogaite eruption, La Palma.

Miss Rosie Rice[1], Dr Amy Donovan[1], Prof Clive Oppenheimer[1]
[1]*University Of Cambridge, Cambridge, United Kingdom*

La Palma, Canary Islands, is one of the most volcanically active islands of the archipelago, with three eruptions occurring within living memory (Carracedo et al., 2001). In September 2021, La Palma gripped the world's media as a fissure eruption began on the 19th of September, after fifty years of quiescence (Longpré, 2021). The eruption quickly became the most destructive in La Palma's history; with over 2,000 buildings destroyed by lava flows, the level of destruction was unprecedented and left deep psychological scars for those who lived through it. The last eruption to occur in La Palma was the 1971 eruption of Teneguía, a strombolian eruption that occurred near the sparsely populated town of Fuencaliente (Araña, 1974). The Teneguía eruption caused minimal damage and was thus fondly remembered for the natural show of a lifetime it gave locals and tourists who flocked from across the globe to view the spectacle (ibid). This dissertation aims to draw upon previous work on memorialisation within disaster risk reduction research (e.g., Longo, 2019 and Madson & O'Mullen, 2013) and cultural geography to apply the lens of memory and identity studies to the 2021 Cumbre Vieja eruption. By conducting interviews with civilians and elites combined with discourse analysis of newspaper articles, this dissertation found a substantial relationship between memories of Teneguía, the Palmero island identity, and the response to the 2021 eruption. A year after the eruption, further research seeks to understand how the 2021 Tajogaite eruption is being memorialised and the ramifications for hazard management in the Canary Islands. Similarly, further research aims to identify the wider importance of understanding how island identities and rich volcanic histories, affect community response and resilience to volcanic hazards.

649

A Vertical Take-Off and Landing (VTOL) Drone for Volcano Monitoring

Professor Tom Richardson[1], Professor Matt Watson[1], Mr Thomas David[1], Mr Duncan Hine[1], Mr Liam Fletcher[1], Mr Alex McConville[1], Mr Robert Clarke[1], Mr Hirad Goudarzi[1], Mr Peiman Moradi[1], Dr Steve Bullock[1], Dr Tom Rendall[1], Dr Emma Liu[2], Dr Kieran Wood[3]
[1]University of Bristol, Bristol, United Kingdom, [2]University College London, London, United Kingdom, [3]University of Manchester, Manchester, United Kingdom

Volcano research and monitoring frequently requires in-situ measurements in hazardous or inaccessible locations. Unoccupied Aircraft System (UAS) technology has undergone transformational advances over the past decade; however, the conditions encountered within volcanic environments, combined with the increasingly long endurance times required, continue to present significant engineering challenges. Here, we discuss the development of a custom Vertical Take-Off and Landing (VTOL) UAS, with volcano monitoring considerations integrated throughout the design process. Building on lessons learned during field campaigns at Fuego (Guatemala), Soufriere Hills Volcano (Montserrat), Manam and Bagana (Papua New Guinea), we have developed a vehicle specifically designed for these types of missions.

In terms of performance, the aircraft must have a minimum service ceiling of 5000 m above mean sea level (AMSL), (b) an endurance of 60 minutes at sea level, reducing to 30 minutes following ascent to 2000 m AMSL, and (c) achieve a minimum cruise speed of 20 m/s. In terms of payload, the aircraft must carry an instrument mass of at least 0.8 kg in a payload bay no smaller than 180 x 150 x 100 mm, and with easy access. Operational considerations necessitate that the aircraft system must (a) fit within the size limits for a single commercial checked bag, (b) weigh less than 23 kg, (c) have a power train with fully electric option, and (d) have VTOL capability from minimum altitude of 1100 m AMSL.

Here, we present preliminary flight test data and discuss the planned future refinements to the aircraft system. Intended to fill a niche that is currently not addressed in commercially available systems, the new custom VTOL aircraft is rugged, flexible, portable, and yet highly efficient. Initial results indicate that the aircraft can meet the defined mission requirements, operating at ranges, payloads and performance metrics relevant to realistic volcano monitoring scenarios.

370

Detailed processes on the margin of a subaqueous rhyolite dome, Cala Genoveses, Cabo de Gata, Spain

Professor Nancy Riggs[1]
[1]Northern Arizona University, Flagstaff, United States

The Cabo de Gata region of southeastern Spain exposes Miocene dome complexes emplaced in subaqueous to emergent environments. Exposures of a rhyolitic dome at Cala Genoveses provide an opportunity to examine mesoscopic processes that occur as lava disintegrates along its margins during intrusion, as well as during explosive eruption and settling of pyroclasts from the water column.

Dome lava was intruded into hyaloclastite below the water-sediment interface and emplaced as a free-standing dome. The dome is made up of clast-supported pumice breccia with altered glass between clasts and rare fragments of flow-banded lava and phyllite. Locally, hyaloclastite is well stratified but completely disorganized within 3-5 cm from the carapace. Elsewhere rhyolite is fragmented both along sharp and angular margins (jigsaw) and as ribbons with fluidal shapes. Jigsaw-fractured fragments often display streams of very-fine-grained hyaloclastite between clasts, but in many locations fractured clasts are lofted away from the main mass and, within ~ 5 cm of the margin, are completely encased in fine-grained hyaloclastite.

Approximately 5 m of laminated sediments overlie the dome and comprise well-bedded pyroclastic fragments with basement clasts. Lenses within the succession as much as 1 m thick have poorly sorted pumice clasts up to 8 cm in diameter. Lateral margins of these lenses are very irregular although bases and tops are sharply planar.

A multi-phase eruptive history for the dome is inferred. Pumice was formed both as a vesiculating carapace and from explosive eruptions. Along carapace margins, vapor-film collapse occurred as the rhyolite intruded into hyaloclastite, causing an envelope in which hyaloclastite was fluidized. Elsewhere, pumice and glass were explosively erupted into the water column, in which they eventually became water logged and sank out. Poor sorting in the lenses suggests that irregular masses of clasts settled together irrespective of clast size.

1476

Architecture of magma pathways and eruptive vent locations controlled by evolving lithospheric stresses.

Dr. Eleonora Rivalta[1,2], Mr. Gaetano Ferrante[2,3], Dr. Francesco Maccaferri[4], Mr. Lorenzo Mantiloni[1], Dr. Tim Davis[1]

[1]Gfz Potsdam, Germany, Potsdam, Germany, [2]Alma Mater Studiorum University of Bologna, Bologna, Italy, [3]Rice University, Houston, USA, [4]INGV-OV, Naples, Italy

Magma is transported through the brittle-elastic lithosphere by diking. Diking is a mechanism similar to hydraulic fracturing, where a volume of fluid creates a crack and propagates by fracturing the rock ahead of the crack tip and pinching shut at its back. The fluid-filled crack's ability to fracture rock comes from the crack shape, which is thicker at its head and thinner at its tail, as dictated by the difference between internal pressure and external stresses. The elastic stress field, by affecting the crack shape, exerts a strong control on dike pathways. If the elastic stresses change due to shifts in tectonic stresses, or to a redistribution of surface loads, or to any other source of stress, then also magma pathways and eruptive pattern will shift as well. This will also affect both the architecture of crustal storage at different spatial scales, from the individual volcano to entire tectonic environments, including subduction zones or continental rifts. The location of individual vents or even entire volcanic provinces can be `reverse-engineered' to reconstruct stresses and loading conditions during the relevant epochs.

1477

Constraining the stress state of volcanoes through magma trajectories and eruptive vent locations.

Dr. Eleonora Rivalta[1,3], Mr. Lorenzo Mantiloni[3], Dr. Tim Davis[2]
[1]Gfz Potsdam, Germany, Potsdam, Germany, [2]Oxford University, Oxford, UK, [3]Alma Mater Studiorum University of Bologna, Bologna, Italy

The pathways of magma-filled dikes are controlled by the orientation and intensity of the principal elastic stresses. Indeed, dike orientations in the field, as well as the orientation of fluid-filled cracks such as hydrofractures, have been widely used to constrain the stress field. Here we show that eruptive vent patterns can be used to constrain the evolution of elastic stresses over the history of volcanic edifices. Biases in the stresses are expected when elastic parameters are ill-constrained or are simplified to homogeneous. New dike propagation models in three dimensions can be combined with our stress inversion strategy to forecast future dike pathways and the location of eruptive fissures.

337

Continental rift rhyolites of the Basin and Range, USA: timescales of activity from the zircon and feldspar record

Dr Tiffany Rivera[1], Dr Brian Jicha[2]
[1]Westminster College, Salt Lake City, United States, [2]University of Wisconsin-Madison, Madison, United States

The Colorado Plateau, USA, is bordered by Pleistocene continental rift volcanism in New Mexico, Arizona, and Utah. While most of the eruptions have been basaltic, rhyolitic domes, tuffs, and lavas have been produced. On the western margin, where the Colorado Plateau meets the Basin and Range extensional province, the Black Rock Desert of central Utah hosts Pleistocene-Holocene bimodal basalt-rhyolite volcanic activity. The South Twin Complex consists of six rhyolites within a single basin erupted between 2.45 and 2.40 Ma, and they precede all Pleistocene basalts of the region. In this work, we share a new rhyolite eruptive stratigraphy based on high precision $^{40}Ar/^{39}Ar$ dates and examine the zircon crystal cargo from each eruptive center. The new eruption ages allow us to examine the spatial and temporal distribution of volcanism in the South Twin Complex, whereas the zircon crystal morphology, geochemistry, and U/Pb dating allow us to assess the conditions and timescales of silicic magma processes in the subvolcanic plumbing system. Our data suggest the plumbing system beneath the region experienced punctuated influxes of magma over a brief period of thousands to tens of thousands of years. Further, the timescales and patterns of silicic magma assembly and evolution of this small anorogenic region are similar to those observed within the voluminous Yellowstone province, suggesting that the volume of magmatic flux does not control magmatic evolution in intercontinental settings.

1449

Volcano monitoring and disaster management on small volcanic islands – the experience of St Vincent and the Grenadines

Professor Richard Robertson[1], Ms Michelle Forbes, Ms Monique Johnson
[1]Seismic Research Centre, St. Augustine, Trinidad & Tobago, [2]National Emergency Management Organisation, Kingstown, St. Vincent and the Grenadines

Volcano monitoring and disaster management on the small island developing nation of St. Vincent and the Grenadines has grown incrementally over several decades both in response to, and incorporating knowledge and experience gained from, multiple hazardous events that have occurred on this archipelagic state. Through the efforts of key individuals, use of a variety of methods (stakeholder workshops, scenario exercises, simulations, community engagements) and the resources provided by grant and emergency funds following hazard impacts, the national system to respond to and cope with volcanic emergencies has become a complex network that incorporates community level activity as well as national and regional coordination. Augmented legislation and capacity building has strengthened the island's formal plans and procedures for hazardous events that can affect the multi-hazard environment of this small volcanic island state. The island's approach has also benefitted from collaborative research projects and incorporated the regional philosophy of comprehensive disaster management to ensure an integrated mechanism for hazard management. While there is always room for improvement particularly in the integration and strengthening of community efforts with the national structure, the entire system was recently tested and proven to be robust during La Soufriere Volcanic eruption of 2020-21. Our presentation will share the experience of over forty years of development including the most recent citizen science recovery project. This was geared towards building a community focused monitoring system including a network of rain gauges for understanding and managing risk related to lahars.

1447

Paving the path for risk analysis through hazard mapping and vulnerability capacity assessments

Professor Richard Robertson[1], Ms Monique Johnson[1], Ms Chagnon Glyn[2], Ms Shivanie Mohase[1]
[1]Seismic Research Centre, St. Augustine, Trinidad & Tobago, [2]Institut de Physique du Globe de Paris, Paris, France

Caribbean Small Island Developing States are exposed to a multiplicity of natural hazards and St. Vincent and the Grenadines, home of the active La Soufriere Volcano, is one of the most disaster-prone islands of the Eastern Caribbean. Geographic Information Systems have played a significant role in mitigation, preparedness, response, and recovery for projects in disaster risk reduction and emergency management. For this project we worked in partnership with local disaster management officials and community members in high-risk zones near the volcano and used GIS to develop a database that combined pre-existing hazard information with data obtained through vulnerability and capacity assessments. Data was captured through questionnaires conducted by community members hired by project funds. GIS was the used to compile and the visualise data which was fed back to community members during town hall meetings where it was validated and supplemented. Mapping the location of vulnerable persons, transportation resources, human resources, evacuation routes, muster points and emergency shelters accelerated the efficiency of the database and made it a fundamental component of ongoing mitigation efforts. The database benefited community members, decision makers, disaster management agencies and first responders. It contains hazard data obtained from several hazard mapping exercises (some done with community members), overlaid with vector data such as roads and buildings. We also worked with community members to help them develop Community Volcano Emergency Plans (CVEPs) that used the databases and incorporated training and equipping of Community Emergency Response teams.

433

Melting a magmatic mush through heating by a hot basal intrusion: an experimental approach

Dr Olivier Roche[1], Jean-Michel Andanson[2], Olivier Bachmann[3], Christian Huber[4], Julien Monteux[1]
[1]IRD - Laboratoire Magmas et Volcans, Aubière, France, [2]Institut de Chimie de Clermont-Ferrand, University Clermont Auvergne, CNRS, Aubière, France, [3]Department of Earth Sciences, ETH, Zürich, Switzerland, [4]Earth, Environmental, and Planetary Sciences, Brown University, Providence, USA

Magmatic mushes are essential components of crustal igneous systems. Understanding the dynamics of mushes is essential to gain insight into the spatial and temporal evolution of these systems in the earth's crust. In this context, we consider heating of a mush caused by a hot mafic basal intrusion and we study this configuration experimentally. The experimental device consists of a 15 cm-diameter and 8 cm-high glass cylinder equipped with two horizontal metal plates respectively at its base and top and whose temperatures are controlled to create a vertical thermal gradient. Heating pads against the cylinder outer wall prevent heat loss from the sides. We use two types of polyethylene glycol (PEG) as analogue materials in order to fulfill scaling requirements and ensure dynamic similarity with natural systems. Initially, the cylinder is at a given mean temperature, with solid PEG particles analogous to the crystals of a mush immersed in a liquid PEG analogous to the interstitial magmatic melt. Then, the temperature of the lower plate is increased to simulate a hot basal intrusion, and the experiment is recorded with a video camera through a narrow vertical window. For an analogue mush with an initial particle concentration of about 50 vol.%, preliminary tests show that at early stages, the particles in contact with the lower plate melt, hence creating a thin basal liquid layer. Then, the upper melt front migrates upward and the liquid layer whose thickness increases with time enters a convective regime. At later stages, the overlying granular bed collapses into the liquid layer, and particle melting continues to occur as long as heating from the lower plate is maintained. Our study offers perspectives to better understand the mechanisms of magmatic mush remobilization.

432

Statistical analysis of the runout distance of pyroclastic density currents and implications for emplacement mechanisms

Olivier Roche[1], Nourddine Azzaoui[2], Arnaud Guillin[2], Christopher D. Henry[3]
[1]IRD - Laboratoire Magmas et Volcans, Aubière, France, [2]Laboratoire de Mathématiques Blaise Pascal, University Clermont Auvergne, Aubière, France, [3]Nevada Bureau of Mines and Geology, University of Nevada, Reno, USA

Knowledge of the parameters that control the runout distance of pyroclastic density currents (PDCs) is essential to characterize volcanic hazards. In this context, we present a statistical analysis of data from 47 PDCs generated by well-documented eruptions of small (<0.01 km^3) to large (>1000 km^3) volumes, with eruption rates (Q) and flow runout distances varying by five and two orders of magnitude, respectively. The analysis shows that the runout correlates with the mass discharge rate and that two distinct trends are defined respectively for dilute turbulent currents and for two-layer currents with a concentrated basal flow. The runout of dilute PDCs scales with ~$\sqrt{(Q/w)}$, with w the particle fall rate, in agreement with the theory for emplacement of axisymmetric currents. For concentrated PDCs the runout scales with $Q^{0.36}$. However, correction of data from small volume (<10 km^3) currents that propagated in valleys, assuming radial spreading, yields a dependence of runout with ~$\sqrt{Q}$. Through further statistical analysis, we determine particle settling velocities of the order of 10 cm/s in the basal flow. Data from other 40 concentrated PDCs for which the mass eruption rate is estimated using a statistical fit to their bulk volume are all within the 99% prediction intervals. In contrast, data from PDCs that formed the Oligocene ignimbrites of the Great Basin (United States), with runouts that may have exceeded 300 km, are clearly outside the prediction intervals and suggest a different emplacement mechanism from other concentrated PDCs. The elliptical shape of the ignimbrites and other field observations indicate that the concentrated flows were channelized into regional paleovalleys, which caused exceptionally long runout distances. Beyond these considerations, the power law relationships we identify can be used to infer mass eruption rates from PDC runout distances.

689

Study of the evolution of the 2013-2017 lava flow field from Santiaguito, Guatemala, using ASTER, OLI and UAV imagery

Dr Lizzette Rodriguez[1], Giovanni Nin[2], Dr. Fernando Gilbes[1], Dr. Andrew Harris[3], Gustavo Chigna[4]
[1]University of Puerto Rico - Mayaguez, Mayaguez, Puerto Rico, [2]USGS - Caribbean-Florida Water Science Center, Guaynabo, Puerto Rico, [3]Université Clermont Auvergne, Clermont-Ferrand, France, [4]Instituto Nacional de Sismología, Vulcanología, Meteorología e Hidrología, Guatemala City, Guatemala

Since 1922, extrusion of dacitic magma led to the formation of the Santiaguito Dome Complex, in Guatemala. A new lava field was emplaced between May 2014 and February 2015, with an average volume of 8.8 x 10^6 m^3 and a 3.24 km long dacitic lava flow. This allowed us to describe and analyze its dimensional and thermal parameters using remote sensing techniques. To have a full perspective of the activity and the flow characteristics, 12 images from Terra-ASTER and Landsat 8-OLI/TIRS were analyzed for the period 2013-2017, together with aerial images taken during four field campaigns. According to the results obtained, at the beginning of 2013 three lava flows were active on the southwest, south, southeast and east side of the El Caliente vent, while only two remained active (southeast and southwest flanks) at the end of the year. A blocky flow began to descend on the southeast part of the dome on May 9, 2014, after one of the largest eruptive events of the past decades. By December 30, 2014 this lava flow continued its slow movement on two different fronts, on Nima 1 and Cabello de Angel drainages. This flow reached its maximum length of 3.24 km between January 31 and February 24, 2015. Surface temperatures calculated for this flow ranged between 135 °C and 31 °C with an advance rate of 1.3-19.1 m/day during the time of emplacement, which is consistent with a whole lava flow viscosity estimate of 2.0-61.0 x 10^9 Pa s. A thick surface estimated at 1.0-5.1 m, a relatively cold temperature and a core cooling rate of 0.02-0.07 °C/h, caused that this lava emplacement advanced a maximum of 3.24 km in 8 months. In comparison with previous work, the effusion rate of 1.01-1.61 m^3/s calculated for the study period shows a significant increase.

269

Magma storage and transport along volcanic rift zones constrained by geodetic data and dynamical models.

Dr Alberto Roman, Dr Paul Lundgren
[1]*Jet Propulsion Laboratory, California Institute of Technology, Pasadena, United States*

Our current understanding of volcanic eruptions is based on a simple model in which a magma reservoir is connected to the surface through a rigid, non-deformable conduit. In this framework, the chamber physical properties control the key features of an eruption, such as its duration. However, intereferometric synthetic aperture radar (InSAR) show that mature volcanic rift zones, which transfer magma to the active vent, produce significant deformation of the encasing rocks. Thus, volcanic conduits act as secondary reservoirs and one expects that their physical properties, such as their geometry, have significant impact on the eruptive dynamics. Here we develop a dynamical model in which the chamber is connected to the surface through a deformable conduit. The results show that magma overpressure increases the width of the conduit, resulting in higher discharge rate than what would be expected from the rigid case. At the same time, conduits with high aspect ratio, have larger compressibility so that the eruption can be sustained over long timescales. The net result is that rift zones can maintain high fluxes over prolonged periods of time, leading to large eruptions and biasing magma compressibility estimates.

We apply our findings to the 2018 Kilauea eruption where episodic collapse of the summit led to pressure pulses that propagated down-rift and that were recorded by both tiltmeters and peaks in the effusion rates. Our results show that deformation of the rift zone is important to account for both the signal recorded by in situ instruments and by effusion rate measurements, and place constraints on the geometry of the conduit.

702

An oxygen isotope study of magma-crust-fluid interactions in the modern Taupō Volcanic Zone

Dr Shane Rooyakkers[1], Dr Kevin Faure[1], Dr Isabelle Chambefort[2], Dr Simon Barker[3], Dr Hannah Elms[3], Prof Colin Wilson[3], Dr Bruce Charlier[3]

[1]National Isotope Centre, GNS Science, Lower Hutt, New Zealand, [2]Wairakei Research Centre, GNS Science, Taupo, New Zealand, [3]School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand

Oxygen isotopes are useful for tracing interactions between magmas, crustal rocks and surface-derived waters. We use them to consider the links between voluminous silicic volcanism and large-scale hydrothermal circulation in New Zealand's central Taupō Volcanic Zone (TVZ). We present >350 laser fluorination $\delta^{18}O$ value measurements of plagioclase, quartz, hornblende and groundmass glass from products of 40 young (<54 ka) silicic eruptions, tapped from three discrete magmatic systems: Ōkataina and Taupō calderas, and the smaller Northeast Dome system. For each mineral phase, mean $\delta^{18}O$ values vary by <~1‰ ($\delta^{18}O$ plag = +6.7–7.9‰, $\delta^{18}O$ qtz = +7.7–+8.7‰, $\delta^{18}O$ hbl = +5.4–+6.4‰, $\delta^{18}O$ glass = +7.1–+8.0‰), and inter-mineral fractionations mostly reflect high-temperature equilibria. Rare outliers (e.g., ~+6‰ or >+10‰ plagioclase) represent contaminants incorporated on short-enough timescales to preserve disequilibrium (~10^2 yrs for plagioclase). Melt $\delta^{18}O$ values calculated from phenocrysts are ~+7.3–+8.0‰. Where multiple magmas were involved in the same eruption their melt $\delta^{18}O$ values are indistinguishable, implying that their parental mush systems were isotopically well-mixed and equilibrated with respect to oxygen. However, small (<0.5‰) but consistent $\delta^{18}O$melt value gradients occur over millennial timescales at Ōkataina and Taupō, with short-term ~0.4-0.5‰ decreases over successive post-caldera eruptions correlating with increases in $^{87}Sr/^{86}Sr$. These changes reflect tens of percent assimilation of a mixture of hydrothermally altered silicic plutonic material and higher-$^{87}Sr/^{86}Sr$ greywacke. These examples represent the first evidence for assimilation of altered crust into silicic TVZ magmas, indicating that its shallow silicic systems do at times spatially overlap and interact with their surrounding hydrothermal envelope. The subtle and short-lived isotopic signals of these interactions are only recognized through the high temporal resolution of the central TVZ eruptive record and complementary radiogenic isotope data. Similar interactions may have been easily overlooked or obscured in other nominally high- or normal-$\delta^{18}O$ magmatic systems where isotopic leverage is limited.

188

Componentry methods in volcanology (point counts, line counts): precision and accuracy based on statistics and numerical modeling

Dr Pierre-Simon Ross[1], Dr Bernard Giroux[1], Dr Benjamin Latutrie[1]
[1]*Institut national de la recherche scientifique, Quebec, Canada*

Componentry is the quantification of the proportion of different components (e.g., clast types) in volcaniclastic deposits and rocks. Such data are highly relevant to interpret various volcanic processes. There are established field and laboratory methods to measure componentry – such as point counts and line counts – but workers are often unsure how many clasts are needed to reach a certain precision. Some existing statistical models predict precision but assume a homogeneous distribution of components, and ignore voids in the material. Furthermore, the accuracy of these methods has been assumed to be good theoretically, but not tested empirically.

Here we use numerical models to address these questions. The models are ≥1 m3 cubes containing red and blue spheres plus voids. The colored spheres have different proportions and sizes. We include particles of unequal sizes and components with proportions as low as 1%. For each model, the true proportions of blue versus red are calculated. Slices are then cut through the models and saved as high-resolution images. These are used to perform numerous point counts and line counts (for different numbers of points and lines), which can the compared with the true proportions (to assess accuracy) and with each other (to assess precision using the standard deviation, σ).

We show that both line counts and point counts can be accurate, if enough objects are counted or intersected to also obtain a reasonable precision. The precision of componentry methods depends on the abundance of the component of interest and the number of points counted or clasts intersected – as was already known – but also on differences between slices (due to heterogeneity within the deposit or rock), and on the proportions of voids/matrix/cement. Empirical 1σ precision charts are presented based on our models, taking all of these sources of variation into account.

187

Assessing primary magma fragmentation through standardized juvenile particle studies

Dr Pierre-Simon Ross[1], Dr Tobias Dürig[2], Dr Pier Paolo Comida[1], Dr James D.L. White[3], Dr Daniele Andronico[4], Dr Lucia Gurioli[5], Dr Julia Eychenne[5], Dr Simon Thivet[6], Dr. Nathalie Lefebvre[7]
[1]Institut national de la recherche scientifique, Quebec, Canada, [2]Institute of Earth Sciences, University of Iceland, Reykjavík, Iceland, [3]Geology Department, University of Otago, Dunedin, New Zealand, [4]Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo , Catania, Italy, [5]Laboratoire Magmas et Volcans, Université Clermont Auvergne , Aubière, France, [6]Ludwig-Maximilians-University Munich, München, Germany, [7]ETH Zurich, Zurich, Switzerland

There is a general trend in science towards more open data. But sharing data is much less useful if other scientists can't use it, which happens when it is not directly comparable with theirs, i.e. the data is not standardized. Unfortunately, this is the present situation in the field of juvenile particle studies aimed at better understanding primary magma fragmentation. Different laboratories have their own favorite methodologies to measure particle size, shapes, internal textures (crystal and vesicles) and particle surface features. Although juvenile particles have been studied for decades by many workers, a methodological consensus has not yet emerged. For example, there is no agreement on what size fraction to use, which imaging device, which shape factors, how many grains, etc.

This means that juvenile particle data from different laboratories or eruptions can be very difficult to compare. To move forward, the "juvenile particle" community should aim to converge on a standardized methodology. This would allow us to progressively assemble a large open international database of comparable measurements from different eruptive styles and fragmentation mechanisms. The advantages of this strategy include more synergy between researchers from different institutions and countries, and ultimately a better understanding of magma fragmentation. Nevertheless, standardization efforts also have potential downsides, including social friction, so we should proceed carefully. In this presentation we will summarize a proposed standardized workflow recently published in Bull. Volc. This workflow and any alternative ideas will be further discussed at a two-day workshop immediately after the conference.

1401

External water influences on explosive eruption dynamics: assessing consequences for plume rise, ash-sulphur scavenging reactions, and volcano-climate impacts.

Mr Colin Rowell[1], Professor Mark Jellinek[1]
[1]*University of British Columbia, Vancouver, Canada*

Compared to “dry” explosive eruptions, the dynamics of hydromagmatic events involving interactions of magma with external surface water or ice can involve greater ambient pressures at the vent, water entrainment and vaporization, and enhanced ash production. Such altered eruption dynamics modify the plume momentum and buoyancy fluxes driving plume rise, influencing the dispersal and ultimate fate of volcanic ash, water and aerosols that impact climate. Using a novel magma-water interaction model that couples eruption dynamics from the conduit through vent decompression, thermal and mechanical interactions with surface water, and finally column rise, we characterize the stratospheric delivery of SO_2, ash, and water, to constrain the climate effects of hydromagmatic eruptions. Fine ash production is constrained by energy partitioning between the heating of entrained water and consumption of surface energy during quench fragmentation. We parameterize ash-SO_2 scavenging reactions to explore the extent to which fine ash will scrub SO_2 from the eruption cloud, thereby limiting climate impacts due to sulfur aerosols. Our results link total water entrainment and eruption behaviour to water depth. Stratospheric delivery is maximized for external water mass fractions of up to about 0.2 in water depths of 10s to about 100 m. By contrast, for water depths greater than about 200 meters, buoyant, ash-laden plumes are unlikely even for very high magmatic eruption rates. We find that stratospheric SO_2 injection in this deep water regime likely requires moist convection in ash-poor secondary plumes following column collapse. In general, increasing abundance of external surface water suppresses injection of SO_2 into the stratosphere by (1) limiting explosive and overpressured eruption behaviour, (2) reducing buoyancy of eruptions columns and driving gravitational collapse, and (3) enhancing the abundance of fine ash and water co-located with SO_2 in the eruption cloud, providing conditions which enhance scavenging of SO_2 by ash and hydrometeors.

1400

Contemporary observations of jökulhlaup discharge and plume height constrain dynamics of the 1918 subglacial eruption of Katla Volcano, Iceland

Meghan Sharp[1,2], Mr Colin Rowell[1], Professor Mark Jellinek[1]
[1]*University of British Columbia, Vancouver, Canada,* [2]*Oregon State University, Corvallis, USA*

The 1918 subglacial eruption of Katla volcano melted a hole through the Mýrdalsjökull icecap within a span of 2 to 3.5 hours. Unlike typical “Nye” type jökulhlaups characterized by steadily increasing outflow resulting from the progressive melting and enlargement of subglacial drainage channels, the initial phase of the Katla jökulhlaup on October 12 peaked rapidly and then declined approximately exponentially. Here we develop a numerical model for meltwater generation, storage, and discharge from the englacial cauldron. Our goals are: (1) explain the timing of the subglacial phase and eruption column emergence, and the total discharge volume of the first flood phase, (2) estimate the evolution of the meltwater layer depth within the cauldron and explore consequences for eruption dynamics using a recently developed model for subaqeuous volcanic jets. Critical observational constraints, obtained from published accounts of the first day of the eruption, include: the timing, physical properties, total discharge, and peak discharge of the meltwater/tephra flood mixture, length of the subglacial phase, the eruption column height, ice thickness, and location of the supraglacial meltwater channel at the eruption site. These observations are mutually restrictive and together are explained by a narrow range of eruption scenarios. We find: (1) A relatively high magma-to-ice heat transfer efficiency of 0.7 to 0.8 is required to reproduce the observed hydrograph and total flood discharge. (2) the magma discharge rate driving the subaerial eruption column was as little as one third of the total discharge rate at the vent. The mass discharge rate of tephra is well-bounded if it is assumed that the volume of water storage inside the cauldron is negligible prior to the eruption. (3) After eruption initiation, some amount of englacial meltwater storage followed by sudden release is required in most scenarios that successfully reproduce the shape of the discharge hydrograph.

1175

A Brief History of Submarine Volcano Studies with the ALVIN Submersible

Professor Kenneth Rubin[1]
[1]SOEST/University of Hawaii at Manoa, Honolulu, United States

This presentation will review seminal contributions to submarine volcano science by Human Occupied Vehicle DSV ALVIN since its launch in the mid-1960s. The submersible vehicle has been used for in situ observations over a variety of depths in the deep ocean to enable geological mapping, volcanic stratigraphy and eruption frequency, volcanic deposit facies characterization, lava and pyroclast sampling, geothermal field characterization, and submarine volcano-hosted ecosystem studies in each of its operating decades, which continue through to the present. Drawing on the literature and my own experiences using the vehicle in the current and each of the last three decades, I will highlight some of the notable volcano studies that greatly refined our understanding of lava flow emplacement conditions and history in submarine settings, including at well-known sites on the northern and southern East Pacific Rise, Mid-Atlantic Ridge, Juan de Fuca Ridge, the Galapagos Spreading Center, Loihi (now known as Kamaehuakanaloa), and the Marianas Back Arc. I will also discuss technical capabilities of the submersible and changes over time that have facilitated this research. Results discussed will include recent dives I and others did at up to 6 km depth in the Mid Cayman Rise and Puerto Rico trench, as part of the ALVIN Science Verification Expedition (SVE), which was conducted in July-Aug 2022. This expedition was funded by the US National Science Foundation to evaluate the capabilities and usability of the ALVIN submersible, operated by Woods Hole Oceanographic Institution, after a major rebuild for operations at substantially deeper depth than before (6.5 km vs 4.5 km).

928

Young Submarine Lava Flow Identified at 6 km Depth on the Mid Cayman Rise

Professor Kenneth Rubin[1], Professor Adam Soule[2], Mr. Jason Almeida[2], Professor Katherine Kelley[2], Dr. Anna Michel[3]

[1]SOEST/University of Hawaii at Manoa, Honolulu, United States, [2]Graduate School of Oceanography/University of Rhode Island, Narragansett, United States, [3]Woods Hole Oceanographic Institution, Woods Hole, United States

A fresh, very lightly sedimented lava flow with fresh, unaltered glassy rinds was discovered on the northern portion of the Mid-Cayman Rise (MCR) during the Deep Submergence Vehicle (DSV) ALVIN Science Verification Expedition (SVE) in Aug 2022, making it currently Earth's deepest known lava flow visited in situ by human observers. The MCR is an ultraslow spreading ridge in the Caribbean Sea thought to represent a series of extensional oceanic core complexes (Hayman et al, 2011).The young eruption deposit is formed entirely of pillow lava of a variety of morphologies (elongate, bulbous, bread-crust textured, flattened pillows) as a function primarily of emplacement slope (steeper to less steep, respectively). Many of the pillows are highly ornamented with glassy extrusions (e.g., pillow buds and toes). Alvin Dive 5097 traversed 1 km of sea bed astride a ridge, staying entirely within the young lava flow terrain. The lava samples collected are mostly very sparsely olivine phyric (1-3 mm crystals) and to first order, devoid of vesicles, except in the cores of pillow ornaments, as is common at other sites. However some of the lava samples, especially those collected from drained pillow rims, exhibit variable-sized and shaped ovate voids commonly thought to form from external water-magma interaction when found at shallower depth. The lavas differ substantially in age, morphology and petrology from a plagioclase ultraphyric collapsed lobate lava sample found nearby on a different dive, 1 km shallower, at the Beebe hydrothermal field. The implication of these characteristics will be discussed in light of the great eruption depth and spreading systematics.

The SVE was funded by the US National Science Foundation to evaluate the capabilities and usability of the ALVIN submersible, operated by Woods Hole Oceanographic Institution, after a major rebuild for operations at substantially deeper depth than before (6.5 km vs 4.5 km).

694

Connecting subsurface fluid oscillations to geophysical observables in geysers - insights from laboratory and numerical models

Dr Maxwell Rudolph[1], Mr Uthkarsh Das[1], Mr Akshat Yaparla[2], Prof Einat Lev[2], Dr Rob Sohn[3]
[1]University Of California, Davis, United States, [2]Lamont Doherty Earth Observatory, Columbia University, Palisades, United States, [3]Woods Hole Oceanographic Institution, Falmouth, United States

Geysers episodically erupt mixtures of hot water and steam. Like magmatic eruptions, the eruptions of geysers are driven by some combination of fluid pressure and the expansion of a volatile phase. Also like magmatic volcanoes, geysers display a variety of oscillatory behaviors on timescales from microseconds to many eruption cycles. Because geysers erupt more frequently and with less disastrous effects than many volcanoes, they provide a unique natural laboratory for understanding the physics of eruptions and the geophysical observables associated with subsurface processes. Over the past decade, there has been an increased recognition that most natural geysers include a laterally-offset reservoir, termed a bubble trap, in which hot water and steam can accumulate. As a reservoir of hot water and steam, the bubble trap plays an important role in the lead-up to eruptions, and because steam is much more compressible than liquid water, it can play a key role in fluid oscillations that occur during and in-between eruptions.

We present new results from a laboratory geyser with a bubble trap in which we trigger and observe oscillations within the geyser conduit and reservoir in both room temperature and steam-filled systems. We develop mathematical models of the oscillation of hot fluids between the conduit and the bubble trap, accounting for the thermodynamics of hot water and steam. We compare the predictions of the mathematical models with the observations from our laboratory experiments to help relate oscillation frequency, amplitude and decay to the geometry of the system and properties of the fluids. Finally, we discuss the implications of the laboratory and numerical models for oscillations observed in the conduit of Old Faithful Geyser (Yellowstone National Park, USA) during the run-up to eruption.

201

The Waiwhatu Project: Developing a Shared Language for Communicating Scientific Terms

Andrea Blair[1], Uenuku Fairhall[2], Corey Ruha, Aroha Campbell[1], Dr Paul Siratovich[1], Dr Isabelle Chambefort[3]
[1]Upflow, Taupō, New Zealand, [2]Tarapō, Rotorua , New Zealand, [3]GNS Science, Taupō, New Zealand

In the Waiwhatu project, we created an opportunity to understand the practice of others. We listened to scientists explain useful technical concepts, relevant to earth sciences, geothermal and volcanology, and then interpreted these through a Māori lens into a shared language, bringing Mātauranga Māori (indigenous knowledge) and western science into one space.

Māori struggle to embrace western science. It's hard to relate to, scientists speak a different language, and concepts aren't easily aligned to their natural knowledge systems of Mātauranga (knowledge). Similarly, scientists find it hard to understand and relate to Māori concepts and thinking. In this presentation, we will share experiences arising from a journey to mutual understanding and collaboration, through the development of shared language.

Many translators struggle to source meaningful, relevant words to define scientific terms. Words driven by English make no sense in Te Reo Māori (Māori language). Instead, words and concepts are often cobbled together with literal translations for parts of words. For example, ngawha means hot spring, but is commonly used to replace the word geothermal. The true test going forward will be in the uptake and use of the words and concepts outside of our project team—that is when language truly exists in the world.

1333

Automated seismo-volcanic event detection and initial analysis applied to Stromboli and Whakaari Volcano

Darius Fenner[1,3], Professor Georg Rümpker[1,2], Professor Horst Stöcker[1,2], Dr Nishtha Srivastava[1,2]
[1]Frankfurt Institute for Advanced Studies, Frankfurt, Germany, [2]Goethe University Frankfurt, Frankfurt, Germany, [3]Johannes Gutenberg University Mainz, Mainz, Germany

Detailed analyses of past major and minor volcanic explosions can help to understand the eruptive behavior of volcanoes and the underlying physical and chemical processes. Catalogs of these eruptions and, specifically, seismo-volcanic events may be generated using continuous seismic recordings at stations in the proximity of volcanoes. However, in many cases, the analysis of the recordings relies heavily on the manual picking of events by human experts. Recently developed Machine Learning-based approaches require large training data sets which may not be available a priori. Here, we propose an alternative user-friendly, time-saving, automated approach labelled as: the Adaptive-Window Volcanic Event Selection Analysis Module (AWESAM). This strategy of creating seismo-volcanic event catalogs consists of three main steps: 1) identification of potential volcanic events based on squared ground-velocity amplitudes, an adaptive MaxFilter, and a prominence threshold. 2) catalog consolidation by comparing and verifying the initial detections based on recordings from two different seismic stations. 3) identification and exclusion of signals from regional tectonic earthquakes. The strength of this python package is the reliable detection of very small and frequent events as well as major explosions and paroxysms. Here, the analysis is applied to publicly accessible continuous seismic recordings from stations at Stromboli volcano in Italy and Whakaari Volcano in New Zealand. Based on seismo-volcanic events detected by AWESAM, we derive new amplitude-frequency relationships which can be used as a starting point for further investigations such as inter-event time analysis, identification of temporal patterns of volcanic activity, and event classification.

1255

Seismic signals of crater instability at Oldoinyo Lengai volcano, Tanzania

Professor Georg Rümpker[1], Dr Ayoub Kaviani[1], Amani Laizer[2], Dr Miriam Christina Reiss[1], Professor Emmanuel Kazimoto[2]
[1]Goethe University Frankfurt, Frankfurt, Germany, [2]University of Dar es Salaam, Dar es Salaam, Tanzania

Oldoinyo Lengai in the North Tanzanian Divergence is one of the few highly active volcanoes of the East African Rift System. Its eruptive cycle is characterized by effusions of carbonatite lava and severe explosions. The most recent of these occurred in 2007 and left a circular crater nearly 400 wide and approximately 100 m deep. The crater is currently being refilled with new lava which has formed several characteristic hornitos. In this study, we analyze data from a small-scale seismic network of nine short-period stations in operation for about five weeks during 2019. The recordings show tremor activity as well as more than 80 distinct events characterized by high-frequency seismic signals apparently located within the immediate vicinity of the network. However, the recordings lack clear S-wave arrivals. We apply two different localization methods and account for the shape of the volcanic edifice during the inversion: (1) a grid-search approach that includes topographic information by using a Bayesian formulation and (2) a linearized iterative approach where the regularization is controlled by the topography. The results show that most of the events are located at high altitude in the vicinity of the circular crater rim. We argue that the events are caused by sliding segments of the crater wall which have become gravitationally unstable, possibly due to magmatic undermining. The interpretation is supported by surface observations of opening cracks at the outer base of the crater rim.

919

Cryptic Magma Storage in the Great Basin Derived from Soda Lakes Maar Olivine Crystal Records

Dr Philipp Ruprecht[1], Kathleen Rodrigues[2]
[1]University of Nevada, Reno, Reno, United States, [2]Desert Research Institute, Reno, United States

While direct source-to-surface magma transport is commonly conceptualized for small volume, mafic eruptions, evidence for intermittent crustal storage regions getting remobilized as part of such rapid magma transport is less abundant. Especially in regions with scarce volcanic activity, crustal magma storage is typically not envisioned. Such a region of rare Holocene magmatism is Nevada's Great Basin, a region with large scale-extension and crustal thinning that may drive decompression melting over a large area. Whether such magmas are rare or potentially get trapped in the crust and contribute to elevated, localized geothermal activity remains unknown.

Here we present mineral (and glass) chemistry from the Soda Lakes maar eruptions that support this polybaric magma assembly and highlight that small melt pockets may exist throughout the Great Basin where no magmatic activity has yet been recorded. Olivine phenocrysts (and antecrysts) in the basaltic to basaltic-andesitic juvenile clasts and the pyroclastic deposits range in major element composition (Fo55-Fo88) with peaks at the primitive end (Fo84-Fo88) and another common composition at ~Fo75. Trace element signatures in olivine are consistent with fractional crystallization. Incompatible elements (e.g. Li, Y) are continuously enriched from the most mafic (Fo88) to the highly evolved compositions (Fo55) requiring >>50% of fractionation for magmas hosting the evolved olivine. This suggests that compositionally distinct and spatially separated magma bodies were involved in this eruption including mantle-derived primitive magmas.

In addition to our work tracing the magma origin, we present new, exploratory work using luminescence to date this eruption of unknown age. A maximum age of ~<13 ka before present is currently the best age constraint given that eruptive deposits cover lake sediments of pluvial Lake Lahontan. Luminescence of xenolithic and xenocrystic quartz can not only record the eruptive age, but may also provide constraints on the magma dynamics and ascent history.

765

Nucleation delay of feldspar in water saturated rhyolite during decompression in shallow volcanic systems

Dr Monika Rusiecka[1], Dr Caroline Martel
[1]*Institut Des Sciences De La Terre D'Orléans (Université d'Orléans-CNRS-BRGM), Orléans, France*

Microlites, of which plagioclase is the most common in silicic rocks, are crystals of a few to few hundreds of micrometers. They can form when magma moves upwards in volcanic conduit. Because they crystallise on the timescales of magma ascent and subsequent degassing their presence, size and textures can provide valuable informations about the conditions and timing of ascent. In this contribution we present the model of nucleation delay – the time between when the melt is brought below its liquidus and the onset of crystallisation. Using the Classical Nucleation Theory (CNT) we developed a model of plagioclase nucleation delay during decompression in water-saturated rhyolite. With the thermodynamic and kinetic parameters proposed in this study, the model agrees with the experimental results of this study to within a factor of two. To account for the variety of conditions encountered by magma during ascent, we propose expanding the model, developed in this study for isothermal decompression, to a wider range of pressures and temperatures (i.e. non-isothermal conditions). We present new measurements of feldspar growth rates during decompression in water-saturated rhyolite, emphasizing the importance of accurately calculating the nucleation delay in order to estimate growth rates. Using these data, we propose a method for estimating the ascent rate of water-saturated rhyolite based on the nucleation delay of plagioclase microlites.

767

Phase relations and storage conditions of rhyolitic magma beneath Krafla Central Volcano (Iceland) – an experimental study

Dr Monika Rusiecka[1], Dr Shane M. Rooyakkers, Dr Caroline Martel
[1]*Institut Des Sciences De La Terre D'orléans, Orléans, France*

Rhyolite forms about 10% of the volcanic products of Iceland, offering insights into silicic magmatism in basalt-dominated oceanic settings. However, because there is a paucity of experimental studies on Fe-rich but Ca- and K-poor rhyolites like the rift zone rhyolites of Iceland, the phase relations and storage conditions (P-T-fO2-XH2O) of these magmas are poorly understood. To address this, we conducted phase equilibria experiments on rhyolite from Krafla volcano using an Internally Heated Pressure Vessel (IHPV). Krafla represents an opportune target for this work because rhyolite magma was unexpectedly encountered there at shallow depth (~2.1 km) during recent drilling of the IDDP-1 geothermal well, providing a unique opportunity to compare experimental results with natural phase assemblages where pressure conditions are known a priori. Our starting material was crystal-free obsidian from the ~24 ka Hrafntinnuhryggur rhyolite, which is similar in composition to products of all rhyolite eruptions of Krafla over ca. 190 ka. Preliminary results show good agreement between the phase assemblages and mineral compositions of the natural Krafla rhyolites and our experimental samples at 850-875 °C and <100 MPa, including the presence of augite at low (1-3 vol%) crystallinity. Our results imply that relatively hot (>800-850°C) and shallow (< ~100 MPa) storage conditions are typical of most rift-related Icelandic rhyolites, and are consistent with the view that the low to moderate H2O contents of on-rift rhyolites reflect H2O saturation at low pressures. They also highlight an especially strong influence of fO2 on the stability of ferromagesian phases in these magmas, reflecting their Fe-rich melt compositions (~3 wt% FeOT). Our experiments offer new perspectives on the enigmatic origins of Iceland's rift zone rhyolites, and provide important temperature and fO2 constraints that support developing plans to study the active IDDP-1 magma body via targeted drilling.

816

Can fault zones and magma reservoirs trigger one another? Unraveling mechanical interactions from 3d elasto-plastic numerical models

Ms Javiera Ruz Ginouves[1,2,7], Dr. Muriel Gerbault[3], Dr. José Cembrano[1,2], Pablo Iturrieta[4,5], Felipe Sáez-Leiva[1,2], Dr Camila Novoa[3], Dr Riad Hassani[6]

[1]Pontificia Universidad Católica de Chile, Santiago, Chile, [2]CEGA, Santiago, Chile, [3]Geoscience Environnement Toulouse (GET), Toulouse, France, [4]Helmholtz Centre Potsdam (GFZ), Potsdam, Germany, [5]University of Potsdam, Postdam, Germany, [6]Géoazur, Valbonne, France, [7]University of Otago, Dunedin, New Zealand

The interplay between magmatic-geothermal systems and crustal fault zones has been recognized in a variety of tectonic settings and studied through different approaches, including structural geology methods, analogue experiments, and numerical modeling. Here we aim to better understand key mechanical variables driving the interaction between a crustal magmatic reservoir and a strike-slip dextral fault zone in a synthetic system inspired by a field case in the Southern Andes. We tested potential mutual triggers by imposing either a dextral strike-slip displacement along the fault zone or a magmatic overpressure around the reservoir walls. To achieve this, we ran a series of 3d elasto-plastic numerical models in Adeli, a 3D FEM code, with parametric tests examining the influence of host rock Young's modulus, and bedrock and fault zone frictional strength. We examined the evolution of shear stress, bulk strain, and plastic strain in the volume of rock between the fault and magma reservoir. Our results show that a fault zone and a magma reservoir can potentially interact over the kilometric scale and that both accumulated fault displacement and magmatic loading can create consistent dilational strain that may then enhance fluid flow pathways and accumulation within the upper crust by increasing permeability. Parametric tests indicate that Young's modulus and fault zone frictional strength are determinant parameters that control failure of the magma reservoir and fault zone, respectively. In the first case, a stiff bedrock facilitates reservoir failure and localized shear failure (e.g. for lower amounts of applied fault motion), whereas a compliant bedrock promotes higher distributed volumetric strain. However, fault slip induced by magma inflation is largely controlled by the host rock and fault frictional strength, and both of these parameters then determine whether fault slip occurs. Finally, we propose that future work should aim to include an active regional stress field.

1107

Understanding the early evolution of fissure eruptions using an experimental artificial fissure

Ms Javiera Ruz Ginouves[1], Ms Rachael J.M Baxter[1], Dr James D.L. White[1], Hamish Bowman[1], Brent Pooley[1], Dr. Rosemary P. Cole[2]
[1]*University Of Otago, Dunedin, New Zealand,* [2]*Institute of Earth Sciences, University of Iceland, Reykjavik, Iceland*

Volcanic eruptions such as Kilauea (2018), Fagradalsfjall (2021), La Palma (2021), and the most recent Meradalir eruption in the Reykjanes peninsula are fed by dikes, sheet-like intrusions that transport magma through the crust to the surface, where they initially form elongated fissures extending typically several hundred up to thousands of meters. Although field, seismic, and geodetic data indicate that feeder dikes can extend laterally and vertically for several tens of kilometers in length and depth, eruption along a fissure becomes discontinuous and localizes to discrete vents only a few hours after the onset of the eruption. Understanding the processes that lead to localization is important for forecasting the evolution of, and flow localization during, future fissure eruptions in almost all volcanic settings. This is of great relevance in areas that could potentially be affected by such eruptions, including Auckland and Mexico City, among others. Here, we aim to understand the thermal processes that drive eruption localization using an artificial fissure (ArtFish), a novel experimental apparatus that replicates a dike-fissure segment with wax as a magma analogue fluid. This analogue model allows for changes in fissure width, fissure geometry, wall temperature, and volumetric flow rate. Our first experimental series intends to solve the relative influence of each of these parameters through systematic variation of the panel matrix. This series, currently being conducted, will allow us to test our hypothesis that localization is favored when the fissure is narrower than a critical width, high thermal contrast between wax and wall and/or with a slow flow rate. Future experiments after this initial series will explore more complex fissure geometries such as lateral and vertical narrowing, as well as variations in wall temperature within the fissure.

476

Rapid melt migration as mushes "unlock" during high-temperature, high-pressure experiments

Dr Amy Ryan[1], Dr Lars Hansen[1], Dr Mark Zimmerman[1], Dr Mattia Pistone[2]
[1]University of Minnesota, Minneapolis, United States, [2]University of Georgia, Athens, United States

We conducted experiments to study melt migration in crystal-rich mushes, with application to magma ascent within transcrustal magma reservoirs. Mushes with crystal fractions of 0.59 to 0.83 were prepared by hot pressing mixtures of crushed borosilicate glass and different amounts quartz particles. Soda-lime glass was used as a proxy for crystal-free magma. Experimental samples comprise (1) a disk of soda-lime glass placed below a disk of mush ("stacked" assemblies), or (2) a rod of soda-lime glass placed within a ring of mush ("rod-and-ring" assemblies).

Stacked assemblies were used in static experiments in which samples were subjected to 100-300 MPa confining pressure and 900°C for up to 6 h. As a result of the experimental protocol, soda-lime melt migrated into the overlying mush in all samples. Soda-lime melt fraction in mush layers is correlated to crystal fraction, increasing with crystal fraction before sharply decreasing at crystal fractions > 0.8. Specifically, soda-lime melt fills 20% of the intergranular space at crystal fractions near 0.6, >80% of the intergranular space at crystal fractions near 0.75, and only 40% of the intergranular space for crystal fractions > 0.8. The reduced soda-lime fraction as mush crystal fractions exceeds 0.8 coincides with the transition from crystals in the mush moving during soda-lime migration (mobile mush) to crystals forming a continuous rigid network (rigid mush). Applied to natural systems, these results indicate magma migration amount and rate peak when rigid mushes "unlock".

Rod-and-ring assemblies will be used in dynamic experiments in which assemblies will be subjected to 200 MPa confining pressure and 900°C and then deformed in torsion at strain rates from 10-5 to 10-3 s-1 to shear strains up to 2. Based on the results of the static experiments, we anticipate enhanced melt migration as the local crystal fraction changes as the mush deforms.

467

Cataloging volcanic structures on the surface of Venus using machine learning

Mr Dominik Rzeszutek[1], Ms Patricia Gregg[1], Mr Matthew Head[1]
[1]*University of Illinois at Urbana-Champaign, Urbana, United States*

Characterizing surface features, such as volcanoes and impact craters, is key for determining their relative ages and understanding the evolution of celestial bodies. Traditional techniques typically require features to be manually logged; however, recent advancements in machine learning algorithms have greatly improved the efficiency and accuracy of recognizing features, allowing extensive catalogs of impact craters to be collated (e.g., Robbins & Hynek, 2012, Wang et al., 2020). With future missions planned to explore Venus in greater detail (i.e., VERITAS, DAVINCI, and EnVision), now is an excellent time to revisit digital elevation models (DEMs) collected by Magellan and enhance previous catalogs of the structures that comprise the surface of Venus. In this study, we use a convolutional neural network approach to produce new databases of volcanoes for the surface of Venus. A training data set is created manually in QGIS using the Magellan DEM and evaluated to determine statistically significant characteristics. We follow the approach of Silburt et al. (2019), binning the Venus data into quads of 30° x 25° about the equator, and train the algorithm "as we go" to increase the volume of training data at each step. This new catalog will provide an important foundation for future investigations of volcanism and the evolution of the surface of Venus.

References:

Robbins, S.J., and Hynek, B.M. (2012) A new global database of Mars impact craters ≥ 1 km: 1. Database creation, properties, and parameters, JGR: Planets, 117 (E5), doi:10.1029/2011JE003966.

Silburt, A. et al. (2019) Lunar crater identification via deep learning, Icarus, 317, doi:10.1016/j.icarus.2018.06.022.

Wang, S., Fan, Z., Zhengming, L., Zhang, H., and Wei, C. (2020) An Effective Lunar Crater Recognition Algorithm Based on Convolutional Neural Network, Remote Sensing, 12, 2694, doi:10.3390/rs1217269.

1321

Pluton Map: Spatiotemporal trends in magmatism, Te Riu-a-Māui/Zealandia, and an example of Nationally Significant Databases and Collections use in research

Dr Matthew Sagar[1], Dr Rose Turnbull[2], Dr Mark Rattenbury[1], Dr Andy Tulloch[2], Dr Kevin Faure[1]
[1]GNS Science, Lower Hutt, New Zealand, [2]GNS Science, Dunedin, New Zealand

All c. 300 known plutons in Te Riu-a-Māui/Zealandia are being defined and characterised using new and existing field, petrographic, geochemical, and geochronological data for the on-going Pluton Map (PMAP) project. Pluton Map will facilitate new research into spatiotemporal trends in magmatism through the Phanerozoic at the paleo-Pacific Gondwana and Te Riu-a-Māui/Zealandia continental margins. For example, analysis of whole-rock geochemistry and U–Pb zircon ages of Devonian–Early Cretaceous plutons show broad compositional trends with time, such as in pluton-averaged Rb/Sr and Sr/Y ratios, reflecting changing magma sources, tectonics, crustal assimilation, and magma evolution. New data have largely been acquired using existing samples from the National Petrology Reference Collection (NPRC), which contains >100,000 samples, and is the most comprehensive collection of geological samples from Aotearoa/New Zealand and its offshore territories. Both new and existing analytical data are stored in the PETLAB database (https://pet.gns.cri.nz/). The second main function of PETLAB is as the digital catalogue for the NPRC and similar collections held by Aotearoa/New Zealand universities. Pluton geological map data are stored in and the Regional Geologic Map Archive and Database (RGMAD). A new GIS-based PMAP web application is being developed that will dynamically link to PETLAB and RGMAD, delivering pluton map-views symbolised according to user-specified criteria.

920

Reflecting on the co-production approach to volcanic hazard education

Dr Sriparna Saha[1], Dr Ben Kennedy[1], Sylvia Tapuke[2], Dr Sara Tolbert[1], Kelvin Tapuke[2], Dr Angus Macfarlane[1]
[1]University Of Canterbury, Christchurch, New Zealand, [2]ECLIPSE Program & Scion, Rotorua, New Zealand

Educators in Aotearoa, NZ, have an ethical responsibility to model the articles of Te Tiriti o Waitangi. However, integrating these articles into the school curriculum is challenging. The education system continually perpetuates the domination of Western knowledge systems while marginalizing Indigenous ways of knowing. We thus need curricular resources that emulate different ways of knowing. But how do we do it in a way that is ethical, scientific, and authentic? To answer this question, we showcase an example of co-production of a culturally responsive virtual field trip resource (LEARNZ "Our Supervolcano"). The LEARNZ resource braids narratives from Mātauranga Māori and Geology to teach about the volcanic landscape around Taupō Volcanic Zone.

We sought to identify what aspects of the engagement process enabled this partnership between the Māori and non-Māori stakeholders. We used the He Awa Whiria (Braided Rivers) cultural framework as an analytical tool and invited the experts from the LEARNZ VFT resource to share their experiences around the collaboration. We identify relations, values, and space for sharing as elements critical to any engagement process with Māori. Using a co-production model through all stages of a project has the potential to break the cycles of mistrust between Māori and non-Māori researchers and stakeholders. Western researchers' participation in the Māori world is at the invitation of Tangata Whenua and based on "goodwill" and may be broken by negligence. To then restore balance in a non-punitive way, following Tikanga is critical throughout can lead to long-term relationships.

We emphasize that the collaborations must reflect the values and the relevant Indigenous knowledge system. The research methodologies that form the heart of this partnership are applicable in other cross-cultural research contexts. We hope the case presented here can inspire more educational initiatives and partnerships around other geological phenomena using a strength-based bicultural lens.

522

Lava flow free surface deformation as a constraint on flow dynamics II: Surface fold expressions of internal viscosity structure

Dr Susan Sakimoto[1,2], Dr. Tracy Gregg[2]
[1]Space Science Institute, Boulder, United States, [2]University at Buffalo, Department of Geology, Buffalo, United States

Folded lava-flow surfaces are common on Earth and other planets. Surface folds for any single flow may be found displaying more than one wavelength, and those wavelengths reflect flow conditions such as eruption rates, viscosity, cooling rates, and underlying topography. Prior work has used analytic models to relate wavelengths to crust/interior viscosity ratios, and thus compositions, with more silicic lava compositions generating longer wavelength folds.

Here, we computationally model lava flow surface folds with COMSOL multiphysics using a deformable free surface, a moving adaptive mesh and a temperature-dependent viscosity that decreases with depth. As in prior analytic approaches, we find that multiple wavelengths are generated when there is a strong (e.g. exponential) decrease of viscosity with depth. However, in contrast with analytic approaches, our computational approach also allows easy exploration of how flow basal topography (roughness, relief, and slope), flow velocity variations, and effusion rate variations modulate wavelengths.

Incorporating heat transfer (and thus flow cooling) and temperature-dependent viscosity functions for subaerial and submarine flows further demonstrates that higher viscosity contrasts generate longer fold wavelengths (or no folding), and that the change of viscosity with depth need not be exponential to generate folding. We present multigeneration computational surface folding examples for basaltic compositions under subaerial and subaqueous environments, and for more silicic compositions under subaerial conditions. These examples again illustrate how flow rates, cooling, and other factors can modulate predicted fold wavelengths.

524

Lava flow free surface deformation as a constraint on flow dynamics I: Numerical analysis of standing waves in channels

Dr Susan Sakimoto[1,2], Dr. Tracy Gregg[2]
[1]*Space Science Institute, Boulder, United States,* [2]*University at Buffalo, Department of Geology, Buffalo, United States*

Measuring key lava flow properties (depth, velocity, flow rate, rheology) of an active lava channel is challenging. Recently, Dietterich and others (2022) used observations of undular hydraulic jumps (wave trains) in lava channels to estimate flow depths and velocities. Others (Le Moigne et al., 2020) have used single hydraulic jumps (solitary standing waves) to derive constraints on flow parameters.

Hydraulic jumps are well-studied in turbulent flow because they are frequently found in fluvial hydraulics; however, they are rarely examined in laminar flow. The flow free-surface deformation, mixing behavior, and velocity distribution/flow rate relationship for laminar flow hydraulic jumps—particularly undular ones—are not well understood. The recent interest in using undular hydraulic jumps for inferring the key parameters of lava flow depths and flow rates suggests that reconsidering this flow regime is important. These lava-channel hydraulic jumps are mostly found in high-effusion-rate, near-vent flows, and mostly within laminar flow regimes. Intriguingly, the published hydraulic jump analyses use relationships derived from turbulent flow studies, but yield plausible flow properties for laminar lava flows.

Although numerical simulation of hydraulic jumps (laminar or turbulent) is complex computationally, recent advances in free surface tracking, along with improvements in computational efficiency, have made this more tractable. Additionally, the presence of undular hydraulic jumps and laminar flow constrains the Reynolds and Froude numbers to a narrow range, which in turn limits possible flow parameters. Using data from Dietterich et al. (2022) and Le Moigne et al. (2020), we model gravity-driven 3-D channelized lava flows with a deformable free surface in both laminar and weakly turbulent flow regimes, and compare velocity distributions, mixing behavior, and flow rates for similar flow densities and viscosities. We present preliminary results on the respective laminar and turbulent relationships between standing wave properties and flow properties.

409

CARBON FLUX FROM RINCÓN DE LA VIEJA VOLCANO, COSTA RICA

Miss Jessica Salas-Navarro[1], Dr. John Stix[1], Dr. Maarten de Moor[2,3], Dr. Alejandro Rodriguez[2], Dr. Christoph Kern[4], Msc. Emily Mick[1]

[1]McGill University, Montreal, Canada, [2]Observatorio Volcanológico y Sismológico de Costa Rica, Universidad Nacional de Costa Rica, Costa Rica, [3]University of New Mexico, Dept Earth and Planetary Sciences, , USA, [4]U.S. Geological Survey, Cascades Volcano Observatory, Vancouver, USA

Carbon is the second most abundant volatile species in most magmas and because carbon partitions to the gas phase at relatively high pressure and depth, volcanic carbon dioxide (CO2) emissions are diagnostic of magma movement within volcanic systems. However, quantifying the total carbon flux from volcanoes that host hydrothermal systems is one of the main challenges for volcanology. This study presents the first step in a comprehensive study to quantify the carbon flux of Rincón de la Vieja volcano, which is currently the most active volcano in Costa Rica. This volcano hosts a large hydrothermal system that has produced hundreds of phreatic/phreatomagmatic eruptions in the last few years. Rincón de la Vieja's hydrothermal system is likely responsible for scrubbing a significant fraction of the magmatic SO2 input before it can be degassed into the atmosphere. This circumstance complicates the estimation of the volcano's total volatile budget and its CO2 flux, in particular. Here, we attempt to constrain the volatile budget of the mixed magmatic-hydrothermal system by separating contributions from the summit crater and the volcano's flanks. Crater degassing of SO2 was quantified using two recently installed NOVAC stations. To investigate flank degassing, we further measured river fluxes and chlorine concentrations from 13 rivers draining the Rincon de la Vieja caldera. These measurements were combined to calculate chlorine fluxes which, following the methodology of Taran and Kalacheva (2018), can be used to estimate hydrothermal volatile fluxes. These data will allow us to compare crater degassing during phreatic eruptive activity to the volatile fluxes continuously being emitted on the volcano's flanks.

References

Taran, Y., & Kalacheva, E. (2018). Role of hydrothermal flux in the volatile budget of a subduction zone: Kuril arc, northwest Pacific. Geology, 47(1), 87-90. https://doi.org/10.1130/g45559.1

798

An Expanded Lava Creek Tuff Eruption, Yellowstone National Park

Mr Raymond Salazar[1], Madison L. Myers[1], Colin J.N. Wilson[2]
[1]Montana State University, Bozeman, United States, [2]Victoria University of Wellington , Wellington, New Zealand

The Lava Creek Tuff (LCT: >1000 km3, 0.63 Ma) is the product of the second supereruption from the Yellowstone volcanic system. In the Yellowstone region it principally consists of two ignimbrite members, A and B, defined by a reversal in welding profiles and the presence of phenocrystic amphibole in Member A1. However, two ignimbrite units mapped as the 2.08 Ma Huckleberry Ridge Tuff in the Sour Creek Dome area of Yellowstone National Park have yielded age estimates of ~658 ka (U – Pb on zircons) and 634 ka (40Ar/39Ar on sanidines) that are identical within error, to parallel age data on the 'conventional' LCT2. This study is characterizing these newly recognized ignimbrites by documenting their spatial distribution and petrographic make-up, and determining how they relate, stratigraphically and geochemically, to the previously described members of the LCT. The first of the two new deposits ('unit 1') is represented by mostly densely welded ignimbrite clasts in a monolithologic lithic lag breccia. This is inferred to be a vent-proximal (<3-5 km) deposit, yet the current mapped caldera boundary is 12 km farther outboard. Unit 1 is overlain sharply by unit 2, an in-situ densely welded ignimbrite. Both newly recognized units are visually distinct from members A and B of the LCT with the second unit being found throughout the Sour Creek Dome. Unit 2 is distinguished from all other 'LCT' units by the presence of mafic scoria, the first mafic product found within what we term the 'expanded Lava Creek Tuff'. Together these results imply the LCT eruption had a more complex history than previously recognized, that it had multiple phases, and suggests that location of the eastern Yellowstone Caldera boundary requires reconsideration.

[1] Christiansen, 2001 USGS Prof Paper 729-G
[2] Wilson et al., 2018 Bull Volcanol 80, 53.

926

Single-grain $^{40}Ar/^{39}Ar$ geochronology and LA-ICPMS trace-element geochemistry of Nariokotome Tuffs, Turkana Basin: a tephrochronological toolkit for tuff characterisation

Dr Hayden Dalton[1], Professor David Phillips[1], Dr Hayden Dalton[1], Professor Janet Hergt[1], Dr Erin Matchan[1], Dr Alan Greig[1], Ms Saini Samim
[1]School of Geography, Earth and Atmospheric Sciences, The University Of Melbourne, Parkville, Australia

The Turkana basin, a renowned geoarchaeological site in Kenya, located within the East African Rift System is known for discoveries of numerous spectacular hominin fossils. The Plio-Pleistocene sedimentary sequences hosting these hominin fossils are interbedded with volcanic ash (tuff) beds that provide time constraints on hominin evolution, the co-existence of multiple hominin species, evolution of technological culture and dispersal of hominins from Africa. It has been postulated that these evolutionary events were driven by abrupt climatic and environmental changes occurring at precessional-level (~21kyrs) cycles. The ability to test these models have been previously hindered by a) the large uncertainties (~30kyrs) in the ages derived from pumice clasts and b) the limited extent of most tuffs, leading to difficulty in intra- and inter-basin correlations.

Here, we use multiple tephrochronological correlation tools, including ultra-high resolution $^{40}Ar/^{39}Ar$ geochronology and single-shard major- and trace-element geochemistry of tuff and pumice glasses, to establish a well-characterised geochemical and geochronological framework for the Nachukui Formation, NW Omo-Turkana Basin. Utilising a new generation mass-spectrometer, we report distinct (preliminary) ages for the Lower Nariokotome (1,276.5 ± 4.2ka), Middle Nariokotome (1,259.1 ± 2.5ka) and Upper Nariokotome (1,228.3 ± 1.2ka) tuffs. Previously reported ages for these tuffs were indistinguishable. In addition, we obtained high-spatial resolution LA-ICPMS trace element compositions for individual glass shards from both tuffs and entrained pumice clasts. These data provide improved characterisation of the tuffs, aiding correlation of temporally-equivalent strata across the basin. In combination, these results facilitate an improved understanding of the volcanism associated within the Turkana basin with the potential to test models associated with hominin evolutionary events.

707

Generation of acoustics waves in the atmosphere by gas flow through Maxwell-type and Bingham- type fluids

Dr Claudia Sánchez[1], Dr Mie Ichihara[1]
[1]*Earthquake Research Institute, Bunkyo , Japan*

Due to decompression during magma ascent, bubbles grow, rise, and burst. These behaviors are coupled with the rheology of magma. Among the complexity, viscoelasticity has been considered essential for infrasound generation by the bubble bursting in volcanic systems. The linear Maxwell model is the simplest model to represent the magma viscoelasticity. Here we investigate the acoustic wave generation by the bubble bursting for two contrasting fluids: a Maxwell-type viscoelastic fluid (CTAB) and a Bingham-type yield-strength fluid (GEL). Although both fluids have similar rigidity in the linear elastic regime, they exhibit different fracture and flow behaviors. The acoustic signals generated with these two fluids are different and depend on flux, Q, and the depth of the air injection, h. In the case of CTAB, we observe the bursting sound only in the brittle regime at large Q, which is defined by the observation of successive fractures within the fluid. At shallow injection, the successive fractures connect from the injection nozzle to the fluid surface, creating an acoustic wave. At deeper air injection, the crack grows, detaches from the nozzle, rises to the surface, and generates an acoustic wave. A round cavity, only generated at small Q, does not generate acoustics waves. On the other hand, the air cavity is always round in the GEL, and the first bursting is silent for the same range of Q and h as in the CTAB. We never observe brittle fractures, either. When we continue the air injection, the successive bursting can generate acoustic waves in both fluids. The experiment demonstrates that the bursting sound is not determined by the rigidity alone but depends on the brittleness of the fluid and the gas-flow conditions (rate, depth, and history).

748

Trapdoor faulting at submarine calderas in Japan and New Zealand: Its potential for volcanic tsunami generation

Dr Osamu Sandanbata

Volcanic tsunamis can be generated by different mechanisms, such as submarine explosion, flank failure, pyroclastic flow, caldera collapse, volcanic earthquake, or interaction between acoustic pressure waves with the ocean. In this talk, I introduce a source mechanism of volcanic tsunamis newly found at submarine calderas in Japan and New Zealand. At these submarine calderas, moderate-sized earthquakes with seismic magnitudes of M5–6 repeated quasi-regularly and unusually caused tsunamis, sometimes with a maximum wave height of about a meter, but the source mechanism of the earthquakes/tsunamis has been unclear for four decades. Our source modeling approach using the tsunami and seismic waveform datasets revealed that the so-called trapdoor faulting, or sudden caldera uplift involving a large intra-caldera fault slip of meters, took place in the submarine calderas due to high magma overpressure and generated the earthquakes and tsunamis. These findings of submarine trapdoor faulting with high potential for the tsunami generation underscore our need to examine/monitor submarine calderas for assessing volcanic tsunami hazards. Additionally, the quasi-regular recurrence of trapdoor faulting reflects their active volcanism under ocean, strongly suggesting its potential for submarine eruptions in the future.

401

Sub-decadal volcanic tsunamis due to submarine trapdoor faulting at Sumisu caldera in the Izu-Bonin arc

Dr Osamu Sandanbata[1,2], Dr Shingo Watada[3], Dr Kenji Satake[3], Dr Hiroo Kanamori[4], Dr Luis Rivera[5], Dr Zhongwen Zhan[4]

[1]*National Research Institute For Earth Science And Disaster Resilience, Tsukuba, Japan,* [2]*JSPS Research Fellow (PD), Chiyoda, Japan,* [3]*Earthquake Research Institute, the University of Tokyo, Bunkyo, Japan,* [4]*Seismological Laboratory, California Institute of Technology, Pasadena, USA,* [5]*Université de Strasbourg, CNRS, ITES UMR 7063, Strasbourg F-67084, France*

At a submarine caldera, called Sumisu caldera, in the Izu–Bonin arc, volcanic earthquakes with Mw < 6 occurred once a decade (in 1984, 1996, 2006, 2015 and 2018) and caused unusual meter-scale tsunamis that are disproportionate to their moderate seismic magnitudes. Since the 1984 event was first recognized, various source mechanisms of the volcanic earthquake/tsunami events have been proposed. In this study, we analyze tsunami and long-period seismic data from the recent 2015 event to explore the source mechanism. Through a modeling approach assuming a source system composed of an intra-caldera ring fault and a horizontal crack, we show that a trapdoor faulting, or large brittle rupture of the ring fault interacted with the magma reservoir deformation, took place due to overpressure in the reservoir and generated the earthquake and tsunami. The trapdoor faulting is characterized by the large fault slip, shallow source depth, and complex source structure. These atypical source properties make the submarine trapdoor faulting efficient in generating tsunamis but inefficient in radiating long-period seismic waves, which explains the large tsunami disproportionate to their seismic magnitudes. The similar radiation patterns and tsunami waveforms of repeated earthquakes suggest that the continuous magma supply into the caldera causes quasi-steady recurrence of similar trapdoor faulting and imply that active submarine volcanism has been sustained over the decades. This newly found source mechanism of volcanic tsunamis underscores the need to monitor submarine calderas for a robust assessment of tsunami hazards.

770

A revised spatial probability map for lateral eruptions at Mt. Etna volcano, Italy

Dr Laura Sandri[1], Alexander Garcia[1], Stefano Branca[2], Mauro Coltelli[2], Gaetana Ganci[2], Cristina Proietti[2], Annalisa Cappello[2]
[1]Istituto Nazionale Di Geofisica E Vulcanologia, Sezione di Bologna, Bologna, Italy, [2]Istituto Nazionale Di Geofisica E Vulcanologia, Osservatorio Etneo, Catania, Italy

Mt Etna is one the most active volcanoes in the world, characterized by lateral and summit activity occurring on different time scales. Here we present the preliminary results obtained in the framework of the PANACEA project (INGV's project "Pianeta Dinamico", funded by the Italian Ministero dell'Università e la Ricerca) regarding the updating of the spatial probability map for lateral eruptions from Mt Etna.
First, a revised dataset of lateral mapped fissures opened in the last 2500 years has been compiled; where fissures are not visible, an inferred vent, with uncertainty radius, has been defined. In order to test the effects of (i) unavoidable incompleteness in the mapped fissures, and (ii) possible migration through time in the location of lateral activity, the fissure data have been split into training and testing subsets, over different time frames. By exploiting different Kernel functions (Exponential, Cauchy, and Gaussian functions), we have calculated the degree of clustering of lateral features in the training subsets. Different reference maps based on such data, with different Kernel functions and corresponding degrees of clustering, have been built. The likelihood of the testing data when using the different reference maps has been compared with those of 100 synthetic datasets of fissures sampled from the reference maps. This has allowed an objective definition of the best reference models, that identify persistent broad areas where the propensity of future lateral fissure-opening is larger. Finally, we have repeated the procedure to test whether the stress induced on the mapped fissures by previously-proposed sources of deformation at depth may identify a structural conditioning on where lateral fissures tend to open.

1336

Short-term Probabilistic Volcanic Hazard Assessment in operational environment from Campi Flegrei, Italy

Beatriz Martinez Montesinos[1], Dr Laura Sandri[1], Antonio Costa[1], Giovanni Macedonio[2], Arnau Folch[3,4], Leonardo Mingari[4], Daniela De Gregorio[5], Stefano Nardone[5], Prof. Giulio Zuccaro[5]
[1]Istituto Nazionale Di Geofisica E Vulcanologia, Sezione di Bologna, Bologna, Italy, [2]Istituto Nazionale Di Geofisica E Vulcanologia, Osservatorio Vesuviano, Napoli, Italy, [3]CSIC, , Spain, [4]Barcelona Supercomputing Centre, Barcelona, Spain, [5]Centro Studi PLINIVS, Università degli Studi di Napoli, Federico II, Napoli, Italy

Within the framework of ChEESE (Center of Excellence for Exascale in Solid Earth) we created an optimized HPC-based workflow coined PVHA_HPC-WF to develop Probabilistic Volcanic Hazard Assessment (PVHA) for a specific volcano. Increasing the computational capabilities of current PVHA products, PVHA_HPC-WF provides probability and hazard maps, with uncertainty, for tephra fallout at ground and airborne ash concentration and time-persistence at strategic flight levels, exploring the natural variability in Eruptive Source Parameters (ESPs) and wind conditions through a large number of ash dispersal simulations with the model Fall3D. Among other tests, we showcased the workflow through a live exercise for Campi Flegrei, proving the feasibility and usefulness for end-users, such as the Centre of Competence of the Italian Civil Protection PLINIVS and ARISTOTLE, of such hazard evaluations to produce useful short-term impact assessment of tephra ground load at the scale of a country, in particular over mobility networks (road, railways, seaports and airports) and electrical networks, in an operational environment, dealing with real-time performance-distributed workflow. We ran 300 large-scale and high-resolution tephra dispersal simulations with the Flagship code Fall3D on MareNostrum at BSC fetching weather forecast from GFS, and we processed them on the computer cluster ADA at the Istituto Nazionale di Geofisica e Vulcanologia (INGV) of Bologna fetching real-time monitoring data from Osservatorio Vesuviano surveillance system. Results show the ability of the PVHA_HPC-WF to perform PVHA in a reasonable time, with a sufficient level of detail, and therefore its usefulness for civil protection officials and society in reliably assessing volcanic hazard.

1044

Connection between fumaroles surface temperatures acquired by IR surveillance network of INGV-Osservatorio Vesuviano and seismicity at Campi Flegrei caldera (Italy)

Dr Fabio Sansivero[1], Dr Giuseppe Vilardo[1]
[1]*Ingv - Osservatorio Vesuviano, Napoli, Italy*

Surface temperatures of diffuse degassing areas in Campi Flegrei caldera (Italy) are continuously monitored by the permanent Thermal InfraRed surveillance Network (TIRNet) of INGV - Osservatorio Vesuviano since year 2004. Night-time infrared scenes acquired by TIRNet IR stations are processed by the automated system of IR analysis (ASIRA) and the de-seasoned temperatures time-series are displayed in the Surveillance Room of Osservatorio Vesuviano.

Starting from winter 2019, seismicity gradually increased at Campi Flegrei caldera reaching in the spring 2022 the highest magnitude earthquakes registered after the 1984 seismic crisis due to bradyseismic unrest. In the same period, the surface temperatures and the heat fluxes, estimated by TIRNet stations, particularly at the degassing areas of Solfatara crater and Pisciarelli, showed alternating increasing and decreasing trends of acquired values. Statistical analysis tools were applied to both infrared and seismic time-series in order to compare the different data sets. In almost all IR stations the related sudden variations of surface temperatures and heat fluxes are connected to earthquakes of significant magnitude (Md > 1). This interesting link between seismicity and surface temperatures of diffuse degassing areas testifies the complex interaction processes governing heat transfer inside the Campi Flegrei caldera. The IR data, acquired by TIRNer station, can give a significant contribute to build a thermo-hydro-geophysical model aimed to reconstruct the influence of seismicity on the fluid circulations and temperature distributions in the monitored volcanic area.

925

Role of lithospheric mantle assimilation on the volatile contents of lamproites and kimberlites: New insights from olivine and apatite compositions

Mr Soumendu Sarkar[1,2], Dr. Hayden Dalton[1], Andrea Giuliani[3], Prof David Phillips[1]
[1]School of Geography, Earth & Atmospheric Sciences, The University Of Melbourne, Melbourne, Australia, [2]Department of Geology and Geophysics, Indian Institute of Technology Kharagpur, Kharagpur, India, [3]Institute of Geochemistry and Petrology, Department of Earth Sciences, ETH Zurich, Clausiusstrasse, Switzerland

Lamproites and kimberlites are diamondiferous, volatile-rich (CO_2-H_2O) ultrapotassic/potassic magmas. They might be derived from broadly similar sub-lithospheric convective mantle sources that are variously modified by interaction with compositionally diverse lithospheric mantle wall rocks during transit to the surface based on linear correlations between mantle olivine (xenocryst) and magmatic olivine compositions. Lamproites and kimberlites have contrasting volatile compositions: lamproites are more H_2O-rich whereas kimberlites are enriched in CO_2. This raises the question as to whether there is any connection between lithospheric assimilation and the volatile composition of these magmas.

Apatite is a common primary late-stage groundmass phase in lamproites and kimberlites. Apatite compositions differ between dykes/sills (low Sr, high-variable Si) and root-zone kimberlites (high-variable Sr, low Si). The Si enrichment of apatite is attributed to the coupled incorporation of CO_3^{2-} and SiO_4^{4-} for PO_4^{3-}, reflecting higher CO_2 contents in their parental melts. Hence, Si contents in apatite reflect, in part, the CO_2 content of the parental melt.

We use the apatite chemistry to assess the late-stage volatile compositions (relative CO_2 content) of lamproites and kimberlites. We show that xenocrystic mantle olivine Mg# (proxy for the composition of traversed and entrained lithospheric mantle wall rocks) and apatite Si contents are correlated in lamproites and kimberlites from different cratons. This relationship suggests that the volatile contents of lamproites and kimberlites at surface are directly controlled by lithospheric mantle assimilation. Entrainment and assimilation of Fe-rich mantle material (i.e., low Mg# olivine xenocrysts) lead to lower CO_2 and therefore lower Si in apatite, whereas assimilation of Mg-rich mantle olivine leads to retention of more elevated CO_2 concentrations in the ascending melt and hence higher Si in apatite. This correlation may suggest that lamproites and kimberlites have similar initial volatile composition before modification by interaction with lithospheric mantle of variable composition en route to the surface.

877

Geochemical and petrological investigation into the Kamakaiʻa Hills basaltic andesites erupted from the Southwest Rift Zone of Kīlauea Volcano, Hawaiʻi

Dr Drew T. Downs[2], Dr Mai Sas[1]
[1]Western Washington University, Bellingham, United States, [2]U.S. Geological Survey, Hawaiian Volcano Observatory, Hilo, United States

Kīlauea is a frequently active volcano on Hawaiʻi that is well-known for its tholeiitic basalts. It intermittently erupts more evolved magmas, such as andesite in 2018 and basaltic andesites from its Southwest Rift Zone (SWRZ) in the early 1800s. The SWRZ is exposed over ~30 km from Halemaʻumaʻu Crater to the coast and has a pronounced ~30° SSW bend at its halfway point. Evolved magmas are the products of summit derived basaltic magmas stored within the SWRZ. These evolved magmas can then erupt when intruded with new, hot, basaltic magma. While a minor erupted component, investigation of these evolved magmas offers an opportunity to understand the origins and emplacement of shallow reservoirs, storage conditions and architecture, assimilation, and magma mixing processes, including eruptive triggers.

This study focuses on the largely basaltic andesite SWRZ eruptions of the Kamakaiʻa Hills, a two-phase eruption (an eastern ʻaʻā flow followed by a western pāhoehoe flow, whole-rock SiO_2 wt. % of 51.5–54.5 and 53.5–54.7, respectively) that is bracketed between 1790–1823 CE lavas. These crystal-poor lavas contain sparse (<1%) glomerocrysts and individual crystals of plagioclase and pyroxene, with minor olivine at the distal end of the western flow. Preliminary clinopyroxene-liquid thermobarometry suggests hotter crystallization temperatures and more variable pressures for the western flow (1176±3°C, 1.97±0.73 kbar) than the earlier eastern flow (1123±9°C, 1.61±0.77 kbar). Although prior work has suggested magma mixing to produce the observed range in compositions, new whole-rock data indicates magmas of the western and eastern flows largely resulted from fractionation (olivine+plagioclase+pyroxene and plagioclase+pyroxene+Fe-Ti spinels, respectively), with any mixing playing a minor role. The storage, evolution, and eventual eruption of these magmas near a ~30° SSW bend in the SWRZ hints at a complex interplay with tectonism influencing magma storage, and thus composition within segments of the rift zone.

494

The bickering sisters: Using mineral geochemistry to assess interconnectivity and magmatic cogenesis at two neighboring stratocones–central Oregon, USA

Sean Halstead[1], Emma Calvert[1], James Peale[1], Dr Mai Sas[1]
[1]*Western Washington University, Bellingham, United States*

The Three Sisters (Klah Klahnee) volcanic complex of central Oregon is dominated by three Cascade arc stratocones. Although closely related both spatially and temporally, these exhibit a tremendous diversity of eruptive behaviors and compositional products alike at this tectonically complex location. This investigation employs a petrologic approach to reconstructing past magmatism at Middle and South Sisters, where the locus of activity has alternated periodically between eruptive centers over a shared constructive history in the last 50 ky. Specifically, we compare mineral chemistry from three pairs of coeval lavas erupted from Middle and South Sisters, with each pair erupting during a notable change in volcanic activity, in order to identify and describe disparate crystal populations, pinpoint discrete melt sources, and interpret the extent of magmatic interactions beneath both volcanoes across this 6 ky window of joint eruptive history. In doing so, we hope to strengthen the basis of understanding regarding the magmatic inputs feeding these complex stratovolcanoes, as well as the nature of any interconnectivity which may contribute to their ongoing tug-of-war. In light of recent uplift detected in the vicinity of South Sister, it is as important as ever to utilize crystal records of the past to understand the complex processes of the system as a whole.

1352

Volcanic ash estimation method using dual-polarization weather radar

Mr Eiichi Sato[1]
[1]*Meteorological Research Institute, Japan, Tsukuba, Japan*

The Meteorological Research Institute (MRI), has been conducting observations around Sakurajima using X-band dual-polarization weather radar (MRI-XMP) and two-dimensional video disdrometers (2DVDs). MRI-XMP is used to observe volcanic ash in the atmosphere, and 2DVDs are used for ground-based ash fall observations. Using these data, the author is currently developing a method to estimate the amount of volcanic ash in the atmosphere, in order to improve the ashfall forecast issued by the Japan Meteorological Agency.

Conventional, or single-polarization weather radars observe a parameter called reflectivity, however, it does not provide enough information on volcanic ash in the atmosphere. On the other hand, dual-pol radars can also obtain parameters related to particle shape. Once a relationship between particle size and shape is assumed, we can estimate the amount of volcanic ash.

2DVDs play an important role in the estimation method. This equipment was originally designed to measure precipitation particles, and can observe the size, shape, and fall velocity of each particle. Using the data observed by 2DVDs, we can obtain a relationship between the grain size and shape of falling volcanic ash.
In this presentation, a method for estimating the amount of volcanic ash in the atmosphere using dual-pol radar will be presented. In this method, a data set of particle size, shape, and fall velocity observed by 2DVDs is prepared as an independent data set in advance. Assuming a grain size distribution, reflectivity and differential reflectivity can be calculated using this data set. After running this calculation multiple times, we can obtain a final estimate of the grain size distribution. The presentation will also include some examples of the estimation.

320

Magmatic processes and timescales of shallow plumbing system at Zao volcano, NE Japan: perspectives from compositional zoning in orthopyroxene phenocrysts

Mr Motohiro Sato[1], Dr Masao Ban[2], Dr Takashi Yuguchi[2], Mr Tatsuya Adachi[1]
[1]*Graduate School of Science and Engineering, Yamagata University, Yamagata-city, Japan,* [2]*Faculty of Science, Yamagata University, Yamagata-city, Japan*

We present magmatic processes and timescales in the shallow reservoir of the historical activity of Zao volcano (Okama pyroclastics, Okp), NE Japan, using orthopyroxene compositional zoning (crystal system analysis) combined with diffusion chronometry. The variety of orthopyroxene core compositions revealed three magmas (M1–3). The orthopyroxene phenocrysts with Mg# 68–76, 62–68, and 55–62 were precipitated from M1, M2, and M3, respectively. M1, the most mafic magma, would be from a deeper part of the plumbing system and recharged into M2, which mainly occupied the shallow reservoir of the system. M3, the evolved magma, may have been differentiated from M2. Narrow and broad high-Mg (Mg# 68–76) bands of orthopyroxene phenocrysts were crystallised by the interaction between M1 and M2, implying the recharge of mafic magma (M1) into the shallow reservoir. Most of these bands are surrounded by lower Mg parts. The existence of these lower Mg parts implies that recharged magmas (M1) were merged into the shallow magmas (M2) ephemerally. These processes have taken place in the entire period of Okp activity. Rarely observed gradual reverse zoned outer-core of low-Mg core orthopyroxene suggests an entrapment of the crystal from the marginal part of the reservoir (M3) into the main part (M2). The residence times of three to ten years obtained from compositional gradients of the broad band indicate that the interaction between M1 and M2 began approximately ten years before the eruptions. By contrast, the shorter residence times (one day to three years, mostly less than three months), obtained from compositional gradients of the narrow band, suggest that the interaction was accelerated just before the eruptions. In addition, the residence times from the gradual reverse zoning showed a wide range of ~100 years, which indicates compositionally zoned shallow reservoir was formed long time before the eruptions.

673

Twenty-two years of volcanic hotspots detected via neural network analysis of VIIRS and MODIS infrared imagery of Alaska volcanoes

Pablo Saunders-Shultz[1,2], Dr. Taryn Lopez[1,2], Dr. Hannah Dietterich[2], Dr. Társilo Girona[1,2]
[1]University Of Alaska Fairbanks, Fairbanks, United States, [2]Alaska Volcano Observatory, Anchorage, United States

Volcanic "hotspots", or areas of elevated surface temperature, may be produced by various types of volcanic activity, including lava flows, dome growth, and degassing through a hot vent and/or fumarole field. Monitoring volcanic hotspots can provide information about when a volcano is erupting, the eruptive style, and increases in surface temperature which may precede eruption. Hotspots cause an increase in infrared radiance, which can be observed in data from infrared satellite sensors such as the Visible and Infrared Radiometer Suite (VIIRS) and the Moderate Resolution Imaging Spectroradiometer (MODIS).

Here we present a model that automates the detection of volcanic hotspots with the aim to generate a historical time series that characterizes the thermal evolution of background, precursory, and eruptive activity of Alaska volcanoes. A U-net Fully Convolutional Network (FCN) is trained on 3800+ manually classified VIIRS images from periods of background and eruptive activity at Mount Veniaminof and Mount Cleveland volcanoes, Alaska. This model achieves an accuracy of ~96% when tested on 1200+ images from the same volcanoes and an accuracy of ~96% when tested on 2900+ images from six other Alaska volcanoes (Augustine, Bogoslof, Okmok, Pavlof, Redoubt, and Shishaldin). We also test the applicability of this model to MODIS data in order to extend the time series of detections back to 2000, finding a similar accuracy of ~98% on a labeled dataset of 600+ MODIS images. Finally, we apply the U-Net model to 10 years of VIIRS data and 22 years of MODIS data for all eight previously mentioned volcanoes, producing a 22-year multi-sensor time series of volcanic hotspot detections. Case studies are highlighted to show how these data can inform volcano monitoring.

1191

Seismic anisotropy on volcanoes and geothermal areas: Potential for monitoring

Professor Martha Savage[1], Associate Professor Yosuke Aoki[2], Associate Professor Jessica Johnson[3], Professor Richard Arnold[1], Dr. Finnigan Illsley-Kemp[1], Dr. Hubert Zal[1]

[1]Victoria University Of Wellington, Wellington, New Zealand, [2]Earthquake Research Institute, University of Tokyo, Tokyo, Japan, [3]University of East Anglia, Norwich, United Kingdom

Seismic anisotropy may reveal the state of stress in the crust, and its temporal changes have been attributed to deformation, seismicity, magmatic activity and geothermal extraction. We review crustal anisotropy in volcanic and geothermal regions from articles published through the end of 2019. We provide a database of anisotropy measurements to test hypotheses about the origin of anisotropy and about its utility for monitoring magmatic unrest or geothermal production. The majority of the articles (~100) examined shear-wave splitting.

Of the 88 studies examining the effects of stress vs. structure, the results were about evenly divided between causes related entirely to regional stress (16), local stress (10) or structure (11) alone or combinations of these possibilities. Delay times (a measure of anisotropy strength) increased with period and with depth in the two sets, but with much scatter. Because geothermal areas tended to be studied at shallower depths (median 2.5 km), they yielded lower delay times (0.1 s) at shorter periods (0.1 s) than volcanoes (median 12 km depth, 0.25 s period, 0.19 s time delay and 6% anisotropy).

Time variations in shear wave splitting were examined in 29 studies, but few of these presented statistical tests. Studies were divided between those that reported changes in delay times (12) or fast azimuths (8) alone, or both (8). Time variations were mostly reported to vary with the occurrence of eruptions or intrusions (19 volcanoes), seismicity or tremor rate changes (9), or deformation changes such as GNSS, tilt or strain measurements (10). Focal mechanisms, b-value, isotropic velocity, Vp/Vs ratio, gas flux, coda Q, unrest level, geothermal activity, and fluid injection were also correlated with splitting in some studies. There is a clear need for studies that examine statistical relationships between anisotropy and other parameters to test monitoring capabilities.

787

Application of tephrochronology in the Omo-Turkana Basin; using 40Ar/39Ar-geochronology to develop a high-resolution stratigraphic framework for the Okote Tuff Complex.

Ms Ashley Savelkouls[1], Professor David Phillips[1], Dr Hayden Dalton[1]
[1]The University Of Melbourne, Melbourne, Australia

The Omo-Turkana Basin preserves a detailed record of tuffs (tephra) interbedded with fossiliferous sediments spanning >3 million years. The stratigraphy of the eastern Basin has yielded fossils indicating several co-existing hominid species, which can be temporally anchored to bracketing tephra horizons. Research to determine the eruptive ages of the tuffs has been undertaken since the 1970s, pioneering the use of tephrochronology for archaeological applications. However, more recent developments in geochronology allow for increased certainty when determining the ages of eruptive events. The Okote Tuff Complex is a series of rapidly emplaced tuffs in the Koobi Fora Formation (East of Lake Turkana). Previous attempts to date these tuffs (via feldspar crystals from entrained pumices) using 40Ar/39Ar geochronology lack the certainty required to differentiate the ages of closely spaced eruptions. The uncertainties associated with age determinations are further exacerbated by the complexity of the volcanoclastic deposits in the Basin due to reworking from post-eruption fluvial processes. Here we report preliminary work aimed at unravelling the complexity of the Okote Tuff Complex using geochemical fingerprinting combined with precise (~ 1-2ka resolution) 40Ar/39Ar geochronology. Differentiation of eruptive events is determined using the major element geochemical signature of pumices and correlations with parent tuffs, in order to determine temporal markers across the Basin. After geochemical correlation, 40Ar/39Ar single crystal ages were obtained from anorthoclase grains extracted from the pumices, to further constrain eruptive events within the stratigraphic framework. Precise ages were determined using a high-resolution ARGUSVI multi-collector mass spectrometer. This project compares several 40Ar/39Ar age interpretation techniques that can be applied to single-crystal ages within pumices. The combination of geochemistry and age data allows the development of a high-resolution framework for the Okote Tuff Complex that will have major implications for archaeological applications.

665

A Glaciovolcanic Ridge at Pavonis Mons, Mars

Dr Kat Scanlon[1], Dr. Brent Garry[1], Prof. James Head[2]
[1]NASA Goddard Space Flight Center, Greenbelt, United States, [2]Brown University, Providence, United States

Based on large-scale morphometry, several studies have identified potentially glaciovolcanic landforms in the late Amazonian (~125 - 220 Ma) glacial fan-shaped deposits (FSDs) adjoining the three Tharsis Montes volcanoes on Mars. Only in the Pavonis Mons FSD do some of these landforms crop out from beneath the unconsolidated mantling unit that overlies the region. We surveyed HiRISE images of these outcrops at ~26 - 52 cm px-1 resolution, and DEMs derived from the images using the Ames Stereo Pipeline. The structures and textures visible in these high-resolution datasets enable better comparison to terrestrial analogue landforms than has previously been possible for candidate glaciovolcanic landforms on Mars, and hence more information about the style and glacial setting of volcano-ice interactions at these sites. We focused our study on a steep-sided, ~1 km long, ~250 - 300 m high ridge in the Pavonis Mons FSD. On the basis of the slopes of its flanks and their relationship to the inferred direction of ice flow for the Pavonis FSD, the distribution of faults along the ridge, the morphology of the layers that comprise the ridge, and other structures in the local area (e.g. pit craters, coarse columnar joints), we interpret the ridge as a tindar, or hyalotuff-dominated subglacial volcanic ridge. This implies interaction with liquid water throughout the ridge-forming eruption, which reinforces the potential astrobiological relevance of the Tharsis Montes FSDs as the sites of uniquely voluminous late Amazonian near-surface liquid water bodies. The presence of pervasive layering in this ridge and the other well-exposed candidate glaciovolcanic landform in the Pavonis Mons FSD are also inconsistent with the emplacement mechanisms that were inferred from the large-scale morphometry of other landforms within the FSDs, suggesting a diversity of glaciovolcanic processes in these environments.

992

Style Transitions and Physical Parameters of Explosive Activity During the 2021 Tajogaite Eruption (La Palma, Canary Islands)

Dr Piergiorgio Scarlato[1], Dr Jacopo Taddeucci[1], Dr Daniele Andronico[2], Dr Tullio Ricci[1], Dr Riccardo Civico[1], Dr Elisabetta Del Bello[1], Dr Laura Spina[1], Dr Clothilde Biensan[1], Dr Luca D'Auria[3,4], Dr Maria Asensio-Ramos[4], Dr David Calvo[4], Dr Eleazar Padron[3,4], Dr Pedro A. Hernandez[3,4], Dr Nemesio M. Perez[3,4]

[1]Istituto Nazionale Di Geofisica E Vulcanologia, Sezione Roma 1, Roma, Italia, [2]Istituto Nazionale Di Geofisica E Vulcanologia, Osservatorio Etneo, Catania, Italy, [3]Instituto Tecnológico y de Energías Renovables, Tenerife, Spain, [4]Instituto Volcanológico de Canarias, Tenerife, Spain

The 2021 Tajogaite Eruption (La Palma, Canary Islands, Spain) featured multiple styles of explosive activity, including, as broadly defined, lava fountaining, Strombolian explosions, rapid Strombolian, spattering, ash-rich and ash-poor jets, and ash venting. These styles occurred both alternately and simultaneously at multiple vents. To understand the processes underlying these styles and parameterize their defining features and transitions, we performed two multiparametric filed campaigns between 22 September-1 October and between 5-9 November 2021. Deployed instruments included: three high-definition cameras (25 FPS, 0.03-1.2 m/pixel ca.), one thermal camera (up to 50 FPS and 0.2-0.8 m/pixel .ca), one high-speed camera (frame rate 250 to 500 frames per second (FPS) and 0.021-0.147 m/pixel resolution at the vent), and one microphone (flat response between 0.5 and 10000 Hz, sampling rate 20 kHz). Manual tracking of pyroclasts and Optical Flow analysis of the videos returned pyroclast ejection velocities in a broad range from 20 to 220 m/s, the highest and the lowest peak velocities pertaining to Strombolian explosions and ash venting, respectively. During all eruption styles, pyroclast ejection velocity fluctuated over time, displaying variably marked ejection pulses. These pulses were associated with variably pronounced acoustic transients, with larger-amplitude and more abrupt ones during the phases of lava fountaining that featured the highest mean ejection velocity and a transition towards Strombolian explosions. Image analysis reveals that the eruption rate of the coarse lapilli to bomb-sized pyroclasts was in the broad range from to < 2x10^2 to >2x10^4 kg/s, the lowest and highest values pertaining to ash-poor jets and lava fountaining, respectively. Finally, the in-flight grain-size distribution of pyroclasts larger than ash-sized particles is coarsest during the spattering activity and finest during the ash-poor jetting. These results underline once more how a physical parameterization is essential to discriminate the markedly gradual activity shifts typical of mafic explosive activity.

1126

Can petrological monitoring forecast the end of an eruption?

Dr Jane H. Scarrow[1], Dr MJ Pankhurst[2,3], Dr Olivia Barbee[2,4], Dr KJ Chamberlain[5], Dr DJ Morgan[6], Dr DA Neave[7], Dr J Hickey[8], Dr Penny Wieser[9], Dr BC Coldwell[2,3], Dr W Hernández[2], Mr AG Stewart[7], Dr GK Rollinson[8], Dr L D'Auria[2,3], Prof N Pérez[2,3]

[1]University Of Granada, Granada, Spain, [2] Instituto Volcanológico de Canarias, San Cristóbal de La Laguna, Spain, [3]Instituto Tecnológico y de Energías Renovables, Granadilla de Abona, Spain, [4] Whitman College, Walla Walla, United States, [5]Teesside University, Middlesbrough, United Kingdom, [6]University of Leeds, Leeds, United Kingdom, [7]University of Manchester, Manchester, United Kingdom, [8]University of Exeter, Penryn Campus, United Kingdom, [9]University of California, Berkeley, United States

Volcanic deposits contain a record of processes that prime, drive, and ultimately halt eruptions. High-frequency sampling of the 2021 Tajogaite eruption (La Palma) - 19th September to 13th December 2021 - reveals subtle compositional transitions. Petrological changes are intimately connected with volcanological phenomena and geophysical monitoring signals. Although the all lavas have comparatively restricted, primitive, metaluminous, alkaline whole-rock compositions a subset of samples (from 107 lavas, 10 ballistics and 448 tephras) allows identification of three principal stages through time.

Opening Stage 1 (S1): days ~0–(5-7) (19–24-26 Sept), included mineralogically mixed 6.0-6.7 wt% MgO alkali basalts, produced by bottom-up triggering and top-down eruption of mixed mush (~8-12 km).
The S1-S2 transition coincided with increased eruption mass fluxes and eruption of hotter, lower viscosity, faster flowing lava which changed hazard profiles.

Steady-state Stage 2 (S2): days ~(6-7)–67 (25-26 Sept–25 Nov), consists of 7.4-8.3 wt% MgO alkali basalts and can be divided into substages A and B using key compositional inflections between days ~14-19 (4-9th Oct), indicating a progressive tapping of deeper (~15-30 km), more primitive, magma lenses.
The S2-S3 transition signalled magma reservoir collapse and beginning of the end of the eruption.
Ending Stage 3 (S3): days ~70-85 (29 Nov-13 Dec), represent progressively lower ~8 wt% MgO alkali basalts erupted as depressurisation and subsequent reservoir collapse caused release of more evolved magma lenses.

Our new time series petrological data provide detailed insights into evolution and termination of active volcanic magmatic plumbing processes of use for crisis management and policy on La Palma and other comparable contexts. Conventional forecasting and monitoring efforts typically focus on determining when an eruption may start; petrological insights into when an eruption may end feed into syn-eruption risk assessment and hazard response with important socio-economic consequences, such as beginning recovery efforts and allowing return of displaced populations.

1108

Preparation and Resistance to Eruption of IberoAmerican Volcanes (PREVIA): an interdisciplinary study of Apoyeque, Nicaragua

Dr JH Scarrow[1], Dr MP Ibarrondo-Dávila, Dr A García-Yeguas[1], Dr C Argüello-Gutiérrez[2], Dr J Garrido Manrique[1], Dr J Carrillo-Rosúa[1], Prof JM Ibáñez[1], Dr LA Gutiérrez[1], Dr J Prudencio[1], Ms SE Layton Jaramillo[1], Ms MA Díaz Corchuelo[1], Dr E Espinoza Jaime[3], Dr JA Saballos Peréz[3], Dr C Gutiérrez Gutiérrez[3], Prof W Strauch[3], Dr D Matus Sanchez[3], Dr D Chavarría González[3], Dr S Balladares-Navarro[4], Dr L Lechado-Ríos[4], Dr AL Amaya López, Dr L Torres[4], Prof H Calderon[5], Dr E Perez[5]
[1]University of Granada, Spain, Granada, Spain, [2]International University of La Rioja, Logroño, Spain, [3]Nicaraguan Territorial Studies Institute, Managua, Nicaragua, [4]National Autonomous University of Nicaragua, Managua, Nicaragua, [5]Centro de Investigaciones de Geofísica, National Autonomous University of Nicaragua, Managua, Nicaragua

'The biggest eruptions tend to occur at volcanoes we know nothing about' (1). Long-dormant volcanoes with highly explosive past eruptions are particularly dangerous and frequently impact disproportionately on vulnerable and marginalised societal groups. Thus, the necessity for a paradigm shift from response to anticipation in study and monitoring of such systems.

In May 2022 fieldwork was undertaken in collaboration with colleagues from the Nicaraguan Institute for Territorial Studies (INETER) and the National Autonomous University of Nicaragua (UNAN-Managua) with a focus on Apoyeque volcano: last known eruption 50 BCE (tephrochronology), VEI 6, located ~30 km from Managua (population ~1 million).

Geological fieldwork was completed to understand style and extent of volcanic activity and collect samples for geochronological and geochemical analysis to date magmatic storage and interpret eruptive processes. Geophysical studies are underway to develop early warning protocols for eruptions, imaging of subsurface melt geometry, and machine learning detection and classification of volcanic events. In the social sciences, historical and archaeological records are being mined for cultural evidence of previous eruptions to place constraints on past activity. Existing regulations for prevention and mitigation of natural hazards and influences of these on urban and territorial planning are being investigated – including consideration of hazard maps. Related to this, expected economic losses will be estimated. Risk perception analysis of communities regarding volcanic activity and their sense of preparedness is being assessed with an online survey. Talks were given in local communities and at the UNAN, and STEAM workshops in primary and secondary schools assessed children's mental models of volcanism, risk and hazard before and after outreach activities.
The aim of this research is to develop a hazard and risk action plan to drive a change towards anticipation and adaptation and, as a result, increased autonomy resilience for potentially affected communities.

1. Oppenheimer 2011, ISBN:978-0-521-64112-8.

690

Cross-program collaboration to address volcano landslide hazards at the U.S. Geological Survey

Lauren Schaefer[1], Shaul Hurwitz[2], Jon Major[3], Jonathan Godt[4]
[1]Geologic Hazards Science Center, U.S. Geological Survey, Golden, United States, [2]California Volcano Observatory, U.S. Geological Survey, Moffett Field, United States, [3]Cascades Volcano Observatory, U.S. Geological Survey, Vancouver, United States, [4]National Hazards Mission Area, Denver, United States

Large landslides on volcanoes initiate, mobilize, and deposit through a cascade of complex processes with sometimes disastrous consequences. As a result, integrated, multidisciplinary analyses are required to accurately assess their provenance, likelihood, and hazards. In 2022, scientists from across the U.S. Geological Survey, with expertise in volcanic landslides, deeply seated slope failure, physical and mechanical characterization of volcanic material, fluid-gas-rock interactions, in-situ and remote monitoring, and cascading landslide hazards (e.g., tsunamis and lahars), convened to discuss the state of knowledge and the future needs of volcano stability research and observatory efforts. The workshop identified the knowns and unknowns of volcano instability hazards and provided a forum for discussions on technological advances useful for assessing where large landslides may occur, how they may evolve, and how to monitor them. Participants identified opportunities for multi-disciplinary research related to mapping, modeling, detection, and experimentation related to large rock slope failures and associated cascading phenomena. Research alignment and collaboration using a wide range of multi-hazard expertise and resources will result in more robust analyses of volcano instability and develop relationships and coordination to respond to disasters more effectively.

692

Linking subsoil types, alteration and degassing processes at Rotokawa geothermal field, New Zealand

Bettina Scheu[1], Cristian Montanaro[1,2], Lena Ray[2], Shane Cronin[2], Aimee Calibugan[3], Stefanie Rott[1], Candice Bardsley[3]

[1]Earth and Environmental Sciences, LMU München, München, Germany, [2]School of Environment, University of Auckland, Auckland, New Zealand, [3]Mercury NZ Ltd., Rotorua 3040, New Zealand

Surface expressions of hydrothermal systems such as mud pools, fumaroles, and collapse pits or hydrothermal eruption craters are manifold, highly complex and variable in space and time. Often they are part of major tourist attractions (e.g. Yellowstone, USA, or Wai-o-Tapu, NZ), or are present in operating geothermal fields, for instance in the Rotokawa Geothermal Field.

We mapped the spatial distribution of surface thermal features and temperatures, as well as the physical and mechanical properties of top and subsoils within the Rotokawa steamfield. Three main domains were identified based on the prevalent group of the geothermal features, soil types and the apparent differences in alteration. The spatial distribution of these domains suggests that fluid circulation, alteration intensity, and degassing are strongly controlled by i) field- and regional scale fracture systems oriented ~NE-SW, ii) the presence of a series of intercutting eruptive craters, iii) the heterogeneous Taupo Pumice deposit, and iv) sulphur mining activity in the 19xx.

Five main groups of soil layers are recognized according to their formational environment (undisturbed vs. reworked, unaltered vs. altered), granulometry, petrophysical and mechanical properties. Degassing and fluid circulation within top and subsoils appear strongly affected by the dominant layer type. Pumiceous permeable soil layers (e.g. sand/pebble-rich) act as lateral fluid pathways. Whereas the presence of low-permeability layers (e.g. clay/silt-rich) within the Taupo Pumice/reworked material, and/or the formation of silica sinters and cemented, hard grounds, inhibit surficial fluid degassing.
A close characterisation of the near-surface environment enables precious insights to better understand the spatio-temporal evolution of the surface expressions of hydrothermal systems, and any hazards associated with near-surface fluid-rock interaction processes. Such natural processes can promote a broad range of geological phenomena, including migration of thermal manifestations and gas outputs, subsidence and/or ground collapse, and worst-case scenario small-sized hydrothermal eruptions.

693

Evolution of silica sinters within active geothermal environments: Maturation and petrophysical properties of young silica sinters from Rotowaka geothermal field

Bettina Scheu[1], Eleonora Carocci[1], Simon Thivet[1], Cristian Montanaro[1], Shane Cronin[2], Daniel Weidendorfer[1], Stefanie Rott[1], Aimee Calibugan[3], Candice Bardsley[3], Donald B. Dingwell[1]
[1]Earth and Environmental Sciences, LMU München, München, Germany, [2]School of Environment, University of Auckland, Auckland, New Zealand, [3]Mercury NZ Ltd., Rotorua 3040, New Zealand

Silica sinters are heterogeneous deposits precipitated from either mineral-rich, near-neutral alkaline chloride hydrothermal fluids, or acidic hot springs covered by microbial mats. These are common in hydrothermal areas, and part of major tourist attractions, e.g., at Yellowstone (USA), El Tatio (Chile), Wai-o-Tapu and Te Puia (both NZ), and they are also present in operating geothermal fields such as the Rotokawa Geothermal Field (NZ).

Silica sinters may significantly affect the evolution of surficial manifestations in geothermal fields. In particular, growing (thickening) and maturation processes can strongly reduce sinter permeability over time, and in addition they might act as thermal shields. In Rotokawa, we identified several types of sinter deposits based on their diagenetic origin and textural features and further characterised their petrophysical properties, mainly permeability, density and porosity.

Early stages of sinter formation are dominated by microspheres of hydrate non-crystalline silica, i.e. opaline-A ($SiO2 \cdot nH2O$). During the maturation stages opaline-A evolves with continuous water loss into opaline-C, opal-T or, more commonly, in a not-proportional mix of the latter two: opaline-CT. The last diagenetic stage includes the transformation in dehydrated quartz microcrystals. The maturation from opaline-A to quartz microcrystalline results in changes of sinter's petrophysical properties (e.g. porosity and permeability). Yet this process is not uniform and can happen over different temporal and spatial scales.

We aim to clarify the configuration of different opaline states and their bounded water amount, by (1) Raman spectroscopy to decipher degree of disorder of opaline-A and opaline-CT, and (2) Thermal Gravimetry Analysis (TGA) and Evolved Gas Analysis (EGA) to determine the amount of water (molecule or hydroxyl group) physisorbed. By linking structural, textural and petrophysical characterisation of sinters, we aim to provide insights into sinter evolution which can be useful information in assessing the surficial manifestations of hydrothermally active environments and associated hazards.

890

Phreatomagmatism at Kīlauea volcano, Hawaii: exploring Unit D of the Keanakākoʻi Tephra

Dr Johanne Schmith[1], Dr Donald A. Swanson[1]
[1]*USGS Hawaiian Volcano Observatory, Hilo, United States*

In July 2019 water started to form a lake in Halemaʻumaʻu crater and inspired interest in Kīlauea's explosive past – especially regarding explosive magma-water interaction. The most recent explosive period (Keanakākoʻi Tephra, ca. 1500 to early 1800 CE) contains unit D, which is proposed to result from phreatomagmatic activity. We studied the proximal stratigraphic and lithologic changes in unit D using field observations, componentry, granulometry, and grain morphology characterization from dynamic image analysis to assess the nature of the deposit.

Unit D consists of four subunits – two ashy subunits and two lapilli-bearing subunits. The lapilli-bearing subunits consist of couplets of millimeter-thick homogeneous ash layers and centimeter-thick poorly sorted lapilli-bearing layers containing significant but variable amounts of pumice and free olivine crystals; they are interpreted as fall deposits. The ashy subunits primarily show three bed types: millimeter-scale laminated planar beds, diffusely bedded decimeter beds of poorly sorted ash, and homogeneous ash beds commonly carrying accretionary lapilli. Crossbedding is also observed. We interpret these subunits as a mix of fall and surge deposits.

Grain-size data show Mdϕ-values of lapilli-bearing subunit couplets between -1.96 ϕ and 2.69 ϕ, averaging 0.24 ϕ (coarse ash). Mdϕ-values of ashy subunits are between 0.43 ϕ and 3.98 ϕ, averaging 2.34 ϕ (fine ash). All samples are poorly to very poorly sorted. Ash grains are predominantly juvenile and dense with blocky and equant shapes. Mean shape parameter values for the 20–1000 microns size-range are 0.82 for compactness, 0.78 for sphericity, and 0.33 for surface roughness. These values are all higher than those of Keanakākoʻi units K1 (0.77, 0.63, 0.15) and B (0.72, 0.56, 0.12) from dry Hawaiian fountains.

The fine and poorly sorted nature of the deposits, as well as the blocky and regular grain types, all support an interpretation of unit D as a phreatomagmatic deposit.

894

Geyser-like gas jets in Halemaʻumaʻu lava lake, Kīlauea Volcano, Hawaii – the story of tephra generation in the 2020 eruption

Dr Johanne Schmith[1], Dr Matthew Patrick[1]
[1]*USGS Hawaiian Volcano Observatory, Hilo, United States*

On December 20, 2020 a new eruption started in Halemaʻumaʻu summit crater at 20:29. A 50-meter-deep water lake already occupied the crater and caused concerns about explosive magma-water interaction, but at 23:00 three lava fountains from the crater wall were observed feeding a growing lava lake in Halemaʻumaʻu. The water lake was gone and no tephra was on the ground. However, a 1-centimeter-thick tephra deposit was covering the southern crater rim the next morning. Here, we use observational, video, and 2D grain-shape data from dynamic image analysis (DIA) to investigate the origin of the crater-rim tephra.

Ground observations and time-stamped samples collected during the early eruption places primary tephra deposition between midnight and 02:45. The deposit mostly consists of scoriaceous sideromelane and tachylite ash grains with mean DIA shape parameters of sphericity: 0.69, compactness: 0.78, and surface roughness: 0.23 that characterize moderately irregular particles. Phreatomagmatic Keanakākoʻi unit D (0.78, 0.82, 0.33) deposits have higher values pointing to more regular grains, whereas wind-advected fountain deposits of pumice from Keanakākoʻi unit K1 have lower values (0.63, 0.77, 0.15) characterizing more irregular grain shapes. The DIA modeling suggests that neither lava fountains nor explosive lava-water lake interaction were the primary contributors to the tephra deposit.

However, seven gas-release events from the northern part of the lava lake, reminiscent of short-lived erupting geyser jets with precursory surface unrest and post-jet degassing, were recorded between 23:22 and 01:00. Events increased in size, duration, and repose interval over time, and three jets produced small, dark plumes that rose out the crater. The largest jet erupted at 01:00, which correlates with the time window of the main deposition. Our study suggests that the geyser-like gas jets were the primary source of the crater-rim tephra deposit, though their cause and gas source remain under investigation.

1085

Future needs for quantitative volcanic ash forecasts in support of aviation: The role of volcano observatories

Dr David Schneider[1], Paula Acethorp[2], Dr. Sara Barsotti[3], Dr. Samantha Engwell[4], Dr. Claire Witham[5]
[1]US Geological Survey Alaska Volcano Observatory, Anchorage, United States, [2]New Zealand Civil Aviation Authority, Wellington, New Zealand, [3]Icelandic Met Office, Reykjavík, Iceland, [4]British Geological Survey, Edinburgh, Scotland, [5]UK Met Office, Exeter, United Kingdom

The 2010 eruption of Eyjafjallajökull caused huge disruption to aviation, highlighting a need to identify volcanic ash concentration thresholds that could improve route efficiency without posing a safety concern for aircraft. In response, the International Civil Aviation Organization (ICAO) developed standards for quantitative volcanic ash (QVA) information, to be provided by Volcanic Ash Advisory Centers (VAACs). QVA information will allow airlines to conduct safety-risk assessments to avoid both long-term aircraft damage and unnecessary flight disruptions, while ensuring flight safety. QVA information is expected to replace the current volcanic ash advisories issued by VAACs over the next decade. QVA information will be provided in gridded probabilistic data sets and deterministic data "objects" – analogous to a set of shapefiles that describe areas of volcanic ash meeting pre-defined concentration thresholds. There have been major advancements in satellite retrievals of volcanic cloud properties and modeling of cloud transport and dispersion, but much more work is needed to meet these future requirements.

Engagement with volcano observatories is vital to these efforts, especially in eruption forecasting, eruption characterization and hazard communication. Flight planners use status reports of pre-eruption unrest from volcano observatories in their safety-risk assessments. Prompt notification of the onset of eruptive activity to local air traffic control and VAACs is critical. Estimates of volcanic cloud height (or a time-series of heights) if available provide necessary inputs to VAAC ash dispersion models. Communication of eruption information through use of the Volcano Observatory Notice for Aviation (VONA) and the Aviation Color Code is being elevated by ICAO to a recommended practice (from a suggested practice). Our overall goals are to convey the details and challenges of these policy changes underway, to solicit feedback from the observatory scientists and the broader volcanology community, and to incorporate feedback into revised guidance to volcano observatories.

477

A thermomechanical model to study the influence of an exsolved carbon dioxide-water phase on magma chamber growth and longevity

Kathryn Scholz[1], Prof. Meredith Townsend[1], Prof. Christian Huber[2], Dr. Juliana Troch[3], Prof. Olivier Bachmann[4]
[1]University Of Oregon, Department of Earth Sciences, Eugene, United States, [2]Brown University, Department of Earth, Environmental and Planetary Sciences, Providence, United States, [3]National Museum of Natural History, Smithsonian Institution, Mineral Sciences, Washington, United States, [4]ETH Zurich, Institute of Geochemistry and Petrology, Zurich, Switzerland

Magmatic volatiles play a critical role in the physical evolution of magma reservoirs by driving pressure and temperature changes and altering physical magma properties. Recent numerical studies focused on H_2O in silicic magmas have shown that H_2O content strongly influences the growth and longevity of eruptible silicic reservoirs by regulating the size and frequency of eruptions. Although CO_2 is less abundant than H_2O in most silicic magmas, there is growing recognition that CO_2 plays an important role on the stability of different mineral phases and the solubility of H_2O. However, the effects of CO_2 on the physical state of magma reservoirs remain poorly understood. We present a new thermomechanical model to understand the effects of CO_2 on the growth and longevity of magma chambers undergoing crystallization, eruptions, and recharge. The model enables us to explore the role of volatile species in silicic magma reservoirs and mafic magma reservoirs where the exsolved fluid phase is typically CO_2-dominated. For geologically realistic CO_2-H_2O contents, we find that CO_2 influences magma chamber responses to recharge and eruptions by changing magma compressibility; however, we find that these changes do not affect the time-averaged eruptive flux and that CO_2 content has little impact on growth and longevity of mafic and silicic systems. In contrast, H_2O strongly influences growth and longevity by changing the time-averaged eruptive flux and the crystallization path of the magma. In silicic systems, H_2O restricts growth by increasing the time-averaged eruptive flux and narrowing the temperature range over which magma crystallizes to the locking threshold. In mafic systems, H_2O enhances growth and longevity by expanding the temperature range over which magmas crystallize. This work highlights that the magma chemistry and the presence and composition of an exsolved fluid phase are crucial elements in the thermal and mechanical evolution of shallow crustal magma reservoirs.

1171

Values-based engagement with Indigenous communities leads to better science

Dr ACUSHLA SCIASCIA[1], Professor JONATHAN PROCTER[2]
[1]Ngāti Ruanui, Ngāruahinerangi, Te Ati Awa, Pukerua Bay, Porirua, New Zealand, [2]Muaupoko, Te Horo, New Zealand

In Aotearoa New Zealand, application and decision making based on indigenous knowledge has in the past been ignored or in conflict with decision making based on western science specifically in the complex, trans-disciplinary nature of reducing disaster-risk for our communities. Aotearoa New Zealand has a legal obligation to recognise the rights of indigenous peoples, Māori, over its volcanic landscapes. Large tracts of this landscape is specifically under Māori ownership which requires a new approach to undertaking volcanological research, volcano monitoring and volcanic hazard analysis. In this research we present a model of engagement to address the need to recognise indigenous knowledge alongside volcanology and volcanic hazard analysis. We present a case study from Mt. Ruapehu (Ngāti Rangi) and Mt. Taranaki (Te Ati Awa, Ngāti Mutunga, Ngāti Maru, Ngāti Tama, Ngāti Ruanui, Ngāruahinerangi, Taranaki, Ngā Rauru) where local tribes live and practice traditional values in and around their land, mountains and waterways. Engagement in both of these case studies required different approaches; on one hand we have a tribe who has dealt directly with volcanic hazards and the other, 8 tribes who have never had to deal with volcanic phenomena. Both approaches required agreement from participants to work from principles derived from cultural values and knowledge. These principles then determine whether a co-design (Mt Ruapehu) or collaborative (Taranaki) approach was needed. The co-design approach focused on developing solutions to volcano monitoring and response to volcanic phenomena whereas the collaborative approach within Taranaki has focused on understanding past volcanic scenarios combined with their narratives and building resilience to future events. Both case studies have sought researchers /practitioners from their tribes (iwi) and sub-tribes (hapū) to contribute knowledge alongside Western science – this duality of knowledge systems represents a weaving together as complimentary rather than Western knowledge dominating indigenous knowledge as inferior.

386

A testing framework to evaluate hazard models for forecasting

Ms Emmy Scott[1], Dr Melody Whitehead[1], Dr Stuart Mead[1], Prof Mark Bebbington[1], Prof Jonathan Proctor[1]
[1]*Volcanic Risk Solutions, Massey University, Palmerston North, New Zealand*

Accurate hazard forecasts are needed to help mitigate the risks of volcanic hazards to society. Numerical and statistical models can be used to estimate hazard footprints and intensities of volcanic phenomena such as tephra, PDCs, lahars, and ballistics. These models require inputs of unknown future eruption source parameters such as flow rate and total erupted mass. Before simulation of future events, internal parameters are commonly tuned to fit any past observations. The assumption is then – if a model can be tuned to replicate past observations, it may be able to simulate future behaviours. Model complexity is a key issue. Generally, the more tuneable parameters a model has the more complex it is. More complex models can be more finely tuned to past events, but this fine-tuning does not translate to reliable forecasts of future events. How to test model forecasts before an event remains an open question.

Model parameters used for forecasting are constrained by significant uncertainty. This research seeks to understand the interaction between model complexity and reliability of hazard model forecasts. This work presents an ontology of volcanic hazard models across the complexity spectrum alongside a statistically robust testing framework that represents a first step towards model selection for hazard forecasting. This framework considers model assumptions, limitations, and the trade-offs between bias and variance. The work will provide a transparent approach to measure forecasting skill and recommendations of where and how each numerical/statistical model can (or cannot) be appropriately deployed.

1227

Using trace element and isotope geochemistry of Taupō Volcanic Zone (New Zealand) granitoids to understand processes contributing to silicic magmatism

Miss Laura Seelig[1], Professor Colin Wilson[1], Dr Isabelle Chambefort[2], Dr Bruce Charlier[1]
[1]*Victoria University of Wellington | Te Herenga Waka, Wellington, New Zealand,* [2]*GNS Science, Wairakei Research Centre, Taupō, New Zealand*

The central Taupō Volcanic Zone (TVZ) is an area of vigorous Quaternary silicic volcanism, with rhyolite output from caldera-forming events alone exceeding 6000 km^3 over the past 1.85 Myr. Our understanding of the geochemical evolution and magmatic processes operating within the modern TVZ rhyolitic systems (Taupō & Ōkataina) comes from the study of past eruptive products. Volcanic rocks provide a snapshot of the eruptible magma system during and immediately prior to eruption. Whereas their plutonic counterparts record magma accumulation over time, cooling and thus complementary insights into the processes in central TVZ magmatic systems.

Within the central TVZ, rare plutonic fragments have been erupted as lithic clasts in several silicic and mafic eruptions. This work focusses on erupted granitoid lithics from various central TVZ eruptions, with a specific interest in those erupted during the caldera-forming Rotoiti event at Ōkataina, due to the large number erupted. Petrographic investigation (mineralogical and textural), geochemical, and isotopic analyses have been undertaken on these granitoids to better understand their environment of crystallisation and the magmatic processes contributing to their petrogenesis.

Trace element geochemistry suggests central TVZ granitoid compositions are controlled by plagioclase fractionation. Granitoid lithics show variations in Eu/Eu* that correlate with Rb/Sr ratios, both across the whole suite of central TVZ granitoids and within granitoids from the same eruptive unit. The central TVZ granitoids show a weak compositional gap in silica content (75 -77%), where granitoid groups either side of this divide correlate to distinct high Sr (112-215 ppm) and low Sr (8-50 ppm) compositional groups. The granitoids show a typically narrow range of $^{87}Sr/^{86}Sr$ isotope ratios (0.7050 – 0.7070) but with a weak bimodality. This bimodality between granitoids from different eruptions could potentially reflect a link to two crustal domains that could tentatively be attributed to Waipapa- (lower $^{87}Sr/^{86}Sr$) versus Torlesse-influenced greywacke sources.

456

Too hot to stop! Processes governing deposit-derived (zombie) pyroclastic density currents and ash clouds: examples from 1991-2000 at Mt. Pinatubo

Dr. Noah Randolph-Flagg[1], Dr. Ronnie Torres[2], Professor Stephen Self[3]
[1]USRA, NASA Ames Research Center, Moffat Field, CA 94035-1000, and Blue Marble Space Institute for Science, Seattle, WA, USA, Mountain View , United States, [2]Hawaii Army National Guard, Department of Defense, Kapolei, United States, [3]University of California, Berkeley, Alameda, United States

Pyroclastic density currents (PDCs), high-temperature volcanic ash and gas flows, are arguably the deadliest, focused volcanic hazards. More widespread hazards are posed by volcanic plumes where buoyantly lofted volcanic ash and gas can damage aircraft, affect respiratory health, and threaten global food security through volcanic aerosols' effect on climate. A largely unstudied source of focused hazard is deposit derived or 'zombie' PDCs and plumes. For example, a deposit-derived block and ash PDC from the 2018 Volcán Fuego eruption in Guatemala caused 400+ casualties (Risica et al., 2022) while a deposit-derived atmospheric plume after the 1991 Pinatubo eruption caused airport closures over a month later (Casadevall et al., 1996). Here we use observations from the 1991 Mt. Pinatubo eruption and its aftermath to understand how deposit-derived PDCs and plumes initiate, how they behave, and how they can be identified in the rock record. At Pinatubo, deposit-derived PDCs extended up to 5 km farther than vent-derived PDCs from the June 15 climactic eruption, continued to form up to a decade afterwards, and produced plumes that reached the stratosphere. We use the HYDROTHERM numerical model to show that elevated pore pressure due to boiling water fronts lead ignimbrite deposits to become unstable and initiate slope failures. We then use idealized plume and PDC models to understand the eruptive conditions that lead to the observed deposits. Our work suggest that long-distance low-aspect-ratio ignimbrites observed throughout the western US (e.g., Roche et al., 2022) may, in part, be due to post eruptive remobilization. We also show that ignimbrite deposits may be unstable long after eruption and deposition (even on quite low slopes), are prone to collapse as deposit-derived PDCs, and may pose underappreciated hazards to surrounding communities and infrastructure.

451

Block-and-ash flow deposits of the c. AD 1314 Kaharoa eruption of Tarawera volcano, Okataina caldera, North Island, Aotearoa New Zealand

Professor James Cole, Professor Stephen Self, Dr. Ian Nairn
[1]*Univ. Of California, Berkeley, Alameda, United States,* [2]*University of Canterbury, Christchurch, Aotearoa New Zealand,* [3]*Geological Investigations, Lake Okareka, Rotorua, Aotearoa New Zealand*

The long-duration, complex c. AD 1314 Kaharoa eruption of Tarawera volcano, Okataina caldera, North Island, NZ, ended with effusion of rhyolitic lava domes and production of block-and-ash flow pyroclastic density currents and deposits. This eruption phase, starting months after the earlier explosive phases, was of undetermined duration (but estimated to be ~ 3-4 years long) and the deposits are labelled N in the eruption stratigraphy. Activity was concentrated at three vents, Tarawera, Ruawahia, and Wahanga. The sequence of activity at each was similar but the order of eruption is indeterminate. During early N-phase, lava domes were built and collapsed to form extensive BAFDs, building 4 fans of BAFD deposits, one from Tarawera vent, two from Ruawhaia vent, and one from Wahanga vent. These BAFD deposits do not overlap each other. The BAFDs are unusual in several aspects but must represent early collapses of unseen lava domes because the preserved domes and flows on Tarawera do not contain scars of collapsed portions; they are more-or less complete. The BAFDs reach a maximum of 9 km from vent and include draped steep-slope facies, valley-ponded facies, and narrow valley-fill facies. Individual BAFD units are 10s of m in thickness and massive, unlike more modern BAFDs at Unzen, or Merapi, but similar to some Soufriere Hiils BAFD units. The DRE volume of the BAFDs is ~ 0.2 km³ while the remnant domes contain ~ 0.8 km³ of lava. Outboard (eastwards) of two of the BAFD fans, a thin combined ash-cloud-surge and fallout deposit extends for at least another 11 and 15 km at the same position as the N deposits in the local stratigraphy. This is testament that ash-cloud surges spread well beyond the BAFDs and, if repeated in a future eruption, could be hazardous to the environment and infrastructure.

1112

Ideas, experiments, and fieldwork on dynamic earthquake triggering of eruptions

Gilles Seropian[1], Ben Kennedy[1]
[1]*University Of Canterbury, Christchurch, New Zealand*

Tectonic earthquakes may trigger a range of phenomena at volcanic centers, from hydrothermal unrest to magmatic eruptions. The underlying mechanisms of these events remain poorly understood, which hinders our ability to monitor them. Here we present an overview of the recent results from a project aiming to characterize seismically-triggered eruptions, and drawing from a wide range of techniques. Starting in the field, we focused on the case of the 1960 Cordón Caulle eruption, which occurred 36 h after the M9.5 Great Chilean earthquake. We compared the chemistry and textures of the pumice deposits with two other eruptions to decipher any signature from the seismic trigger. We also performed two sets of experiments investigating the role of bubbles in seismic triggering. A first series of analogue experiments explored whether seismic waves could accelerate bubble rise. Then, we performed high temperature experiments to test whether pressure oscillations could induce vesiculation in magma. Finally, we position our results in the existing literature, and propose a novel framework to help both researchers and observatories understand and prepare for seismically-triggered eruptions.

1252

Volcanic-tectonic Interactions During the 232 AD Taupō Eruption: Evidence of Proximal and Distal Interactions

Miss Yaasameen Shalla[1], Dr Pilar Villamor[2], Dr Colin J.N. Wilson[1]
[1]*Victoria University of Wellington, Wellington, New Zealand,* [2]*GNS Science, Lower Hutt, New Zealand*

In this study, a series of eruption-triggered faulting, slumping and fissuring events are linked to the 232 AD Taupō eruption. Located in the intra-rifted Taupō Volcanic Zone, New Zealand, the Taupō volcano has produced the youngest supereruption (Oruanui ~25.5 ka) and the largest Holocene eruption (232 AD Taupō eruption) in New Zealand. Recognition of the Parekarangi Fault rupturing during the 232 AD Taupō eruption in a paleoseismic trench, located ~55 km from the source vent, highlighted the spatial extent of stress changes during the eruption. In addition, possible syn or immediately post-eruption triggered faulting on the Twin Creeks Fault, ~ 40 km from the eruption vent, is interpreted in ground penetrating radar. When combined with previously published work, these examples of syn-eruption faulting highlight a dual origin of either stress change related or a passive response to shaking during the eruption. Magmatic volume gain or loss is interpreted as a non double-couple deforming source that appears to have triggered a series of seismically rupturing faults at various distances. The triggered faulting would have resulted in multiple double-couple seismic events with variable spatial-temporal relationships to the original eruption. Furthermore, by mapping examples of syn-eruption triggered slumping and fissuring, comprehension of syn-eruption shaking at distances can be gained. The above highlights the interconnectivity of volcanism and tectonism during the largest Holocene eruption, eluding to a complex series of syn-eruption faulting, during substage controlled shaking and stress changes.

212

Magma mingling and ascent in the minutes before an explosive eruption as recorded by banded pumice

Dr Hannah Shamloo[1], Dr Anita Grunder[2]
[1]Central Washington University, Ellensburg, United States, [2]Oregon State University, Corvallis, United States

Explosive silicic eruptions often contain banded pumice, reflecting magma mingling in the conduit prior to or during eruption. Heterogeneities in tuffs have been attributed to the draw up of distinct magmas, in which low-viscosity magmas ascend more quickly than high-viscosity magmas. However, this model has yet to be tested using modern petrologic tools such as diffusion chronometry. The Rattlesnake Tuff (RST) of the High Lava Plains in Oregon represents the eruption of a zoned magma reservoir, where at least five distinct rhyolite compositions are preserved in banded pumice samples in variable mingled combinations. Geochemical gradients of Si recorded across band boundaries indicate mingling and conduit ascent times within the minutes to eruption. Viscosity calculations of distinct RST rhyolites show a strong correlation between ascent times and magma viscosity, where high viscosity magmas have longer ascent times than low-viscosity magmas. This relationship supports the model for successive tapping of density stratified magma chambers that lead to heterogeneities in tuffs. Additionally, our results provide predictive power to conduit ascent times of magmas based on their viscosities. While diffusion chronometry is most popularly applied to zoned crystals, this study demonstrates that applying diffusion chronometry to banded pumice is a useful means to determine magma mingling and consequent ascent rates for a high-threat explosive eruption.

221

A reappraisal of the crystallinity of volcanic rocks: Implications for eruptibility

Dr Hannah Shamloo[1], Dr Adam Kent[2]
[1]*Central Washington University, Ellensburg, United States,* [2]*Oregon State University, Corvallis, United States*

There is wide consensus that the eruptibility of a magma is strongly controlled by viscosity, and although different factors influence magma viscosity, crystallinity is a critical variable. As crystal fraction increases in a cooling and crystallizing magma there is a critical transition at 40-60 vol.% crystals, where rheological "lock up" prevents magma flow and eruption. However, the relationship between crystallinity and viscosity is complex, and it may be possible that highly crystalline magmas could be erupted in some settings. In addition, the transition to non-eruptible magma may occur at lower crystallinities in silicic magmas due to the higher viscosity of the interstitial liquid.

Although magma viscosity can be studied using a range of experimental, numerical, and theoretical approaches, one underutilized but important source of information for understanding the relationship between crystallinity and eruptibility of magma are the observed crystallinities in erupted material. Earlier compilations have been influential but contain relatively small sample numbers. Here we present a comprehensive compilation of the reported crystallinities of erupted material for almost 1000 erupted samples, across different terrestrial settings, for magmas of different compositions, and for different eruption styles. Samples range from lava, dome, tephra, and ignimbrite. The median crystallinity recorded for the entire distribution is 32 vol.%, and a clear drop-off in frequency occurs at ~60 vol.% crystals - where only dome eruptions exceed this value. There is also no observable correlation between maximum crystallinity and SiO2 content, contrary to existing, but smaller, compilations. Viscosity calculations based on observed compositions also reveal that crystal content has the largest control on viscosity opposed to SiO2 content, temperature, and water content. Our compilation provides valuable insight into the fundamental mechanisms in which drive volcanic eruptions.

193

Contrasting triggers and short timescales for eruptions at Taranaki volcano revealed by plagioclase phenocrysts

Dr Phil Shane[1], Prof Fidel Costa[2], Prof Shane Cronin[1], Prof Claudine Stirling[3], Dr Malcolm Reid[3]
[1]*University Of Auckland, Auckland, New Zealand,* [2]*Université Paris Cité, Paris, France,* [3]*University of Otago, Dunedin, New Zealand*

At volcanoes where eruptions have not been directly observed, retrospective criteria such as phenocryst growth must be used to determine the magmatic conditions conducive to eruption. Indeed, this can also be the case for some well monitored active volcanoes. New Zealand's andesitic Taranaki volcano is capable of nation-wide ash dispersal and is thus, potentially hazardous. However, since AD1790 it has been anomalously quiescent. To access possible eruption triggers, we examined the textural, geochemical, and isotopic features of plagioclase phenocrysts from its most recent episode of activity (~AD1030-AD1790). In-situ 87Sr/86Sr analyses reveal little discordance between the phenocrysts and a uniform source melt for most deposits. However, textural and geochemical features of their final rim zones reveal contrasting conditions just before eruption. In some magmas, plagioclase record late growth in a silicic melt of ~0.5 -1.0 wt % MgO followed by partial resorption and regrowth in a more mafic melt of >3.5 wt % MgO, indicating magma mixing occurred. Modelling of post-crystallisation Mg diffusion indicates periods of <1 day to a week for these events, consistent with the entry of new magma into the system just before eruption. In contrast, in magmas from intervening eruptions, and from some older pre-1 ka episodes, phenocrysts record uninterrupted growth and increased magma crystallinity prior to eruption. For these eruptions, triggering is better explained by volatile pressurisation induced by crystallisation in a closed system. We infer two coupled modes of eruption operated. The eruptions cause the reorganisation of the system influencing the buoyancy and permeability of the conduit that either favours the ascent and eruption of new magmas or their stagnation and subsequent pressurisation via crystallisation. Both modes resulted in similar eruption styles and magnitudes and likely followed short periods of unrest.

186

Deccan Trap Volcanism as the Local Cause for Generation of Medium size earthquakes in Peninsular India (PI)

Professor Daya Shanker[1]
[1]*Indian Institute Of Technology Roorkee, Roorkee, India*

Deccan trap is the youngest and largest geological formation covering about one-third region of Peninsular India (PI) region (80 -250 N and 680 -880 E). Crustal and lithospheric thickness for the rest of the region is relatively large in comparison to Deccan trap because of old geological formation. The duration of the volcanic lava eruption is 4 my in this region. The large eruptive zones of flood basalt are associated with the subsidence of neighbouring crustal rocks into the upper mantle. For these zones the solidus of basalt lies at 22 to 36 km. These are well replicated by prominent positive and negative gravity anomalies. Ninety four years (1900-1993) seismicity data reveal that seismicity of Deccan trap is a separate entity as energy released in this region is 4.5 times more than the rest of the shield which covers 60% of the total area. Data analyses reveals that Deccan trap is seismically more active than the rest of the shield region. A model is presented to explain why all the medium size earthquake are distributed over trap covered region only? The rises and depressions in Moho would develop cracks and faults extending to the deeper crust in the surrounding areas of gravity anomalies and heat flow zones. Such zones may be proper place for accumulation of fluid released in dehydration process. The injection of fluid into the upper crust through faults would accumulate in cracks causing their widening and lengthening to long distances. As the process is continues for a long time fluid would generate stress perpendicular to cracks or fault surfaces resulting an earthquake. The fluid would also act as lubricant reducing friction to promote sliding. Probably this could be the reason why medium size events are confined to such areas.

664

Sticking together mush? A 3D re-evaluation of crystal clustering mechanisms in basaltic magmas

Tom Shea[1], Alexandre Carrara, Revd Kelly McCartney, Julia Hammer, Masako Terada, Msgr. Adrien Mourey, Hrishikesh Bale, Jordan Lubbers, Matthew Andrews, William Harris, Jr. William Nelson, Esq. Rebecca deGraffenried, Jdg. Rose Gallo, Nabila Nizam, Andrea Tonato
[1]*University of Hawai'i at Mānoa, Honolulu, United States*

Groupings of multiple crystals are common in all magma types and likely serve as a constructive framework for the assembly of magma mushes and plutonic bodies. Three mechanisms are generally invoked to rationalize the formation of mono- or polyphase clusters:

(1) Aggregation by accumulation (settling and compaction)
(2) Aggregation by synneusis (the ‘swimming together’ and joining of crystals in a dynamic magma body
(3) Clustering via crystal growth (branching of crystals, twinning and/or epitaxial growth)

These mechanisms predict a number of observations (random vs. non-random crystal and lattice orientations, formation of trapped melt pockets, elemental zoning patterns), but individually they lead to non-unique interpretations. For this study, we integrate various analytical and numerical modeling techniques on a monomineralic olivine cluster. We characterize (a) the number and orientation of grains using Diffraction Contrast Tomography, (b) major element zoning patterns expected from diffusive re-equilibration of Fe-Mg using 3D diffusion models, (c) the zoning patterns recorded by growth-preserving elements via EPMA maps in >30 serial sections, and (d) crystal settling dynamics of non-clustered and clustered crystals using 3D numerical simulations. Our results show that single clusters with 40 different grains have crystallographic orientations and zoning patterns most consistent with growth phenomena. 3D diffusion models also show that seemingly disparate zoning profiles - originally suggested to be symptomatic of synneusis - can simply result from Fe-Mg re-equilibration in grains of different sizes. Ongoing numerical simulations of crystal settling highlight the influence of crystal shape and numbers on cluster re-orientation, and will help provide bounds on possible interactions between crystals in a melt-rich reservoir. This integrated approach gives a new framework to study and interpret mono- and polymineralic clusters in other magma types and may help bridge current gaps in our understanding of crystal arrangements in mush and plutons.

1433

A comprehensive observational database of deformation at global volcanoes for machine learning applications

Dr Lin Shen[1], Professor Andrew Hooper[1], Dr Susanna Ebmeier[1], Dr Matthew Gaddes[1]
[1]*COMET, School of Earth and Environment, University of Leeds, Leeds, United Kingdom*

A key indicator of potential volcanic activity is deformation of a volcano's surface due to magma migrating beneath, which can be measured using InSAR. The Sentinel-1 archive now contains a large number of examples of volcano deformation, which can provide a basis for machine learning approaches to automatically classify and potentially forecast deformation. We therefore aim to systematically extract all deformation signals at volcanoes globally, including smaller scale signals associated with processes such as landslides and local changes in hydrothermal systems. We keep data storage requirements to a minimum by only cropping the area around each volcano, while ensuring the area is large enough to capture all potential deformation. To avoid the loss of decorrelated signal in areas of glacial coverage, winter snow and heavy vegetation, we build a highly redundant small baseline network of interferograms tailored to each volcano using coherence tests. To mitigate the effect of phase propagation through the atmosphere, we provide multiple atmospheric correction methods, including a Spatially Varying Scaling Method that uses interferometric phase to refine the interpolation of the weather model in time and space. We store the processed data in a database with annotated metadata, which is available to the public via a portal due course.

317

Tsunamis generated by underwater volcanic eruptions: An experimental investigation

Dr Yaxiong Shen[1], Dr Colin Whittaker[1], Dr Emily Lane[2], Prof James White[3], Dr William Power[4]
[1]University Of Auckland, Auckland, New Zealand, [2]National Institute of Water and Atmospheric Research, Christchurch, New Zealand, [3]University of Otago, Dunedin, New Zealand, [4]GNS Science, Willington, New Zealand

Violent underwater explosive eruptions can suddenly displace large volumes of water, which have the potential to generate devastating tsunamis. Tsunamis triggered by underwater volcanic eruptions can cause destruction well beyond the range of the eruption itself, as recently demonstrated by the 2022 eruption of the Hunga Tonga-Hunga Ha'apai (HTHH) volcano. The challenges of applying existing predictive methods to the local and transoceanic tsunamis generated during this event highlight the importance of more research into tsunamis of volcanic origin.

Although a large quantity of field data was collected by many modern instruments around the world following the 2022 HTHH eruption, the inaccessibility of underwater environments and the lack of direct observations at/near submerged vents leaves the wave generation mechanisms still relatively poorly understood. In this study, we developed complementary datasets through novel laboratory experiments, where either compressed air or steam was injected into a tank with a range of water depths, applied pressures, jet durations, and tank water temperatures. To investigate the influence of these variables on the jet-plume morphologies, free surface disturbances, and wave properties, we simultaneously recorded the evolution of the eruption and related waves in each experiment. The experimental results suggest that, for a given eruption, there is a critical water depth associated with the most effective wave generation and a containment water depth associated with negligible wave generation. The experiments also show a saturation duration above which the maximum wave height does not increase with increasing jet duration. This study provides insights into the fundamental wave generation mechanisms related to underwater volcanic eruptions and will improve the interpretation and predictive capability of this natural disaster.

601

Volcano Data Communications, Examples From Geohazards Data Tutorials and Blogs

Dr Steven Sherburn[1], Jonathan B Hanson[2], Megan Madley[2], Sara Horne[2], Elizabeth Garlick[2], Elisabetta D'Anastasio[2]

[1]GNS Science Te Pū Ao, Taupo, New Zealand, [2]GNS Science Te Pū Ao, Lower Hutt, New Zealand

The GeoNet programme at GNS Science Te Pū Ao, Aotearoa-New Zealand is responsible for collection and management of multi-hazard data sets, including for volcanoes. Explaining how to find, access, and use GeoNet's data are important components of FAIR and GeoNet's core principle of open data.

A web site is the mainstay of GeoNet's data communications, with data and API documentation, data discovery and visualization applications. There is also a smartphone application, news stories, and public GitHub repositories. Data tutorials and a data blog are relatively new additions to our data communication portfolio.

In 2019, we developed data access and basic use tutorials for seismo-acoustic, GNSS, volcano-specific time-series, and coastal tide gauge data. In 2021, we added tutorials for ocean tsunami (DART) data, and in 2022, for volcano hydrology and fumarole temperature data. All tutorials are available in a GitHub repository as Jupyter notebooks that are largely written in Python.

In 2022, we started a data blog, available as a category of news story on our web site. A data blog post aims to show an aspect or specific use case of GeoNet data that is too specific to become a web page and not "revolutionary" enough to become a publication. Blog posts should take no more than 10 minutes to read, be written in a "casual" style, and not be overly technical, but can contain short segments of "computer code". A data blog is relatively quick to produce, doesn't require changing front-window content on the web site, and doesn't need to be kept current. Early blogs have been written on a volcanic alert level data set and volcano webcam images.

We present examples from volcano tutorials and blog posts and discuss the success of these initiatives.

599

FAIR Volcano Data at GeoNet, Aotearoa-New Zealand

Dr Steven Sherburn[1], Jonathan B Hanson[2], Megan Madley[2], Maria Mavroeidi[2], Elisabetta D'Anastasio[2]
[1]GNS Science Te Pū Ao, Taupo, New Zealand, [2]GNS Science Te Pū Ao, Lower Hutt, New Zealand

The GeoNet programme at GNS Science Te Pū Ao, Aotearoa-New Zealand is responsible for collection and management of multi-hazard data sets, including for volcanoes. FAIR is a cornerstone of GeoNet's data management principles, and we try to apply it to our volcano data.

In 2019, we carried out an assessment of the FAIR status of all GeoNet's data sets using an adaptation of the Australian Research Data Commons FAIR self-assessment tool which is based on the Research Data Alliance (RDA) FAIR Data Maturity Model. As expected, the results varied with the data set. More established data sets, and those used with multi-hazard applications, such as seismic data and photographic images, generally received higher scores. Some of the data sets relevant for volcano monitoring and research had high scores, but some were low.

We will describe how we used FAIR to prioritize data custodianship improvements and present an updated scoring of some example data sets to highlight the impact of this targeted work.

We will provide an overview of FAIR for GeoNet hosted volcano datasets and focus on two specific data sets:

- The history of volcanic alert level values at 12 Aotearoa-New Zealand volcanoes.
- Historic volcanic activity descriptions and timing for Ruapehu and Tongariro volcanoes.

We will highlight an example of a data set DOI (Digital Object Identifier), how this can improve FAIR scores across multiple letters, and how it is a key first step in a user determining if we hold a data set that might address the problem they want to solve.

752

Generation process of large-scale phreatoplinian eruption, Kutcharo volcano, eastern Hokkaido, Japan: Inferred from stratigraphy and water content of volcanic glass

Mr Shohei Shibata[1], Dr Takeshi Hasegawa[1]
[1]*College Of Science, Ibaraki University, Mito , Japan*

Phreatoplinian eruptions are defined by deposits dominated by extremely fine ash over areas covering hundred kilometers or more (Self and Sparks, 1978). However, the generation process of these eruptions still remains unclear due to lack of eye-witness observations. We present a case study of the 40 ka caldera-forming eruption (Kp I: VEI=7) from Kutcharo volcano, based on geological (stratigraphy and lithofacies) and petrological (morphology and chemistry of volcanic glass) data. Water content was estimated by SEM-EDS using the quantitative analysis of oxygen concentration (Geshi et al., 2017).

The Kp I eruption deposits consist of 7 units (Shibata and Hasegawa, 2022). In ascending order, units 1 to 6 are air-falls and 7 is ignimbrite. All deposits contain not only highly-vesiculated pumice (by volatile fragmentation), but blocky-shaped and fine-grained glass shards probably produced by phreatomagmatic (quench) fragmentation. Although glass chemistries show an overall homogeneous composition with SiO_2= 77 wt.%, water content of matrix glass of pumice (3.0 to 3.5 wt.%) is remarkably smaller than that of very fine sand-sized ash (4.0 to 5.0 wt.%). In Plinian eruptions, the water content of matrix glass represents the residual dissolved water content in the melt at the fragmentation level (Martel et al, 2000). Our data suggest phreatomagmatic fragmentation generating blocky fine ash occurred earlier at deeper levels in the conduit by interacting with groundwater before volatile fragmentation that generally occurs below the depth of approximately 1,000 m in water-saturated felsic magma (Zhang, 1999). The Kp I eruption was preceded by the largest caldera-forming eruption at Kutcharo (Kp IV: 120 ka; Hasegawa et al., 2016). Generation of the Phreatoplinian eruption seemed to be controlled by plumbing where conduits penetrated the huge aquifer that preserved/hosted a large amount of external water in the preexisting caldera structure.

913

Quantitative identification of ash particles by visible micro-spectroscopy for monitoring transition in eruption styles

Dr Taketo Shimano[1], Dr Atsushi Yasuda[2], Dr Takahiro Miwa[3], Dr Michihiko Nakamura[4]
[1]Tokoha University, Shizuoka, Japan, [2]Earthquake Research Institute, the University of Tokyo, Bunkyoku, Japan, [3]National Research Institute for Earth Science and Disaster Resilience, Tsukuba, Japan, [4]Tohoku University, Sendai, Japan

Volcanic eruptions are basically non-steady phenomena, and they go through various styles before coming to rest. Understanding the mechanisms of mode transitions in volcanic eruptions is one of the central issues in volcanology. Recent advances in geophysical observation techniques have made it possible to monitor seismic and ground deformation continuously from before to during eruptive activity, and theoretical models of eruptive phenomena have made it possible to at least partially explain these data. However, these understandings are based on a number of assumptions, and in particular, they rely heavily on assumptions about the magma and groundwater that drive the observed fluctuations, as well as on assumptions about the rocks surrounding the conduits that magma and groundwater go through. Therefore, if information on magma and host rock is given independently and continuously, our understanding of eruptive transitions will be enhanced.

In this respect, the ejecta obtained through volcanic eruptive transitions is volcanic ash, and many studies have recently been reported on the characteristics of volcanic ash from many eruptions. In particular, the componentry of volcanic ash particles has been reported in many studies as an important variable that relates the eruption style and magma ascent process. Recent attempts have been made to classify them using expensive particle analysis equipment and machine learning techniques, but the black box nature of the classification criteria makes their interpretability difficult. In this study, we developed a method to identify volcanic ash particle species using objective method for recent eruptions of several volcanoes by using microscopic visible spectroscopy, which is relatively inexpensive and easy to implement. By converting the spectra, which vary widely from particle to particle, into mean intensity and normalized spectral patterns, we were able to classify particles based on explicit criteria.

1439

Pico de Orizaba Volcano, Mexico – monitoring and interacting (secondary) hazard assessment of a sleeping giant

Dr Katrin Sieron[1], Dr. Lizeth Caballero[2], Dr. Francisco Córdoba Montiel[1], Dr. Silvano Ulices Que Salinas[1], M.Sc. Edwin Ulices Monfil León[3]
[1]Centro de Ciencias de la Tierra, Universidad Veracruzana, Xalapa, Mexico, [2]Facultad de Ciencias, Universidad Nacional autonoma de Mexico, Ciudad de México, Mexico, [3]Universidad de Ciencias y Artes de Chiapas, Tuxtla Gutierrez, Mexico

Pico de Orizaba or Citlaltépetl volcano is a 5636 m high stratovolcano at the eastern edge of the Trans-Mexican Volcanic Belt, which hosts a summit glacier at its northern flank and has had historic activity. The volcano elevates more than 3000 m above the Mexican altiplano to the W and more than 4500 m above the Gulf of Mexico coast to the E. Present tectonic activity, glacier retreat, extreme weather conditions as well as hydrothermal and physical weathering of the un-vegetated high slopes, are perfect conditions for any kind of mass movement, as lahars, rockfalls and slides. Therefore, not only the fact of the volcano possible reawakening, but also the threat of phenomena classified as "secondary" is constant. Recent secondary lahar hazard studies, together with new information on the situation of the vulnerability of the population at high altitude villages on the volcano flanks, gave rise to new efforts on enhanced monitoring, including high mountain precipitation and visual monitoring and first attempts to develop an artificial intelligence algorithm, based on artificial neural networks in order to analyze seismic signals for the detection of seismic events of volcanic origin, including mass movements. This algorithm has been able to correctly detect and identify volcano-tectonic events during a period of one year of study, with an accuracy of over 80%.
Next steps are the improvement of data transmission in order to provide real-time monitoring, as well as further hazard studies. Very important is also the outreach and a good communication with other research and governmental institutions as well as the local population.

1026

Experimental constraints on the stability of Fe-bearing nanolites in hydrous dacite melts at 1.0 GPa

Dr Marize Silva[1,2], Dr. Francisco Caceres[2], Prof. Dr. Valdeci Janasi[1], Prof. Dr. Donald Dingwell[2], Prof. Dr. Daniel Weidendorfer[2]

[1]USP, São Paulo, Brazil, [2]LMU, Munich, Germany

The Paraná Magmatic Province (PMP) is composed of a bimodal association of large-volume basaltic rocks and significant, though subordinate (<5%), silicic volcanics of dacitic to rhyolitic composition. In this study we present experiments at 1.0 GPa and 1000 °C on the more primitive natural dacite (Barros Cassal subtype) to investigate for the crystallization dynamics controlling the formation and stability of nano- and microlites as a function of well constrained H2O contents (2-11 wt.%). For the crystallization experiments at high pressure, dacite whole-rock powder was first melted at 1500 °C and 1 atm and quenched to a FeTi oxide nanolite-bearing silicate glass. The formation of FeTi oxide bearing nanolites during the synthesis of the starting material at 1 atm is attributed to the high bulk Fe content of ~9 wt.% total iron. The presence of nano- and microlites was checked after each run by Raman spectroscopy and Scanning Electron Microscopy. Experiments were run between 24 and 48 hours and either quenched isobarically or pressure decreased upon quench from 10 kbar at 1000 °C to ~7 kbar at temperatures below the glass transition. Quenching the samples isobarically or following a dynamic decompression path turned out to not affect the stability of nanolites. Our results indicate that at high-water contents (6-11 wt.% H2O), the run product is a silicate glass which contains an FeTi-bearing mineral as nanolites and < 2% microlites. Decreasing H2O to 4.6 and 3.5 wt.% a nanolite-free glass coexists with FeTi oxide and euhedral clinopyroxene microlites (increasing crystallinity to 13%). At a water content of 1.8 wt.% plagioclase joins the crystallized mineral phase, and nanolites remain absent in the residual glass fraction. Our results can support models of magma extraction from lower continental crust and help understand the bimodal character of the PMP.

757

Statistical approach for LST time series analysis to remotely study changes in the surface thermal state of volcanoes

Dr Federico Rabuffi[1,2], Dr Malvina Silvestri[1], Dr Massimo Musacchio[1], Dr Vito Romaniello[1], Dr Fabrizia Buongiorno[1]

[1]Istituto Nazionale Di Geofisica E Vulcanologia, Rome, Italy, [2]Dipartimento di Scienze, Università degli Studi Roma Tre, Rome, Italy

Remote Sensing technique, in the TIR (Thermal InfraRed) spectral range, is even more used as tool to support volcanic observation and surveillance. Since 2000, a large amount of TIR satellite data have been acquired from different satellites such as Landsat and TERRA, allowing to obtain long time series data. In this work, we considered two satellite sensors: the TIRS (Thermal InfraRed Sensor), on board the Landsat 8 satellite (launched in 2013) and the ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) sensor, onboard the TERRA satellite (launched in 2000). Confident with the results obtained in Rabuffi et al., 2022, the aim of this work is to consolidate the methodology used to investigate the 2021 hydrothermal crisis of Vulcano Island exploiting the same statistical approach to different Italian volcanic sites: the Stromboli Island (Sicily) and the Campi Flegrei area (Campania).

The use of both TIRS and ASTER sensors allowed us to analyze a huge number of images acquired in the period from 2000 to 2022; these images were used to produce LST (Land Surface Temperature) maps in order to obtain long LST time series on specific ROI's (Region Of Interest). In particular, we focused our analysis on volcanic areas characterized by a prominent thermal activity.

For each LST map, the standard deviation of temperature has been calculated and its variation in time analyzed. This study would like to prove if the employed methodology is exportable and can provide a reliable information useful to remotely study changes in the surface thermal state of different types of volcanoes.

866

Detection and Parametrization of Volcanic Plumes from Visible-Wavelength Images with PlumeTraP: Application to Plumes from Sabancaya Volcano, Peru

Mr Riccardo Simionato[1,2], Dr. Paul A. Jarvis[1,3], Dr. Eduardo Rossi[1], Dr. Allan Fries[1], Prof. Costanza Bonadonna[1]
[1]Université de Genève, Geneva, Switzerland, [2]Università degli Studi di Padova, Padua, Italy, [3]GNS Science, Lower Hutt, New Zealand

Tephra plumes from explosive volcanic eruptions can be hazardous for the lives and livelihoods of people living in volcanic areas. Detection, characterization and hazard assessment of these plumes are essential for effective volcano monitoring and hazard forecasting. However, advanced monitoring instruments, e.g., thermal cameras, have significant expense and, thus, are not always available in monitoring networks. Conversely, visible-wavelength cameras are cheaper and more widely available.

We propose an innovative approach to the detection and parametrization of tephra plumes, utilizing visible-wavelength videos. Specifically, the developed algorithm has the objectives of: (i) identifying and isolating plume-containing pixels through image processing techniques; (ii) extracting the main geometrical parameters of the eruptive column; and (iii) determining quantitative information related to the plume motion. The resulting MATLAB-based software, named PlumeTraP, semi-automatically tracks the plume and automatically calculates the associated geometric parameters.

Through application of the algorithm to the case study of Vulcanian explosions from Sabancaya volcano, we verify that the plume boundaries are well recognized, and that the calculated parameters are reliable. The obtained results were also used to characterize and classify strong plumes, determining that they have a transient behaviour typical of Vulcanian explosions, with the timescale of pyroclast and gas release comparable to that of the full development of the plume. We found that two types of plumes occur: a) plumes characterized by higher initial velocities rapidly dropping and constantly slowing down with time, classified as starting plumes or rooted thermals; b) plumes that after smaller initial velocities show an acceleration in rise velocity before slowing down again, described as starting jets dominated by buoyancy. PlumeTraP can be of significant use to the volcanological community, enabling research into the dynamics of explosive volcanic eruptions. It could potentially improve the use of visible-wavelength cameras as part of the monitoring networks of active volcanoes.

1362

"Papa volcano" gives us more than he takes. The case of the Creole and the Fogo volcano (Cape Verde)

Dr Lionel Simon[1], Pr. Frédéric Laugrand[1], Mrs. Justine Masseaux[1]
[1]*Uclouvain, 4802, Belgium*

In many parts of the world, volcanic eruptions wreak havoc, destroying homes and landscapes, humans, plants and animals. In the archipelago of Cape Verde located in the central Atlantic Ocean, on the island of Fogo, multiple small volcanoes have erupted continuously over the last few centuries, shaping the island with mounds, visible lava flows, and many uninhabitable and uncultivable areas. However, such an observation seems incomplete, as the island also boasts green spaces, real gardens where agriculture thrives, partly due to the presence of water and heat. The Creole populations who live in contact with Pico de Fogo have an ambivalent relationship with their volcano. Many fear the eruptions and prefer to stay away. Others note that the volcano opens up exceptional opportunities for agricultural activities, especially in an archipelago where access to water remains the greatest challenge. Even though the last eruption in 2015 destroyed their homes, some families have decided to return to live at the foot of the volcano, also taking advantage of the financial resources that the volcano provides, which attracts many tourists. In this paper, which is the result of a collective ethnographic work, we propose to show how Creole populations live in close contact with the volcano and how the volcano, in and around Fogo, is understood according to several modes of existence, to use a theoretical framework first developed by Etiuenne Souriau and later by Bruno Latour.

The team of researchers is composed by Justine Masseaux, a PhD student, Lional Simon, a postdoctoral fellow, and Frederic Laugrand, a professor, all working at Uclouvain in Belgium. Lionel Simon and Frederic Laugrand together with Pierre Delmelle are preparing a special issue on Anthropology of volcanos to be published in the Canadian journal Frontières.

570

Quantifying sulphate aerosols in OP-FTIR measurements

Dr Jean-François Smekens[1], Prof Tamsin Mather[1], Prof Mike Burton[2], Dr Alessandro La Spina[3], Dr Melissa Pfeffer[4], Prof Clive Oppenheimer[5]

[1]Department of Earth Sciences, University of Oxford, Oxford, United Kingdom, [2]Department of Earth and Environmental Sciences, University of Manchester, Manchester, United Kingdom, [3]Istituto Nazionale di Geofisica e Vulcanologia, sezione di Catania, Osservatorio Etneo, Catania, Italy, [4]Icelandic Meteorological Office, Reykjavík, Iceland, [5]Department of Geography, University of Cambridge, Cambridge, United Kingdom

From mild lava effusion to violent explosive events, volcanic eruptions of all types are accompanied by emissions of gases and particulates to the atmosphere. These emissions often present significant health hazards to nearby populations, and can also affect local weather patterns and the climate. Determining the composition of the emitted gases and particulates and changes to that composition over the course of an eruption is crucial to assess risks and establish appropriate mitigation strategies. A common tool for that purpose, Open Path Fourier Transform Infrared (OP-FTIR) spectroscopy allows for remote determination of gas composition from safe distances. Absorption FTIR methods require a source of intense IR radiation (e.g., incandescent lava, an artificial light source, or the Sun). Emission spectroscopy on the other hand, measures the light emitted by the plume gases against a colder sky background. Absorption measurements yield quantitative measures for a wide range of gases (e.g., SO_2, CO_2, H_2O, HF, HCl, CO), but the presence of particulates in the plume is usually regarded as an interference, and accounted for in the signal using polynomial envelopes. However, sulphate aerosols (SA) show distinctive spectral features at 800-1000 cm^{-1}, which can be accurately modelled in emission measurements. Here we present an algorithm capable of quantifying the abundance of sulphate aerosols from both emission and absorption FTIR measurements, and evaluate its applicability and limitations using datasets from recent eruptions at Fagradalfsjall in Iceland, Etna and Stromboli in Italy and Kīlauea in Hawai’i. We show that the SO_2/SA ratio can be accurately derived along with the size of the aerosol fraction. This offers a new metric to investigate the formation and evolution of primary and secondary aerosols, as well as a new tool for monitoring emission during volcanic crises.

860

Topographic evolution of Nyiragongo's main crater from 2002 to 2021 using Structure-from-Motion (SfM) photogrammetry

Dr Benoît Smets[1,2], Ms Louise Delhaye[1], Dr Julien Barrière[3], Dr Nicolas d'Oreye[3,4], Dr François Kervyn[1]
[1]Royal Museum For Central Africa, Tervuren, Belgium, [2]Vrije Universiteit Brussel, Brussels, Belgium, [3]European Center for Geodynamics and Seismology, Walferdange, Luxembourg, [4]National Museum of Natural History, Walferdange, Luxembourg

Nyiragongo (eastern D.R. Congo) is amongst the most active volcanoes in Africa, whose main eruptive activity usually takes the form of a lava lake in the summit crater. Every few decades this persistent activity is interrupted by a flank eruption, like in 1977, 2002 and 2021, draining the lava lake system and triggering collapses within the crater. As a consequence, the topography of Nyiragongo's main crater has evolved quickly, through episodes of lava accumulation and destruction.

In the present work, we use Structure-from-Motion photogrammetry to quantify topographic changes at Nyiragongo's main crater, from the first days following the 2002 flank eruption to the next flank episode in May 2021. Images used come from space-based stereo acquisitions, helicopter-based photography and footages acquired with an Unoccupied Aircraft System (UAS).

Results highlight the difficulty to acquire ideal and homogeneous datasets on an active crater with steep flanks, for which the visibility is usually impaired by persistent volcanic outgassing, cloud cover and fast changing sun illumination. The co-registration of the different epochs and types of data is therefore challenging, requiring alternative approaches and highlighting the importance of adapting the co-registration technique to the targeted dataset. When compared with estimates from space-based SAR-shadow measurements, the measured volumes of lava accumulated in Nyiragongo's crater between 2002 and 2021 show lower values (i.e., 6 to 7 ⍰ 106 m3 less), but follow the same evolution trend. If the photogrammetric approach does not offer a high temporal resolution, it has the advantage of reliably reconstruct the topography, with structural details at very high spatial resolution. Such photogrammetry-based datasets significantly help for the interpretation of the mechanisms at play, such as during the 2012-2015 ground subsidence around the lava lake or the appearance of a new active vent close to the lava lake in 2016.

202

Highs and lows with BIROC-H2O: A new code to estimate H2O and CO2 concentrations in basaltic glass from FTIR spectra

Ms Elaine Smid[1], Dr David Huijser[2], Dr Jitraporn Vongsvivut[3], Dr Michael Rowe[1], Professor Jan Lindsay[1]
[1]School of Environment, University of Auckland, Auckland, New Zealand, [2]School of Mathematics and Statistics, Victoria University of Wellington, Wellington, New Zealand, [3]Infrared Microspectroscopy (IRM) beamline, ANSTO-Australian Synchrotron, Clayton, Australia

Fourier transform infrared (FTIR) spectrometry is one of the most popular techniques used to estimate H2O and CO2 concentrations in volcanic glass. As technology and volcanological knowledge become more sophisticated, there is an increasing interest in using high-resolution molecular characterisation techniques to analyze chemical heterogeneity in silicate melts at the micron-scale. However, several challenges exist when processing large spectral datasets, including assigning uncertainties to the results. A new Python code, named 'BIROC-H2O,' has been developed to processes FTIR spectral data, particularly 2D spectral maps of basaltic glass. The code was tested using data collected from olivine-hosted basaltic melt inclusions and embayments from the Auckland Volcanic Field, Aotearoa New Zealand. The code requires routinely collected inputs: 1) the raw spectral data, 2) map dimensions (e.g. X pixels wide and Y pixels tall), 3) major element chemistry of the glass and olivine host, and 4) average sample thickness (used when interference fringes are absent). The code offers a number of novel features including the ability to batch process a large number of spectra, automated thickness calculations from spectra containing interference fringes (allowing for variable thicknesses across the sample), thickness extrapolations for map files with partial interference fringes, corrections for host olivine contamination, and a robust error handling strategy. Outputs include a table of H2O and CO2 concentrations from each spectral analysis, 'heat map' images of H2O and CO2 concentrations and thicknesses across the sample, as well as error estimations on key variables. This code is well-suited for processing both single FTIR spectra and 2D spectral maps collected on basaltic glass, and is modifiable for analysis of other glass and mineral compositions.

749

The magmatic supersystem driving an ignimbrite flare-up, central Taupō Volcanic Zone, New Zealand

Sarah Smithies[1], Dr Lydia Harmon[2], Associate Professor Darren Gravley[1], Professor Guilherme Gualda[3], Professor Kari Cooper[4], Professor Adam Kent[5], Associate Professor Chad Deering[6], Dr Sydney Allen[7], Nicole Rocco[5], Dr Alexander Nichols[1]

[1]School of Earth and Environment, University of Canterbury, Christchurch, New Zealand, [2]School of Earth and Space Exploration, Arizona State University, Tempe, USA, [3]Department of Earth and Environmental Sciences, Vanderbilt University, Nashville, USA, [4]Department of Earth and Planetary Sciences, University of California, Davis, USA, [5]College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, Corvallis, USA, [6]Department of Geological and Mining Engineering and Sciences, Michigan Technological University, Houghton, USA, [7]Department of Earth, Environmental and Planetary Sciences, Rice University, Houston, USA

Rhyolitic caldera-forming eruptions show us that the crust is capable of generating massive magma volumes. We use new petrologic data to explore the magmatic “supersystem” that drove an extraordinary ignimbrite flare-up event in the Taupō rifted arc, New Zealand. Between 350 and 240 ka seven caldera-forming eruptions (Whakamaru, Matahina, Chimp, Pokai, Kaingaroa, Mamaku, Ohakuri) erupted 3000 km3 of magma.

We combine multiple petrologic techniques on pumice from each eruption to explore the pathway of individual magma parcels. We use 1) glass major element chemistry by EDS-SEM; 2) glass trace element chemistry by LA-ICP-MS; 3) glass Sr, Pb, and Nd isotopes by Nu-plasma ICP-MS; 4) whole-rock major and trace elements by XRF; and 5) rhyolite-MELTS geobarometry to calculate storage and extraction pressures.

The eruptions that began (Whakamaru) and ended (Mamaku-Ohakuri) the flare-up had very similar, mature, magmatic systems: a storage zone with multiple eruptible magma bodies that sat adjacent to one another in the shallow crust (~100 MPa, ~4 km), in close proximity to a vertically extensive mush zone at ~150–400 MPa (~6 – 15 km). Magma parcels migrated upwards up to 10 km from extraction to storage. Following Whakamaru and Matahina, the magma supersystem appeared to reset itself with a relatively compositionally homogenous Chimp magma extracted and stored deeper again at >285 MPa (>11 km). Then, during the Pokai and Kaingaroa eruptions, eruptible magma bodies and mush became vertically separated (by >2 km) suggesting a thermal conditioning of the crust and/or magma-assisted rifting. The cycle completed as the magma systems expanded and matured, eventually encompassing most of the quartzo-feldspathic crust prior to the Ohakuri-Mamaku eruptions. Isotopic data suggest that the vertically dispersed, immature systems are more diverse than mature systems, possibly assimilating variable crustal components. These maturing magma systems hint at how magma “super”-systems can build during a flare-up.

517

Connecting the dots: evidence from ignimbrites and lavas for the mush systems fuelling a volcanic flare-up, Taupō Volcanic Zone

Sarah Smithies[1], Professor Guilherme Gualda[2], Associate Professor Darren Gravley[1], Dr Lydia Harmon[3]
[1]School of Earth and Environment, University of Canterbury, Christchurch, New Zealand, [2]Department of Earth and Environmental Sciences, Vanderbilt University, Nashville, USA, [3]School of Earth and Space Exploration, Arizona State University, Tempe, USA

Rhyolitic calderas generate very large (>1000 km3) explosive eruptions and small (<1 km3) effusive eruptions. Less attention has been paid to smaller, more frequent eruptions, although these give important insights into the magmatic systems that generate catastrophic caldera-forming eruptions. We use rhyolitic lava domes and ignimbrites erupted during the 350 – 240 ka volcanic flare-up in the central Taupō Volcanic Zone, New Zealand to explore the location and composition of the magma mush supplying the unusually voluminous volcanism.

We collate existing whole-rock data from the domes and new XRF data for the ignimbrites and model the pressure of magma extraction from the mush with the rhyolite-MELTS geobarometer. There are two dominant extraction pressure modes at 1) 150 – 175 MPa and 2) 200 – 325 MPa, consistent with 1) the brittle-ductile transition (~6 km) and just below typical storage depths reported previously (100 – 150 MPa, ~4 – 6 km); and 2) partial melt regions imaged below ~8 km by previous geophysical studies.

Caldera-forming eruptions are typically extracted from 200 – 400 MPa, suggesting that the deeper mush zone is the main "factory" for very large magma volumes. For the first time, we apply rhyolite-MELTS geobarometry to effusive deposits and show the lateral extent of the mush as well as its depth. Domes on caldera margins have shallow extraction and similar compositions to the ignimbrites, suggesting that magmas take advantage of extraction pathways established by caldera formation. Domes within the calderas are aligned along normal faults and have deeper extraction. This hints at the role tectonics play in generating and extracting very large volumes of eruptible magma. By combining petrologic data for small and large eruptions we build a picture of mush development across the central TVZ, with implications for our regional-scale understanding of the largest magma systems on Earth.

427

Dynamics in volcano-ice interactions of Mount St. Helens´ Crater Glacier since the 2004-2008 lava dome emplacement

Ms Linda Sobolewski[1], Mr Thor H. Hansteen[2], Mr Edgar U. Zorn[3], Mr Christian Stenner[4], Mr Lee J. Florea[5], Ms Sarah A. Burgess[6], Mr Artur Ionescu[7,8,9], Mr Eduardo Cartaya[10], Mr Andreas Pflitsch[1]
[1]Ruhr University Bochum, Bochum, Germany, [2]GEOMAR Helmholtz Centre for Ocean Research Kiel, Kiel, Germany, [3]German Research Centre for Geosciences GFZ Potsdam, Potsdam, Germany, [4]Alberta Speleological Society, Calgary, Canada, [5]Washington State Geological Survey, Olympia, USA, [6]Bloomington Indiana Grotto, National Speleological Society, Bloomington, USA, [7]Babes-Bolyai University, Cluj-Napoca, Romania, [8]University of Perugia, Perugia, Italy, [9]International Radiocarbon AMS Competence and Training Center (INTERACT), Debrecen, Hungary, [10]Glacier Cave Explorers, National Speleological Society, Redmond, USA

The crater of Mount St. Helens is a unique place to study landscape evolution impacted by volcano-ice interactions. Crater Glacier, which started forming after the 1980 eruption, is one of the world's last expanding glaciers and provides a remarkable opportunity to characterize the expansion of a glacier in an area of significant thermal flux. Although the lava dome is gradually cooling, present thermal and physical interactions with the encircling glacier are considerable. Glacier surface structures caused by these interactions provide insight to the heat distribution of the dome and illustrate the dynamics of such environments. By combining photographic documentation, subglacial cave surveys, and remote sensing we provide a comprehensive overview of landscape evolution in the active Mount St. Helens crater since the 2004-2008 lava dome was emplaced. Our results show that the glacier toe advanced by several hundred meters, and constant rockfall from the crater walls transformed the glacier into one that is debris-covered, including the development of supraglacial ponds. The shift of the glacier-dome interface towards higher elevations at the dome has led to extensive subglacial cave system formation, particularly around the 2004-2008 dome. Based on the recent evolution of Crater Glacier and our time series analysis of cave surveys and remote sensing data, we speculate about the future development of this volcanic landscape. Investigating volcano-ice interactions may be an important monitoring tool as these interactions provide insight to the evolution of a volcanic edifice and may be an indicator for renewed volcanic activity.

430

Glaciovolcanic caves as an analogue for subglacial settings elsewhere in the solar system

Ms Linda Sobolewski[1], Mr Lee J. Florea[2], Mr Christian Stenner[3], Ms Sarah A. Burgess[4], Mr Artur Ionescu[5,6,7], Mr Andreas Pflitsch[1], Ms Jay Nadeau[8], Mr Michael Paton[9], Mr Eduardo Cartaya[10]

[1]Ruhr University Bochum, Lippetal, Germany, [2]Washington State Geological Survey, Olympia, USA, [3]Alberta Speleological Society, Calgary, Canada, [4]Bloomington Indiana Grotto, National Speleological Society, Bloomington, USA, [5]Babes-Bolyai University, Cluj-Napoca, Romania, [6]University of Perugia, Perugia, Italy, [7]International Radiocarbon AMS Competence and Training Center (INTERACT), Debrecen , Hungary, [8]Portland State University, Portland, USA, [9]Jet Propulsion Laboratory, NASA, Pasadena, USA, [10]Glacier Cave Explorers, National Speleological Society, Redmond, USA

Glaciovolcanic caves are subglacial voids formed due to thermal gradients between the lithosphere and the cryosphere (volcano-ice interactions). These caves may be potential analogues for subglacial settings elsewhere in the solar system, and this research field enhances this understanding currently underrepresented in literature. Glaciovolcanic caves on Earth include a largely fumarolic ice cave system in the crater of Mount Rainier in dynamic equilibrium and rapidly evolving caves in the crater of Mount St. Helens. The slow tempo of life found in these dark, oligotrophic, and low temperature environments is applicable to other ice worlds characterized by extreme cold surface temperatures that include internal heat sources such as Europa (-78°C) and Triton (-182°C). Here, biological cycles may approach the timescales of geological processes such as glaciation and volcanism. Glaciovolcanic cave environments can also serve as analogue testing sites for precursor robotic technologies for solar system exploration, such as at Mount St. Helens and Mount Rainier where NASA “Iceworm” robot tests have been successfully conducted as part of the Exobiology Extant Life Surveyor (EELS) mission. Morphodynamic models considering the variation of gravitation, tidal forcing, atmospheric pressure, and other mineralogies of ice may provide critical context for the exploration of habitable zones in analogous environments by providing insight on geophysical controls on the evolution of extraterrestrial life.

656

Melt viscosity monitoring of the Cumbre Vieja Tajogaite eruption.

Professor Arianna Soldati[1], Donald Dingwell[4], Matthew Pankhurst[2,3], Francisco Caceras[4], Ulrich Kuppers[4], Dirk Muller[4], Luca D'Auria[2,3], Nemesio Perez[2,3]
[1]North Carolina State University, Raleigh, United States, [2]Instituto Volcanológico de Canarias (INVOLCAN), La Laguna, Spain, [3]Instituto Tecnológico y de Energías Renovables (ITER), Granadilla de Abona, Spain, [4]Ludwig Maximillians Uni versitat, Munchen , Germany

The intensity and style of volcanic eruptions may vary significantly during a single episode. These variations directly and indirectly impact the evolving hazard profile and associated risk.

In this study we report the highest-resolution temporal dataset of melt viscosity from a single eruption to date. We measured the viscosity of 81 lava samples collected during the 86-day long (September 19th 2021 - December 13th 2021) Tajogaite eruption of the Cumbre Vieja volcanic system of La Palma, Canary Islands (Spain).

Samples were crushed and remelted to superliquidus conditions, poured into Pt80Rh20 viscometry crucibles and loaded into a high temperature concentric cylinder rheometer. Viscosity was determined in 25°C intervals, cooling from 1500°C to the onset of crystallization.

Viscosities of these melts at the near-eruptive temperature of 1250°C range from 7 to 12 Pa s. Clear trends with time are observed throughout the time series, including a 35 day decrease in melt viscosity at the start of the eruption and a lower magnitude week-long increase in melt viscosity at the eruption end. In the intermediate time range viscosity fluctuates with a recurring pattern.

Geochemical major element analyses of post-experimental quenched glasses reveal chemical variations which correlate well with the viscometry variations and help shed light on the compositional control of liquid viscosity in magmatic melts. The "time-stamped" nature of these data provides an opportunity to build these perspectives on magma properties into advanced models of plumbing system dynamics and magma transportation. We expect that the value of this time-series rheological data will be augmented by comparison with further time-series datasets to be obtained on future eruptions.

We speculate that the higher viscosities of the first and last lavas of this eruption may have their origins in the sampling of the edges of the effective magma reservoir largely evacuated during this eruption.

220

Exploring for supercritical hydrothermal fluids in the Taupō Volcanic Zone: insights from numerical modelling

Thierry Solms[1], Thomas Driesner[1], Olivier Bachmann[1], Isabelle Chambefort[2]
[1]ETH Zürich, , Switzerland, [2]GNS Science, , New Zealand

Geothermal energy production is an important pillar to achieve a carbon-neutral global economy in the future, and one possibility of improving its economic and ecological footprint is the utilization of supercritical geothermal resources. However, while the presence of supercritical hydrothermal fluids has been proven in the context of magmatic intrusions in several locations world-wide, they remain elusive in the Taupō Volcanic Zone (TVZ) in New Zealand. Exploration for supercritical resources in the TVZ is challenging because the presumed magmatic heat sources driving the hydrothermal systems possibly lie beneath ~7 km and thus are not within the depth range currently attainable by drilling. Numerical modelling tools are thus key to identify parameters controlling the presence of supercritical hydrothermal resources in the TVZ.

Several codes used to model fluid flow in geothermal systems lack the possibility to model supercritical fluid flow or cannot simultaneously constrain cooling of the magmatic intrusions. Using the CSMP++ modelling platform we simulate supercritical hydrothermal fluid flow applied to a conceptual cross-section of the TVZ down to 10 km. By incorporating discrete cooling of magmatic intrusions in our models, we further explore the temporal evolution of hydrothermal systems in the TVZ and relate them to their long-lived magmatic drivers at depth.

Preliminary results of models with systematically varied magmatic and hydrothermal parameters (e.g. intrusion geometry, depth, and melt temperature, host rock permeability structure, or brittle-ductile transition temperature) indicate that large, deep-seated (7 – 10 km) cooling intrusions probably cannot produce the reservoir temperatures currently encountered in geothermal fields in the TVZ, unless the greywacke basement's permeability is locally increased (e.g. by brittle deformation) to allow for significant fluid convection. We also find that there is a significant delay between the magmatic activity in the deep TVZ and the geothermal activity in the shallow TVZ.

1307

Transient Crater Depths and Energy Partitioning in Multi-Explosion Subsurface Explosive Events

Dr Ingo Sonder[1], Alison Graettinger, Tracianne B. Neilsen, Robin S. Matoza, Jacopo Taddeucci, Einat Lev, Greg P. Waite, Kenneth S. Befus, Greg A. Valentine, Kae Tsunematsu
[1]*University At Buffalo, Buffalo, United States*

To investigate effects of multiple explosions as
they also occur in volcanic settings, experiments were conducted that involved six timed detonations of explosive charges in prepared, unconsolidated ground material. A diverse set of sensors that included seismometers, microphones for various frequency ranges, cameras from different view angles including some mounted to UAVs, and arrays of ejecta collection boxes was set up to monitor the blast events. The timing between each of the detonations was 0.5 seconds. The combined analysis of the transient seismo-acoustic signals and post-blast crater morphologies shows that the airborne signal amplitude can be used to determine the depth of a crater at a time when it is still forming. This is of interest for hazards analysis, since explosions that occur in close sequence may occur under reduced containment conditions, which creates either more and higher energy ejected material or a much larger pressure pulse, both of which pose a danger for the environment. Two time delays after initial detonation could be probed in the presented experiments: 0.5 s, and 1.5 s. At 0.5 s the crater bottom lies 30% below the detonation depth; 1.5 s after detonation some ejected material fell back into the crater and the depth is comparable to the final value. We estimate that the airborne energy for explosions that occur below and shortly after such a transient crater can be amplified by a factor 22 compared to a single blast at same energy and depth.

1309

Film Boiling Lifetime Dependency on Water Temperature and Its Implications for Explosive Volcanism

Dr Ingo Sonder[1], Pranabendu Moitra
[1]*University At Buffalo, Buffalo, United States*

The Leidenfrost effect plays a key role in the pre-mixing stage of explosive phreatomagmatic process where magma and liquid external water come into direct contact. There the high temperature difference causes a thin, quasi-stable vapor film to form between the two liquids. Even though measured data is rare, it is clear that under film boiling conditions heat transfer rates are much lower than under direct liquid water-melt contact at same temperatures. This state of reduced heat transfer rate enables a time window in which liquid water can mix with magma into cm-sized water domains, which is a precursor state for potential explosive magma-water interaction. Literature sources estimate this "film boiling" state to last on the order of several seconds. These estimates are based on experiments from engineering applications, such as power plants, which have metal as a heat source instead of magma. To verify and/or report deviations from these observations we conducted heat transfer experiments in which all of the various boiling states of water were realized, that occur when magma cools from eruption to ambient temperatures. A spherical melt sample is submerged in a water pool, and the various boiling states are observed with cameras, and sample temperature is measured at the same time. The experiments were repeated for water pool temperatures between 3°C and 93°C. We were able to measure the time dependency of the vapor film thickness and the direct magma-water contact area. Film boiling life times depend strongly on the pool water temperature, but also have a vertical component, because the magma-water interface below raises the boundary temperature, and this way stabilizes (and extends the lifetime of) the vapor film. We report minimum film boiling life times between 0.25 s and 11.5 s, and vertical film collapse rates of up between 5.6 mm/s and 180 mm/s.

1409

How deep long-period earthquakes relate to magmatic processes and volcanic unrests at Alaskan volcanoes

Miss Zilin Song[1], Prof. Yen Joe Tan[1]
[1]*Chinese University Of Hong Kong, Shatin, NT, Hong Kong*

Observed signs of volcanic unrests preceding eruptions typically include earthquake activities, gas emissions, and surface deformation. Among the observed earthquakes, those that predominantly radiate low-frequency energy and detected at mid- to lower-crustal depth are known as deep long-period earthquakes (DLPs). DLPs have manifested as early eruption precursors such as before the 1991 Mount Pinatubo eruption and are often inferred to be associated with magma/fluid movements at depth. However, their emergent phase arrivals make them hard to detect using traditional earthquake monitoring methods. Therefore, their source mechanism and how they relate to volcanic unrests is still understudied. In this study, we select 9 volcanoes in Alaska with sufficient number of manual-labeled DLPs and volcanic unrests/eruptions reported by the Alaska Volcano Observatory (AVO). We use the frequency index method to systematically reclassify all earthquakes and identify the DLPs. We then use the DLPs as templates and cross-correlate their waveforms with years of continuous waveforms to detect more events. At Akutan Volcano, we successfully detected ~560 DLPs which is two times more than the number of templates available from the existing AVO catalog. We find that the DLP swarms occur preferentially with greater moment release during four inflation episodes that occurred in 2005-2017. We are currently extending our analyses to the other Alaskan volcanoes to improve the DLP catalog and investigate how they relate to volcanic unrests and various magmatic processes.

669

Ceres has been revealed as a cryovolcanic world by NASA's Dawn mission

Dr Mike Sori[1], Dr. Michael Bland[2], Dr. Debra Buczkowski[3], Dr. Julie Castillo-Rogez[4], Dr. Scott King[5], Dr. Andreas Nathues[6], Dr. Alicia Neesemann[7], Dr. Lynnae Quick[8], Dr. Carol Raymond[4], Dr. Ottaviano Ruesch[9], Dr. Christopher Russell[10], Dr. Maria Cristina de Sanctis[11], Dr. Paul Schenk[12], Dr. Jennifer Scully[4], Dr. Hanna Sizemore[13], Dr. David Williams[14]

[1]Purdue University, West Lafayette, USA, [2]US Geological Survey, Flagstaff, USA, [3]Johns Hopkins Applied Physical Laboratory, Laurel, USA, [4]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, USA, [5]Virginia Tech, Blacksburg, USA, [6]Max Planck Institute for Solar System Research, Goettingen, Germany, [7]Freie Universitat Berlin, Berlin, Germany, [8]NASA Goddard Space Flight Center, Greenbelt, USA, [9]Westfälische Wilhelms Universität Münster, Münster, Germany, [10]University of California, Los Angeles, Los Angeles, USA, [11]Istituto di Astrofisica and Planetologia Spaziali, INAF, Rome, Italy, [12]Lunar and Planetary Institute, Houston, USA, [13]Planetary Science Institute, Tucson, USA, [14]Arizona State University, Tempe, USA

NASA's Dawn mission orbited Ceres, an ice-rich dwarf planet in the asteroid belt, from 2015–2018. Here, we will show that Dawn observations of Cerean landforms provide compelling evidence that Ceres has experienced recent endogenic resurfacing from subsurface brines, a process we describe as cryovolcanism.

Occator crater contains bright material, called faculae, that represents the remnants of recent brine resurfacing. Crater size-frequency distributions and the chemistry of the faculae show that the resurfacing likely persisted long after impact melt from the Occator-forming impact solidified, implying that endogenic liquid in Ceres' interior must be at least a partial source of faculae material. Ahuna Mons, an isolated mountain, is interpreted as an extrusive, muddy cryolava dome on the basis of geomorphological and geophysical arguments. Both Occator crater and Ahuna Mons are likely to be the most geologically recent examples (approximate ages of 20 Myr for Occator and <240 Myr for Ahuna Mons) of processes that have occurred elsewhere on Ceres throughout its history. Average extrusion rates are ~10^4 m^3/yr over the past 2 Gyr, smaller than silicate volcanic rates on rocky planets even when normalizing for planet size. Thermal evolution and convection modeling show that radiogenic heating can power geological activity and the persistence of a small percentage of interior water-based melt in Ceres under plausible physical conditions.

The Dawn analysis at Ceres shows that relatively small, icy worlds can be geologically and volcanically active, even in the absence of tidal heating. These results motivate the need for further exploration of Ceres – such as mapping and quantifying the amount of melt in the interior today, and sampling resurfacing products at the surface – and other icy worlds in the outer Solar System.

1006

Deceleration as a drag proxy for irregularly-shaped volcanic bombs: Observations from high speed video at Stromboli and Cumbre Vieja

Ms Amilea Sork[1], Dr Ben Kennedy[1], Dr Rebecca Fitzgerald[2], Dr Leighton Watson[1], Dr David Dempsey[1], Dr Jacopo Taddeucci[3], Dr Mathieu Sellier[1], Piergiorgio Scarlato[3], Daniele Andronico[4], Tullio Ricci[3], Luca D'Auria[5,6], María Asensio-Ramos[6]

[1]University Of Canterbury, Christchurch, New Zealand, [2]GNS Science, Lower Hutt, New Zealand, [3]Istituto Nazionale di Geofisica e Vulcanologia, Sezione Roma 1, Roma, Italy, [4]Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo, Catania, Italy, [5]Instituto Technológico y de Energías Renovables (ITER), Tenerife, Spain, [6]Instituto Vulcanológico de Canarias (INVOLCAN), Tenerife, Spain

Volcanic ballistics are a frequently fatal volcanic hazard, especially within 5 km of active volcanic vents. It is therefore important in modelling and assessing hazard to accurately calculate potential ballistic trajectories. The approximately parabolic trajectory of volcanic ballistics is mainly controlled by the forces of gravity and air resistance (or drag). Many numerical models of ballistic trajectories use regular shapes such as spheres to approximate ballistic drag, which is integrated into calculation of potential range. However, many ballistics, and especially hot, low-viscosity bombs, are highly irregular in shape.

In this work, we delve into the wide variety of bomb shapes and their effect on bomb flight behaviour. Using high-speed 2D video of explosive eruptions at Stromboli (Italy) and Cumbre Vieja (Canary Islands, we tracked a sample set of bomb trajectories and characterised shape progressions of each in-flight bomb. Multiple irregularly shaped end-members have been identified, each exhibiting unique in-flight behaviours which may affect its trajectory. A late-trajectory deceleration due to drag can be quantified for each tracked bomb; ongoing research is focused on constraining the effect of shape on this deceleration. The results of this study can better inform expectations of bomb behaviour and provide uncertainties on existing numerical models which use regular shapes to estimate drag, and which are in turn incorporated into hazard models and maps.

864

Insights into the dynamics of the 2021 Fagradalsfjall eruption using a network-based analysis of volcanic tremor

Dr Jean Soubestre[1,2], Corentin Caudron[3], Thomas Lecocq[4], Kristin Jonsdottir[2], Yesim Cubuk-Sabuncu[2], Gaspard Farge[5], Nikolai M. Shapiro[1], Cyril Journeau[1]
[1]Univ. Grenoble Alpes, Univ. Savoie Mont Blanc, CNRS, IRD, IFSTTAR, ISTerre, Grenoble, France, [2]Icelandic Meteorological Office, Reykjavik, Iceland, [3]Université Libre de Bruxelles, Brussels, Belgium, [4]Royal Observatory of Belgium, Brussels, Belgium, [5]Université de Paris, Institut de Physique du Globe de Paris, CNRS, F-75005, Paris, France

The 2021 Fagradalsfjall eruption lasted six months from March 19 to September 18, 2021. The eruptive activity first took place at up to eight different fissures, then focused on one main vent from April 27 onwards. The eruptive style varied from month-long lava effusion from one or different fissures, minute-long lava fountains (pulsating or not) episodes lasting days to weeks, and intermittent activity with hour- to day-long repose intervals. The eruption was monitored with many different geophysical techniques including InSAR, GNSS, seismic, infrasound and Distributed Acoustic Sensing.

Here, we analyze seismic data from a set of 15 seismic stations operated by the Icelandic Meteorological Office (IMO) and the Czech Academy of Science, focusing on the co eruptive tremor. These stations form a network with an aperture of about 25 km. Studying this co-eruptive tremor is challenging because of the diversity and complexity of physical mechanisms that could trigger tremor, potentially overlapping in time. Yet, this is critical to further our understanding on the dynamics of the eruption.

The application of a network-based method enables us to automatically detect the pre-eruptive seismic swarm, as well as different continuous, minute-long and hour-long tremor patterns associated with different phases of the eruption. The systematic hypocentral location of the tremor sources using successive 4 hour-long time windows, combined with visual information from webcam images, provides a characterization of some spatio-temporal features of the different tremor patterns. A physical modeling of the underlying source processes is finally proposed for two of those patterns, providing insights into the physical processes at play during this eruption.

865

Monitoring seismic tremor at different geological features in Iceland with a network-based covariance matrix analysis

Jean Soubestre[1,2], Kristin Jonsdottir[2], Thomas Lecocq[3], Corentin Caudron[4], Bethany Vanderhoof[2], Sylvain Nowé[3], Alexander Yates[1], Yesim Cubuk-Sabuncu[2], Ólafur Guðmundsson[5], Sara Barsotti[2]
[1]Univ. Grenoble Alpes, Univ. Savoie Mont Blanc, CNRS, IRD, IFSTTAR, ISTerre, Grenoble, France, [2]Icelandic Meteorological Office, Reykjavik, Iceland, [3]Royal Observatory of Belgium, Brussels, Belgium, [4]Université Libre de Bruxelles, Brussels, Belgium, [5]Department of Earth Sciences, Uppsala University, Uppsala, Sweden

Seismic tremor is a continuous or nearly continuous ground vibration that can last from minutes to months. It can be generated by different physical mechanisms and recorded on various geological settings including volcanoes, faults, geothermal fields, glaciers, etc. Being often due to the presence of fluids, its characterization is challenging but important for understanding the dynamics of processes at play. However, the continuous nature of the tremor signal prevents the use of traditional seismic methods based on phase picking to study it.

In many natural hazards observatories, including at the Icelandic Meteorological Office (IMO) in Iceland, tremor is often monitored using a single-station approach, with methods such as the Real-time Seismic Amplitude Measurement (RSAM) or its variants. This RSAM method consists of computing an average signal amplitude in a moving window at a single station. It has the advantage of simplicity and robustness, but it suffers some limitations including the impossibility to locate the tremor source or to separate source and propagation effects. Conversely, network-based methods analyzing records from several seismic stations enable to locate the tremor source. Moreover, those methods improve the signal-to-noise ratio, making them priceless for characterizing low energy tremors.

Here, we use an automatic method based on the seismic network covariance matrix to characterize tremor from different geological features in Iceland including two volcanic systems (Askja, Katla), one glacier (Grimsvötn) and one fault (Húsavík Flatey fault). We analyze several years of data (up to eight years: 2015-2022) from individual networks featuring between eight (Askja) and 17 (Grimsvötn) stations. Newly discovered tremors are detected and their sources are located, providing insight into some physical processes occurring within those systems. Finally, these methods are implemented and running in near-real time at IMO since September 2021 for monitoring purposes (at least at three sites : Askja, Katla and Grimsvötn).

1075

Experimental investigation of Lithium and Boron behavior during decompression-driven magma ascent

Dr Roberta Spallanzani[1], Prof. Dr. Kenneth T. Koga[2], Dr. Sarah B. Cichy[3,4], Dr. Michael Wiedenbeck[4], Prof. Dr. Max Wilke[3]
[1]Montana State University, Bozeman, United States, [2]Université d'Orléans, Orléans, France, [3]University of Potsdam, Potsdam, Germany, [4]GFZ German research Centre for Geosciences, Potsdam, Germany

Volcanic eruptions are deeply affected by the concentration and behavior of volatile components during magmatic ascent. Particularly, volatile elements influence the dynamics of magmatic degassing, and accurate descriptions of such process are needed to understand the whole volcanic system. Lithium and boron are two fluid-mobile elements which partition into the gas phase during magmatic degassing and ascent. Because of their similar properties, they have been chosen for this study, where we want to evaluate whether Li and B can be used as geochemical tracers for magmatic ascent and decompression-related degassing.

We present the results of decompression experiments performed with an internally heated pressure vessel (IHPV) at constant temperatures of 900 °C and 1000 °C, with continuous pressure release from 300 MPa to 75 MPa with decompression rates ranging from 0.125 to 0.004 MPa/s. Synthetic glasses of rhyolitic composition were used as starting material, having an initial water content of 4 wt%. Li and B results obtained by SIMS analyses highlighted that both elements have progressively lower concentrations with decreasing decompression rates, suggesting that Li and B prefer to exsolve more from the melt phase at slower magma ascent rates. Profile measurements show a concentration increase near the bubble/melt interface for the fastest run (0.125 MPa/s), which was interpreted as an accumulation of Li and B due to the sudden occurrence of a gas bubble nucleation. Longer decompression durations show a progressive decrease of Li and B at the melt/bubble interface, being attributed to the diffusion of the two elements into the bubble. This contrast in the profiles confirms that Li and B have the potential to be used as geospeedometer for magmatic ascent, further investigation, especially in comparison to, is needed, once the process is quantitatively modelled with respect to the decompression rates.

298

The influence of grain size distribution and gas composition on experimental volcanic lightning

Ms Christina Springsklee[1], Prof. Dr. Bettina Scheu[1], Prof. Dr. Michael Manga[1,2], Dr. Valeria Cigala[1], Dr. Corrado Cimarelli[1], Prof. Dr. Donald B. Dingwell[1]
[1]LMU Munich, Munich, Germany, [2]University of California, Berkeley, USA

Volcanic lightning (VL) has recently gained attention as a monitoring tool for explosive volcanic eruptions. Understanding the charging and discharging mechanisms as well as the controlling parameters underpins the growing use of VL as a monitoring tool, capable of documenting plume and vent properties in real-time. Experimental laboratory studies represent a valuable approach for gaining insights into the mechanisms controlling VL. Here we present experiments that quantify the influence of the initial grain size distribution on the size and number of discharges in rapidly decompressed jets. We explored the effect of grain size distribution on three different materials: tholeiitic basalt, phonolithic pumice, and dense soda-lime glass spheres, the latter is used as standard material. The discharges are measured with a Faraday cage and recorded with a high-speed camera. The results highlight the importance of very fine particles (<10 µm) for the occurrence of electrical discharges in the jet and point out that the coupling of the particles to the transporting gas phase and their dynamics are crucial for generating VL. Using a newly developed setup, we also tested how changes in the ejected gas phase and the surrounding atmosphere affect the discharges within the experimentally decompressed jet. Insights into the controlling parameters derived from such experiments, strengthen VL as a monitoring tool and provide a basis for exploring the role of VL on prebiotic synthesis reactions on the early Earth.

297

Electric discharge in erupting mud – a potential mechanisms for the self-ignition of mud volcanoes

Ms Christina Springsklee[1], Prof. Dr. Michael Manga[1,2], Prof. Dr. Bettina Scheu[1], Dr. Corrado Cimarelli[1], Prof. Dr. Donald B. Dingwell[1]
[1]*LMU Munich, Munich, Germany,* [2]*University of California, Berkeley, USA*

The self-ignition of gas in violent eruptions of mud volcanoes can result in flames that reach hundreds of meters and the methane emitted at their vents can continue to burn for many years. Although the phenomenon of self-ignition of mud volcanoes has fascinated generations, the various mechanisms that can lead to ignition remain under-investigated, with syn-eruptive electrical discharges being mostly neglected. Here, we present an experimental study of electrical charging and discharging of erupting mud. Natural mud samples pressurized with argon gas are subjected to rapid decompression and ejected into a Faraday cage, enabling the measurement of electrical discharge events in the decompressed jet. High-speed camera recordings of the decompressed jets yield clear visible observations of the discharge activity. We varied the water content and the grain size distribution to assess their influences on the magnitude and number of electrical discharges. We find that an increase in the fine fraction (<10 µm) and a decrease in water content each increase discharge activity within the expanding jet. Although our choice of argon as a carrier gas (for laboratory safety) prevents the experimental observation of gas combustion in our experiments, we are confident that the electrical discharges observed here will cause ignition in the presence of methane. Thus, we argue that our results demonstrate that electric discharges during eruption of predominantly dry mud can serve as a potential ignition mechanism during violent mud eruptions.

1083

Volcanic degassing during the recent Fagradalsfjall and Meradalir eruptions, Iceland

Dr Samuel Scott[1], Dr. Melissa Pfeffer[2], Dr. Clive Oppenheimer[3], Ríkey Kjartansdóttir[1], Professor Andri Stefansson[1]

[1]University Of Iceland, Reykjavik, Iceland, [2]Icelandic Meteorological Office, Reykjavik, Iceland, [3]University of Cambridge, Cambridge, United Kingdom

The recent eruptions of Fagradalsfjall and Merardalir (Iceland) marks the first eruptive episode on the Reykjanes Peninsula in nearly 800 years. Open-path Fourier Transform Infrared (OP-FTIR) measurements of major and minor gas molecular species (including H2O, CO2, SO2, HCl, HF and CO) in the gas emissions have been performed on more than twenty occasions throughout the eruptions in 2021 and 2022. Generally, the gas emissions are water-rich (60-95 mol % H2O) and show CO2/SO2 molar ratios of ~4, consistent with magma generation at >15 km depth. Comparison of measured gas emissions with geochemical models of degassing of the Fagradalsfjall basaltic melt suggest that fractional degassing is necessary to explain the high-water contents of the fountaining gas at Fagradalsfjall, implying that a significant fraction of the CO2 that has exsolved from the magma is lost at depth prior to eruption. The measured vent gas emissions display enigmatic changes as a function of time, with lowest H2O/CO2 and H2O/SO2 ratios measured early in the eruption at Fagradalsfjall in 2021 an d higher ratios during later stages and during the Merardalir eruption in 2022. The chemistry of the gas emissions is significantly affected by the style of degassing, with gas emitted by surface lava flows characterized by higher H2O/CO2 and H2O/SO2 and lower SO2/HCl and SO2/HF ratios compared to gas emitted at actively erupting vents. Moreover, the data record significant short-term temporal changes in chemistry on the timescales of minutes associated with intermittent fountaining and cooling/solidification of lava flows. This study highlights the utility of OP-FTIR techniques for tracing basaltic magma degassing in space and time.

1047

Supercritical fluids in hydrothermal systems – chemical composition and targeting

Professor Andri Stefansson[1]
[1]*University of Iceland, Reykjavik, Iceland*

Supercritical hydrothermal fluids with temperatures of ~400-600°C have been observed in several active geothermal systems. Despite such fluids having potentials of multiplying power production from geothermal boreholes, fingerprinting and vectoring such resources has been challenging without drilling. Here a geochemical method is introduced to target such supercritical geothermal reservoirs using temperature dependent volatility of non-reactive elements like boron and chlorine. Near constant boron concentration and increased chlorine concentration with increased discharge enthalpy suggest supercritical fluid input into overlying and conventional subcritical geothermal reservoir while decreasing B and Cl concentrations with increasing enthalpy indicate depressurization boiling at subcritical temperatures followed by fluid phase separation. Volcanic gas input would increase both B and Cl concentration. Moreover, thermodynamic modeling reveals that such supercritical hydrothermal fluids are characterized by low non-volatile element concentration (e.g., Si, Na, K, Ca, Mg, Al) controlled by salt, oxide and aluminum silicate solubility, where volatile elements (e.g., C, S, B) are predicted to be mobile with their concentrations controlled by the volcanic and/or surrounding hydrothermal fluid composition. The approaches introduced here were successfully applied to target supercritical geothermal reservoirs and to predict supercritical hydrothermal fluid chemical composition for three geothermal fields in Iceland (Krafla, Nesjavellir and Hellisheidi), where l fluids have been directly observed at depth or predicted to exist based on subsurface borehole temperature measurements.

250

Automatic recognition of pre- and syn-eruptive seismic patterns at andesitic, dome-building stratovolcanoes

Bastian Steinke[1], Roberto Carniel[2], David E. Dempsey[3], Nick Varley[4], Shane J. Cronin[1]
[1]University Of Auckland, Auckland, New Zealand, [2]Università degli Studi di Udine, Udine, Italy, [3]University of Canterbury, Christchurch, New Zealand, [4]Universidad de Colima, Colima, México

We apply a pattern recognition approach to continuous perennial tremor time-series recorded at Mt. Redoubt, Augustine volcano (both Alaska, US) and Volcán de Colima (México). We compare the 2006 eruption of Augustine volcano and the 2009 Mt. Redoubt eruption, both of which occurred after two decades of repose, with the 2013-2017 eruptive sequence of Volcán de Colima. This sequence represents Colima's most recent phase of major explosive and effusive activity during a near-continuous eruptive period (since 1998) with few repose intervals. All three volcanic cases are characterised by Vulcanian explosions and Pyroclastic Density Currents, as well as episodes of recurrent growth and collapse of lava domes. We investigate how the seismic precursors compare for multi-phase eruptions of this type and scale (Vulcanian to sub-plinian). We use an automatic classifier based on Self-Organising Maps (SOM) and k-means clustering. The approach is extendable to a variety of volcanic settings through systematic tuning of the classifier. We apply a Kernel Density Estimation approach to automatically detect changes within the observed seismicity. These changes reveal a sequence of distinct seismo-volcanic regimes representing different states of the respective volcanic system during multiple eruptive phases. Preliminary results emphasise the strength of the classifier to detect the onset of different eruptive phases. Feature analysis further indicates separation between pressurisation and depressurisation regimes through the course of individual eruption sequences. These results suggest that the SOM classifier could be a useful tool to help track the course of a long eruption sequence, and with more fine-tuning, to detect short-term precursors of heightened eruptive phases that pose greatest hazard.

1148

The emplacement of phonolitic diatremes: insights from a paleomagnetic investigation of the Port Chalmers Breccia, Dunedin Volcano, New Zealand

Miss Ayla Stenning[1], Dr Christian Ohneiser[1], Professor James White[1], Dr Marco Brenna[1]
[1]*University of Otago, Dunedin, New Zealand*

The alkaline intraplate Dunedin Volcano (DV) (South Island, New Zealand), constructed between 16-11 Ma from compositionally diverse lavas, pyroclastic deposits and subvolcanic intrusions, linked to numerous vents, preserves the record of a complex eruptive history. A unique and significant deposit is the Port Chalmers Breccia (PCB); a phonolitic, vent-filling unit exposed in a series of NW-SE trending diatremes. The massive, poorly sorted, matrix supported PCB contains minimal identifiable juvenile material and comprises an abundance of lithic fragments (up to 1.6m). The lithic clasts, derived from varying depths, include a wide range of volcanic and subvolcanic fragments, plus pre-volcanic sedimentary rocks and basement schist.

Questions surround the PCB's emplacement. Originally understood to have occurred early within DV activity, the predominance of lithic phonolite clasts within the PCB given the scarcity of phonolite during early activity, shifted understanding towards a later timing of emplacement. Field evidence dictates the PCB cannot have reached temperatures high enough to weld the deposit, so by determining paleotemperatures for a variety of lithic clasts we can reconstruct the thermal state of the diatreme during emplacement.

Here we present results from a paleomagnetic investigation of the PCB. Orientated samples collected from several lithic clast sizes and types (volcanic, plutonic, schist), will be stepwise thermally demagnetised at 25°C increments in a ASC Scientific TD-48 single-chamber oven and magnetic moment measurements made on a 2G Enterprises pass-through long core superconducting magnetometer. Pilot alternating field demagnetisation data of matrix reveal a complex collection of multiple components including a strong horizontal viscous magnetisation. Rock magnetic analyses conducted on a Princeton Instruments Vibrating Samples Magnetometer indicate the primary magnetic mineral is magnetite. Whilst elucidating the PCB occurrence, this work will serve to further overall understanding of diatremes, a volcanic landform for which the emplacement is inherently difficult to study given its subsurface nature.

1403

Insights into one of the largest submarine caldera eruptions of the last 2000 years, the ~AD1450 Kuwae eruption, Vanuatu.

Sönke Stern[1], Shane Cronin[1], Stuart Bedford[2], Chris Ballard[2], Robert Henderson[2], Salkon Yona[3], Dan Tari[4], Ingrid Ukstins[1]

[1]University Of Auckland, Auckland, New Zealand, [2]College of Asia and the Pacific, Australian National Unversity, , Australia, [3]Vanuatu Kultural Senta, , Vanuatu, [4]Department of Geohazards, , Vanuatu

Around AD1453 one of the largest climate-forcing eruptions of the last 2000 years world-wide took place, with an impact similar to the "year without a summer" caused by the 1815 Tambora eruption. The AD1450's event was sourced at the currently submarine Kuwae caldera (~50 km²), located between the islands of Epi and Tongoa in central Vanuatu. Locally, this eruption caused a mass exodus of people and re-arranged the social structures. We examined new coastal outcrops on islands around the caldera caused by cyclone erosion. Now we establish the first complete stratigraphy of this event sequence. The eruption began with fine ash fall deposition from small explosive events, accompanied by faulting of paleosols and earlier volcanic deposits. This corresponds with oral traditions describing precursory earthquakes that fore-warned people. The climactic event(s) began with a long-lived, stable plinian eruption column, depositing subaerial lapilli fall of up to 4 m-thick on northern Tongoa Island, dominated by low-density andesitic-dacitic pumice. This evidences a subaerial source, corresponding with local legends of how the islands of Tongoa and Epi were joined before the eruption. The next eruption stage of collapsing columns is represented by widespread set of surge deposits showing antidunes. This passes up to a massive lithic lag breccia of 10-50 m-thick, containing megaclasts (>10 m-diameter) recording caldera collapse and destruction of an earlier andesitic stratovolcano. Following pumice-rich pyroclastic flow deposits (5-50 m-tthick) were emplaced on all surrounding islalnds by a series of explosions, with increasingly diverse textures of chilled, glassy bombs and lapilli reflecting an overal increasing role of magma-water interaction. The pyroclasts evidence mixed and mingled magmas were involved in this event ranging from 62-72 wt% silica. The largely sub-aerial nature of the climactic phase of this large eruption likely led to its huge global atmospheric impact.

975

Twenty years of the International Volcanic Health Hazard Network: an overview and celebration

Professor Claire J. Horwell[1], Dr Peter J. Baxter[2], Dr David E. Damby[3], Tamar Elias[4], Dr Evgenia Ilyinskaya[5], Professor Steven J. Sparks[6], Dr Carol Stewart[7], Dr Ines Tomašek[8]

[1]Durham University, Durham, United Kingdom, [2]University of Cambridge, Cambridge, United Kingdom, [3]U.S. Geological Survey Volcano Hazards Program, Menlo Park, USA, [4]U.S. Geological Survey Hawaiian Volcano Observatory, , Hilo, USA, [5]University of Leeds, Leeds, United Kingdom, [6]University of Bristol, Bristol, United Kingdom, [7]Massey University, Wellington, New Zealand, [8]Université Clermont Auvergne, Clermont Ferrand, France

The International Volcanic Health Hazard Network (www.ivhhn.org) was founded in 2003 to bring together the diverse scientists and practitioners working to protect the health of communities during volcanic eruptions. Initially formed as a network, and a forum for discussion and collaboration, IVHHN has included volcanologists, medical doctors, public and environmental health specialists, epidemiologists, toxicologists and exposure scientists.

IVHHN became an IAVCEI Commission in 2005 and soon expanded its remit to provide public information and scientific protocols for use during eruption crises. Since then, IVHHN has evolved from an interdisciplinary forum into an international organization that provides World Health Organization-endorsed, evidence-based public information and advises governments on preparing for, and responding to, the health-related consequences of eruptions.

IVHHN has continued to develop and test geochemical and epidemiological protocols and supports enactment of these protocols during eruption responses. IVHHN's suites of informational products have grown and now include crisis management briefing notes and public-facing audio-visual and printable materials. IVHHN has brought together groups of agencies to coordinate health responses to eruptions and provision of aligned public information, such as via the Hawaii Interagency Vog Dashboard (https://vog.ivhhn.org/). IVHHN also houses a library of all research articles published in the broad field of volcanoes and health.

Twenty years after its inception, we reflect on IVHHN's development, progress and future directions. IVHHN's existence has helped to identify critical gaps in knowledge but has also highlighted global locations where eruption health impacts are rarely assessed. Despite the constraints of being an unfunded endeavour, we remain committed to addressing these challenges through worldwide, interdisciplinary, operational and research collaborations.

844

Ash hazard characterisation and development of public messaging for the 15 January 2022 eruption of Hunga volcano, Tonga

Dr Carol Stewart[1], Taaniela Kula[2], Dr Graham Leonard[3], Prof Shane Cronin[4], Prof Thomas Wilson[5], Dr Richard Wysoczanski[6], Grace Frontin-Rollet[6], Dr Matt Ashworth[7], Prof Claire J. Horwell[8], Dr Siautu Alefaio-Tugia[1], Emeline Afeaki-Mafile'o[9], Matt Luani[1], Dr Shaun Williams[6], Dr Gabriele Chiaro[5], Shaurya Sood[5], Dr Ingrid Ukstins[4], Dr Joa Paredes-Marino[4], Dr David Damby[10]

[1]Massey University, Wellington, New Zealand, [2]Tonga Geological Services, , Tonga, [3]GNS Science, Lower Hutt, New Zealand, [4]Auckland University, , New Zealand, [5]University of Canterbury, , New Zealand, [6]NIWA, , New Zealand, [7]ESR, , New Zealand, [8]Durham University, , United Kingdom, [9]Affirming Works, Auckland, New Zealand, [10]US Geological Survey, , USA

The 15 January 2022 eruption of Hunga volcano, Tonga, was the most explosive volcanic event of the last 140 years. The volcanic plume reached 55 km, with an umbrella cloud of ~500 km diameter. Approximately 20-30 mm thick ashfalls were reported across Tongatapu (~75 km to the SSE; population ~75,000). Ash thicknesses of up to 40 mm were reported across the islands of the Ha'apai and Vava'u groups as well as 'Eua. Samples of ash from Tongatapu were collected first by the NZ Defence Force on 22 January 2022, and then between 23-30 January by local agencies and residents on Tongatapu, Nomuka, Fonoifua and Tungua. Samples were sent to Aotearoa New Zealand where a multi-institutional team carried out a range of ash analyses for hazard assessment. These included: 1) particle size determinations reported in health-relevant size bins of <100, <10, <4, <2.5 and <1 µm; 2) leachate analyses to assess the soluble surface salt content of the ash and its potential to affect rainwater tanks, agriculture and human health; 3) leaching with seawater to assess hazards to coastal marine environments; and 4) tests of the engineering properties of the ash to inform re-use and disposal options. Ash deposits were determined to have a moderate to high potential to cause ongoing air quality issues due to the volume of ash and proportion of fine-grained material (38-53 wt.% <100 µm). The ash leachates were not acidic. Compared to other eruptions globally they had much higher soluble sodium and chloride, lower calcium and sulfate, and very low concentrations of fluoride and trace metals. Preliminary results formed the basis for public messaging, including a bilingual Tongan-English infographic that was developed in partnership with Tongan community leaders in Auckland, New Zealand.

843

Modelling SO2 dispersion for a future eruption in the Auckland Volcanic Field, Aotearoa New Zealand

Siena Brody-Heine[1], Dr Marwan Katurji[1], Dr Carol Stewart[2], Prof Thomas Wilson[1]
[1]University of Canterbury, Christchurch, New Zealand, [2]Massey University, Wellington, New Zealand

Auckland City is built upon the intraplate basaltic Auckland Volcanic Field (AVF). An important component of evaluating and quantifying volcanic risks to Auckland has been the development of credible, detailed AVF eruption scenarios. While hazard footprints for each of the eight scenarios have been developed for lava flows, pyroclastic density currents, ballistics and tephrafall, this project is the first to quantitatively assess volcanic gas hazards for an eruption scenario. For basaltic volcanism, sulfur dioxide (SO2) gas is typically the most consequential volcanic gas emitted. The Māngere Bridge eruption scenario was used as the basis for this study, as preliminary SO2 emission fluxes have been derived using the petrologic method. The aim of this exploratory study was to model SO2 dispersion from a Māngere Bridge eruption for a realistic meteorological case study, to derive ground level SO2 concentrations influenced by the complex interactions of locally-driven flow circulations and topographically-influenced weather patterns. The meteorological case study was selected on the basis of a correlation between high ground level concentrations of measured particulate matter and the associated synoptic weather regime. The Weather Research and Forecasting mesoscale gridded weather model was used to provide the meteorological conditions for HYSPLIT modelling. Trajectory and concentration model outputs illustrate the effect of the sea breeze convergence zone on SO2 dispersion. Results suggest that under worst-case dispersion conditions, extensive areas of up to hundreds of square kilometres to the north and northwest of the eruption location would exceed New Zealand short-term health-based 1-hour and 24-hour air quality standards and guidelines for SO2, indicating volcanic air pollution risks to downwind communities. Future directions of this work could include applying the modelling approach developed here to other AVF eruption scenarios, using a greater range of meteorological conditions, and exploring consequences for health services utilisation such as emergency department respiratory admissions.

213

Sudden explosive eruptions: perspectives on plumbing systems, precursors, and warnings

Professor John Stix[1], Dr. Maarten de Moor[2], Professor Alessandro Aiuppa[3]
[1]McGill University, Montreal, Canada, [2]Observatorio Vulcanológico y Sismológico de Costa Rica, Heredia, Costa Rica, [3]Università degli Studi di Palermo, Palermo, Italy

Sudden explosive eruptions can be phreatic, phreatomagmatic, or magmatic, occurring with few precursors or warnings. Here we discuss the associated plumbing systems, timescales of precursors, and communication issues for providing adequate warnings. Plumbing systems comprise both “bottom-up” and “top-down” components, wherein the bottom-up component represents input of magmatic material from deep levels extending to the mantle, typically magmatic gases and/or volatile-rich magma, and the top-down component is a surface to near-surface phenomenon such as a hydrothermal seal, lava flow, or crystallized shallow intrusion which acts to regulate and help pressurize the system. Useful precursory signals include changes in degassing behavior, tremor, and tilt, although such signals do not always appear before an eruption. These signals may be complementary at different timescales before an eruption, although caution is warranted when comparing a phreatic eruption to a magmatic eruption. Magma injection, for example, is characterized by increased CO2 emission prior to an eruption, signaling arrival of deep magma into the shallow plumbing system. In contrast, top-down eruption triggering may be associated with decreased SO2 emissions due to blocking of the upper conduit or scrubbing by hydrothermal fluids. Tremor may occur weeks to days prior to an eruption, reflecting interacting magmatic and hydrothermal fluids. Increases in tilt in the minutes before an eruption indicate final ascent of material (fluids, lithic material, and/or magma) in the shallow conduit system. Together, these precursory signals could be used to observe and understand a system’s behaviour over an extended period. Warning systems could be based on this multiple timescale approach, e.g., long-term, medium-term, and short-term. Short-term warnings (minutes) could be modeled on those used for earthquakes. Real-time statistical and machine learning methods may help improve timely recognition of precursors. Clear communication of eruptive scenarios and large uncertainties in forecasting are crucial issues for risk management.

300

Hindcasting the 9 December 2019 eruption of Whakaari (White Island), New Zealand

Professor John Stix[1]
[1]McGill University, Montreal, Canada

A series of tremor signals beginning on 18 November 2019 provide insight into the timing and causes of the 9 December 2019 eruption of Whakaari. These tremor signals show distinct peaks until 2 December, with a further set of less pronounced peaks until 6 December, three days before the eruption. I interpret these peaks as banded tremor. This type of tremor sometimes appears at "wet" volcanoes with well-developed magmatic-hydrothermal systems. Banded tremor is important as a precursor to explosive eruptions, e.g., Karkar 1979 and Nevado del Ruiz 1985. Prior to the Whakaari eruption, the interval between tremor peaks decreased with time in a quasi-linear fashion. Using this observation, it is possible to extrapolate this trend to a tremor interval value of zero. Using the full dataset from 18 November to 6 December, the extrapolation yields 19.59 days from the initial tremor band at 2020 hours UTC on 18 November. This "zero point" is 14.7 hours before the eruption on 9 December. Hence this approach provides an accurate hindcast for the date of the eruption. Using data only from 18 November to 2 December provides an even more accurate hindcast of 19.89 days, which is 7.5 hours before the eruption. My model for this eruption includes increasing pressurization of the hydrothermal system by injection of magmatic fluids from 18 November to 2 December (15 days), as revealed by the tremor peaks. The hydrothermal seal began to weaken on 2 December, as shown by the decreased amplitude of the tremor peaks at this time. The seal continued to weaken for 8 days until it failed during the 9 December eruption. This eruption demonstrates the importance of tremor for understanding, forecasting, and even potentially predicting these types of eruptions.

1391

Long-Term Probabilistic Volcanic Hazard Assessment for tephra fallout from Neapolitan Volcanoes on Southern Italy

Mr Manuel Stocchi[1], Dr Silvia Massaro[1,2], Dr Beatriz Martinez Montesinos[2], Dr Laura Sandri[2], Dr Jacopo Selva[2], Dr Antonio Costa[2], Dr Roberto Sulpizio[1,2,3], Biagio Giaccio[3], Massimiliano Moscatelli[3], Marco Nocentini[3,4], Edoardo Peronace[3], Roberto Isaia[5], Manuel Titos Luzòn[6]

[1]Dipartimento di Scienze della Terra e Geoambientali, Università degli Studi di Bari, Bari, Italy, [2]Istituto Nazionale di Geofisica e Vulcanologia, Bologna, Italy, [3]Istituto di Geologia Ambientale e Geoingegneria, Consiglio Nazionale delle Ricerche, sede Montelibretti, Rome, Italy, [4]Dip. Servizio Geologico d'Italia, Istituto Superiore per la Protezione e la Ricerca Ambientale, Rome, Italy, [5]Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Vesuviano, Napoli, Italy, [6]University of Granada, Signal Processing, telematics and Communications, Granada, Spain

Vesuvius, Campi Flegrei, and Ischia are three active volcanoes in the Neapolitan Area (Italy) that can show explosive behavior. In this work we evaluated the combined tephra fallout hazard posed by the three volcanoes.

In order to explore the intrinsic variability of the investigated volcanic phenomena we used a probabilistic approach (Probabilistic Volcanic Hazard Assessment, PVHA). We defined a set of possible size classes of each volcano (Small, Medium, and Large for Vesuvius and Campi Flegrei; Large for Ischia). We created a synthetic dataset of ground loads by performing 1500 tephra dispersion simulations for each size class of each volcano (total of 10500 simulations) using the numerical model Fall3D. For each simulation we randomly sampled eruptive parameters and meteorological conditions. The hazard evaluation has been performed using a Bayesian Event Tree (BET) approach accounting for the results of the simulations, the variability in vent opening and the mean annual rates of eruption for each size class.

In this way we obtained a set of hazard maps for Southern Italy showing the threshold tephra load that would be exceeded with selected mean annual rates. We found that, in general, greater tephra load thresholds are exceeded with lower annual rates and that the hazard is greater in the proximity of the Neapolitan area and in the South – South-Eastern regions.

It has also been performed hazard disaggregation in order to understand which of the analyzed volcanic sources and which size classes give a greater contribution to the hazard in each zone.

1412

Yellowstone Volcano Observatory eruption scenarios highlight Scientific Advisory Committee roles in two settings—Yellowstone National Park and the southwest USA

Dr Wendy Stovall[1], Dr. Michael Poland[2]
[1]*USGS Volcano Science Center, Vancouver, United States,* [2]*Yellowstone Volcano Observatory, USGS, Vancouver, United States*

The Yellowstone Volcano Observatory (YVO) is responsible for monitoring and responding to volcanic activity at Yellowstone Caldera (Wyoming) and in the southwestern USA. Two volcanic response exercises in 2022 highlighted various degrees to which Scientific Advisory Committees (SACs) might facilitate scientific activities to complement YVO's hazard response and messaging.

To evaluate and update the existing response plan for volcanic unrest and eruptions related to Yellowstone Caldera, YVO conducted a one-day in-person tabletop exercise in May 2022. Although Yellowstone is well-monitored for regional activity, the exercise emphasized the need to tailor additional monitoring, hazards assessment, and forecasting based on specific characteristics of future unrest. YVO has well-established Yellowstone-related scientific coordination among the nine members of the YVO consortium, including U.S. Geological Survey (USGS) and academic and state institutions. Research opportunities outside of the consortium exist and are facilitated by the National Park Service. However, a crisis response would strain this workflow, which would warrant establishing a SAC to act as a research project viability check and buffer. As such, the SAC would help ensure that academic collaborators' scientific goals are recognized and pursued to the extent possible.

In the southwestern USA, a volcanic crisis response would be complicated by the lack of volcano-observatory presence or existing consortium. In February, a 4-week-long virtual scenario organized by the NSF-funded Community Network for Volcano Eruption Response Research Coordination Network focused on a hypothetical basaltic eruption near Flagstaff, Arizona. Regional ground-based monitoring is sparse, and rapid-response monitoring and research plans would require coordination between USGS, researchers, and government institutions. The SAC would act as a two-way communication stream between the USGS and the research community, soliciting proposals based on USGS needs and accepting novel plans. The SAC collects and assesses plans, facilitates researcher coordination, and communicates the plans to USGS.

1365

Olivine CaO + Cr-spinel as proxy to in-situ mantle wedge depletion: a study from the Transmexican Volcanic Belt

Dr Susanne M Straub[1], Dr Valentina Batanova[2], Dr Alexander V Sobolev[2], Dr Arturo Gómez-Tuena[3], Dr Ramon Espinasa-Perena[4], Mr W Lindsay Fleming[1], Dr Ilya N Bindeman[5], Dr Finlay M Stuart[6], Dr Elisabeth Widom[7]
[1]Lamont Doherty Earth Observatory of the Columbia Climate School, Palisades, United States, [2]ISTerre, Université Grenoble Alpes, Grenoble, France, [3]Centro de Geociencias, Universidad Nacional Autónoma de México, Querétaro, México, [4]Instituto de Geologia, Investigación Científica, Copilco Universidad, Coyoacán, Ciudad de México, México, [5]Department of Earth Sciences, University of Oregon , Eugene, United States, [6]Isotope Geosciences Unit, Scottish Universities Research and Reactor Centre , East Kilbride, United Kingdom, [7]Department of Geology and Environmental Earth Science, Miami University, Oxford, United States

Forsteritic olivines in primitive high-Mg# arc magmas carry information on mantle wedge composition and processes. Here we investigate the causes of the low CaO contents in forsteric olivines from high-Mg# basalt to andesites in the Quaternary Trans-Mexican Volcanic Belt (TMVB). We paired olivine CaO with the Cr# [molar Cr/(Cr+Al) *100] of their Cr-spinel inclusions from a range of arc front volcanic rocks that include calc-alkaline, high-K and OIB-type varieties, and from n=4 monogenetic rear-arc basalts that lack subduction signatures. At similar high olivine Fo [molar Mg/(Mg+Fe2+) *100] of 80-90, arc front olivines have lower CaO (0.135±0.029 wt%) than the rear-arc olivines (0.248±0.028 wt% CaO) which overlap with those of olivines from mid-ocean ridge basalts. The high 3He/4He (5-8 Ra) of all olivines show that they crystallize from primary mantle melts, which originate at the arc front from a mantle wedge strongly modified by slab components. Combined olivine Fo-CaO-Ni and Cr-spinel systematics argue against a control of the low olivine CaO by elevated melt water or by secondary pyroxenite mantle lithologies. Instead, we propose that the low olivine CaO primarily reflects the low melt CaO of the TMVB arc front magmas, which becomes enhanced by slab-flux driven serial melting that progressively depletes the mantle beneath the individual arc front volcanoes. The typical low CaO and Al2O3 and high Cr of melt from depleted mantle then becomes preserved in the early crystallizing olivine and their Cr-spinel inclusions. The mechanism of mantle depletion by 'in-situ' melting also implies that the slab dominates the budget of incompatible elements in arc magmas. This conforms to models based on the high-Ni contents of the same olivines, suggesting that the high-Mg# andesites of the TMVB are principally created by slab-mantle (and not by crustal) processing.

1364

Cyclicity of Plio-Pleistocene Volcanism of the Kurile-Kamchatka-Aleutian arcs recorded at ODP Site 882, northwest Pacific

Dr Susanne M Straub[1], Dr Arturo Gomez-Tuena[2], Dr Kuo-Lung Wang[3], Dr Richard Arculus[4]
[1]Lamont Doherty Earth Observatory, Palisades, United States, [2]Centro de Geociencias, Universidad Nacional Autónoma de México, Queretaro, Mexico, [3]Institute of Earth Sciences, Academia Sinica , Nankang, Taipei , Taiwan , [4]Research School of Earth Science, Australia National University , Canberra, Australia

Global cooling, glaciation cycles and increased volcanic activity mark the Plio-Pleistocene transition (PPT) at ~2.5 to 3 Ma. In order to assess cause-and-effect relationships between climate and volcanism, we studied the tephra fallout record at ODP Site 882 in the northwest Pacific. Site 882 is located ≥700 km east of the Kurile-Kamchatka arc and ≥460 km south of the western Aleutian arc in 3244 meters water depth. Plio-Pleistocene sediments were 100% recovered and contain n=78 fallout tephra beds younger than 4.2 Ma in the spliced record of Holes A and B.

Site 882 tephra beds are mostly composed of low- to high K rhyolitic volcanic glasses; low- to medium-K andesitic to dacitic glasses are subordinate. Tephra bed thickness ranges from a few mm to up to 19 cm (average of 4.6± 4 cm) which suggests emplacement from explosive eruptions with minimum volcanic explosivity indexes (VEI) of ~5-7. Ash bed composition and thickness are uncorrelated. Both parameters fluctuate with time, but the only unidirectional change with time is the marked increase in ash bed frequency at the end of the PPT and after the intensification of the Northern Hemisphere glaciation at 2.73 Ma. Similar observations were made from the fallout tephra record of ODP Site 881 which located ~575 km to the southwest and nearer to the Kuriles-Kamchatka arc. Moreover, at both sites, peak eruptions occur shortly after the PPT (~2.5 to 2 Ma) and at ~1.1 Ma during the Mid-Pleistocene Transition, while a volcanic hiatus at ~0.7 to 0.5 Ma precedes a late Pleistocene surge of Kamchatka arc volcanism. Time series analyses and of volcanic provenance will further test the existence of such regional patterns and whether and how they may relate to Pleistocene climate change.

824

Composition and age of Columbia River Basalt dikes

Dr Martin Streck[1], Mary Mass[1], Rachel Sweeten[1], Professor John Wolff[2], Professor Anthony Koppers[3], Professor James Muirhead[4], Dr. Ashley Steiner[2]

[1]Portland State University, Portland, United States, [2]Washington State University, Pullman , USA, [3]Oregon State University, Corvallis, USA, [4]University of Auckland, Auckland, New Zealand

The four main units of Columbia River Basalt Group LIP are the Imnaha, Grande Ronde (GRB), Steens, and Picture Gorge Basalt (PGB) and likely erupted from the Chief Joseph, Steens and Monument Dike Swarms (CJDS , SDS, MDS, respectively) exposed from SE Washington to N Nevada. Here we focus on the composition and age of the dikes, examining along-strike variations and how dike compositions correlate with lava flow units. Our current data set consists of >100 CJDS, >50 MDS, and >40 SDS dikes, supplemented by published data. Dikes of CJDS and MDS have comparable thickness with averages of 5 to 9 m, but dikes of the SDS tend to be thinner mostly between 2-3 m. Dikes intrude CRBG lavas, Cenozoic volcanic rocks, or older accreted terrain/plutonic rocks; sills were only observed in the NE MDS and the SDS. Dike compositions correspond well with Imnaha and Grande Ronde lavas in case of the CJDS, with PGB for MDS, and with Steens Basalt for SDS. However, there are dikes that are not recorded by lavas, highlighted by one with high MgO (11 wt.%), low SiO2 (47 wt.%), and assigned to Imnaha Basalt, making this by far the most primitive composition. We decipher a low-Si and high-Si trend for the CJDS, the former corresponding on the primitive end with compositions of the Rock Creek subunit of the Imnaha Basalt with ages around 16.55 Ma and the latter with the lowest flows of the American Bar subunit and the PGB, and ages range from 15.9 ± 0.04 Ma for the lowest (51.4%) silica sample to 16.4 ± 0.05 Ma for the highest (58.0%). There is no spatial preference of compositions, and distinctly different dikes can be only meters away from one another, except where dikes intrude GRB, with compositions of older units generally missing.

677

Contrasting source–accumulation–storage histories as framework in explaining compositional characteristics of rhyolite fields, voluminous lava flows, and tuffs, eastern Oregon

Dr Martin Streck[1], Dr. Vanessa Swenton
[1]*Portland State University, Portland, United States*

Abundant mid- to late-Miocene rhyolites of eastern Oregon are cogenetic with flood basalts of the Columbia River Basalt Group or with the later High Lava Plains province. Here, we focus on rhyolite fields, single rhyolite lavas, and ignimbrites with comparable rhyolite volumes of ~100-300 km³.
The duration of peak activity of large fields consisting of rhyolite lavas and tuffs is ~200-400 ka, such as the Mahogany Mtn.-Three Fingers rhyolite field (16–15.7 Ma), the Strawberry rhyolite field (15.3–14.8 Ma), and the Dooley Mtn. field (15.6–15.4 Ma). In all these cases, rhyolite batches with distinct, yet occasionally subtle compositional and/or mineralogical characteristics erupted in short succession, leading to a complex volcanic stratigraphy. While rhyolites can show evolution trends with time, they are unlikely the product of an evolving reservoir(s), but rather, rhyolite batches were individually delivered from a source region, accumulated, and erupted shortly thereafter.

Conversely, the compositionally distinct Lower Littlefield (16.11 Ma; 100 km3) and Upper Littlefield (16.02 Ma; 150 km3) rhyolite lava flows represent single, voluminous, and homogenous rhyolite batches (virtually no variation in composition and mineralogy). These data demand a homogenous source, rapid accumulation, and eruption without significant shallow reservoir modifications.

Voluminous ignimbrites range from nearly homogenous to strongly compositionally zoned within the rhyolitic compositions. Homogenous ignimbrites (e.g., the Dinner Creek tuffs) show compositional characteristics resembling units of the Littlefield Rhyolite and hence suggest similar source, accumulation, and storage conditions. In contrast, rhyolites of compositionally zoned tuffs (e.g., the Rattlesnake and Devine Canyon tuffs) resemble diverse rhyolites of rhyolite fields yet distinct rhyolites of tuffs erupted from a contiguous magma body as evidenced by rhyolites commingled in banded pumices. We propose that rhyolites of zoned tuffs progressively accumulated from distinct sources with a relatively prolonged storage accompanied by some shallow reservoir evolution prior to evacuation during caldera eruptions.

1049

UASs Optimization - An evaluation of multiple mode vehicles in monitoring and communication

Mr Donald Sullivan[1]
[1]*NASA Airborne Science Program, Moffett Field, United States*

This presentation will describe the author's experience as Co-I in the NASA/USFS Project: "Strategic Tac Radio and Tac Overwatch (STRATO): Last Mile Communications and Realtime Observation Stratospheric Platforms for wildland fire". This project utilizes an uncrewed Stratospheric (> 70Kft) lighter than air Uninhabited Aerial System (UAS), carries 50 Kg of sensor and communications equipment, and remains on station over a wildfire for up to 30 days. The air vehicle is capable of in excess of 180 days on station, but while the full duration capabilities were not utilized in this project, they could, and would, be used in monitoring a feature like a volcano

In addition to duration, the ability of these Stratospheric Platforms to persistently monitor an area, while carrying "smart" sensors - generating information products, rather than just data - is game changing. Utilizing technologies such as LoRa, the platform can now be the nexus of an ad-hoc sensor web, receiving LoRa based data from low power in-situ sensors in the area being monitored, combining it with high fidelity information gained from on-board sensors, and sending the information product to a remote research facility, using Satellite communication, in real time.

The author will relate the evolution of information collection, derivation and delivery mechanisms in the entire range of NASA's UAS fleet, to today's world, where information products conventionally derived in desk top computational environments, and made available to the Science Community in weeks or months, are now being generated and delivered in near real time.

701

Numerical simulations of the 15 January 2022 eruptive plume of Hunga Tonga-Hunga Ha'apai volcano

Dr Yujiro Suzuki[1], Dr Antonio Costa[2]
[1]*The University of Tokyo, , Japan,* [2]*Istituto Nazionale di Geofisica e Vulcanologia, Bologna, Italy*

The submarine eruption of Hunga Tonga-Hunga Ha'apai (HT-HH) volcano on 15 January 2022, produced an exceptionally high plume and a large expanding umbrella cloud that were clearly detected by satellites. To understand the eruption dynamics, it is important to quantify the magnitude, intensity, and contribution of seawater to the eruption. Therefore, we performed numerical simulations of the volcanic plume and searched for eruptive conditions that would correctly reproduce the observed data of the HT-HH eruption cloud. We used the 3D model of Suzuki and Koyaguchi (2009), which correctly reproduced the large-scale plume of the Pinatubo 1991 eruption. This is a pseudo-gas model that ignores the relative motion of solid particles and the gas phase. Based on atmospheric reanalysis data, horizontally uniform atmospheric conditions were given as initial conditions. A mixture of magma with a temperature of 1233 K, a volatile content of 0.04 was considered together with the vaporized seawater entrained into the ejected material. In order to evaluate the maximum altitude of the plume and the radius of the umbrella plume, we carried out a parametric study considering different magma eruption rates, eruption durations, and the amount of entrained vapor produced by the seawater performed. Our results suggest that in order to explains the observed data, the eruption was characterized by a magma eruption rate of ~10^9 kg/s, an eruption duration of ~1000 sec, and ~10-20 wt% of seawater. More accurate quantification of eruption magnitude, intensity, and seawater contribution is required through more precise comparison of numerical results and observation data.

714

Constraining the tempo and frequency of explosive eruptions since 30 ka occurred in the north Izu Islands, off Tokyo, Japan

Professor Takehiko Suzuki[1,2], Dr. Kaori Aoki[2], Professor Makoto Kobayashi[2,3], Dr. Masanori Murata[2], Dr. Fumikatsu Nishizawa[2,4], Assistant Professor Takayuki Takahashi[2,5]

[1]Department Of Geography, Tokyo Metropolitan University, Hachioji, Japan, [2]Research Center for Hazard Mitigation in Volcanic Islands and Urban Areas, Tokyo Metropolitan University, Hachioji, Japan, [3]Mt. Fuji World Heritage Centre, Shizuoka, Fujinomiya, Japan, [4]Kanagawa Prefectural Museum of Natural History, Odawara, Japan, [5]International Research Institute of Disaster Science, Tohoku University, Sendai, Japan

Twelve Quaternary volcanoes composed of basalt to rhyolite rocks distribute in north Izu Islands, the north part of Izu-Bonin Arc. Comparing to other Quaternary volcanoes in the main Japanese Islands, their long-term explosive eruption histories are unclear. To constrain the tempo and frequency of explosive eruptions that occurred at rhyolitic volcanoes (including submarine volcanoes) in the north Izu Islands, we aimed to establish tephrostratigraphical framework for terrestrial and marine tephras in north Izu Islands for the past 30 kry. Niijima and Kozushima Volcanoes located in the back arc side are originated from rhyolitic magma. Although both volcanoes erupted within a short interval of ca. 50 years in 9th century as last explosive eruptions, eruption histories for these volcanoes differ during last 30 kyrs. At Niijima Volcano, eruptions with the magnitude equivalent to the AD886 event (>0.1 DRE km^3) have occurred every thousand years since the Miyatsukayama event (12.8-8.5 cal ka), and the island was covered with PDC at each eruption (Kobayashi et al. 2020). On the other hand, at Kozushima Volcano preceding the latest eruption (AD 838 event; 0.54 DRE km^3), only Kz-CbA (30-22 ka) and Kz-CbB (ca. 30 ka) events have been recognized as explosive eruption except unclear Kz-CbA' event (14-12.8 ka?) (Murata et al. 2021). Recent studies on a submarine volcano (Oomurodashi) clarified the 13.5 ka event associated with an explosive submarine phreatomagmatic activity followed by lava effusion at ca. 7–10 ka (McIntosh et al. 2022). On the other hand, we had detected two older tephras derived from submarine volcano(es), that is, Iz-Tos2 (30-19 ka; Takahashi et al. 2022) and Od-2 (30 ka; Aoki et al. 2022). Discovery of tephras associated with explosive submarine eruptions suggests potential future hazards such as generation of Tsunamis and pumice rafts that have been not well considered before.

1240

Mineral Recorders of Ascent Processes in Explosive Eruptions at Mt. Taranaki, New Zealand

Mr Jordan Swann[1], Dr Michael Rowe[1], Professor Richard Hervig[2]
[1]*University of Auckland, Auckland, New Zealand,* [2]*Arizona State University, Phoenix, United States*

Eruption styles and magnitudes of intermediate composition volcanoes can vary significantly from one eruption to the next. Processes which influence the eruption style are numerous and include both magmatic and external forcings. Mt. Taranaki, New Zealand, is one such volcano demonstrating a range of eruption styles, from dome building to plinian. Here we attempt to analyse ascent processes and crystallisation histories to compare their relative impact on eruption style. Because of their rapid diffusive properties, H and Li concentrations, and their isotopic compositions are compared here from a single eruptive formation, including a plinian, sub-plinian, and block and ash flow deposit. This is complemented by detailed image analysis and X-ray diffraction determination of groundmass crystallisation history.

Minerals extracted from pumice samples were analysed for H and Li isotopes and concentrations using secondary ion mass spectrometry. Concentrations differ from core to rim in plagioclase minerals across all eruption styles, with inconsistent core-to-rim trends in H, Li, and their isotopic ratios from grain to grain within the same eruption deposit. Generally, H concentrations are higher in plagioclase cores from the sub-plinian and block and ash flow deposit, compared to the plinian sample. Li concentrations, which have previously been used to argue for volatile enrichments in shallow magmatic systems show little change from core to rim in the sub-plinian and block and ash flow deposits. Li shows a slight increase in plagioclase rims of the plinian deposit compared to core values. Results indicate that multiple factors likely influence the concentration of Li and H in mineral rims, and support the trend that the Taranaki magmatic system contains a mixture of grains with different crystallisation and thermal histories.

595

Volcanic debris avalanches in a landscape context: pre-eruption topography, post-eruption erosion, and implications for deposit preservation

Dr Kristin Sweeney[1], Dr Jon Major[2]
[1]University Of Portland, Portland, United States, [2]USGS Cascades Volcano Observatory, Vancouver, Unite States

Since the 1980 eruption of Mount St. Helens and its associated volcanic debris avalanche, more than one thousand volcanic debris avalanche deposits (VDADs) have been identified at volcanoes around the world, with volumes up to tens of km3. Past work on VDADs has focused on event identification and dating, emplacement mechanisms, deposit sedimentology, primary deposit topography, and hazards. By contrast, there are few discussions of the hydrologic and geomorphic implications of VDADs, except at Mount St. Helens, which we see as an opportunity to better understand how these massive events impact landscapes on timescales of decades to millennia. Here, we use remote sensing to examine possible controls on the post-emplacement geomorphic evolution of VDADs worldwide. We mapped the areal extent of fluvial erosion (as a proxy for post-emplacement modification) on 78 VDADs spanning a wide range of regional climate, event age, and topographic confinement. In our mapping, we used a variety of remote sensing products, including digital topographic data of varying resolution, Google Earth imagery, and Open Street Map layers. The quality of topography data is highly variable among deposits, ranging from 1 meter resolution lidar to 30 m resolution TanDEM-X radar data; lower resolution data tend to lead to an underestimate of fluvial modification because small channels are not detectable. Other sources of uncertainty include anthropogenic modification of channels such as channelization and damming, and vegetation that obscures channel features in Google Earth imagery. Preliminary results suggest that topographic confinement and climate affect the extent of deposit modification by influencing the spatial footprint of channel migration; channels in wetter and more topographically confined environments can migrate across more of the areal footprint of a VDAD, reducing long-term preservation potential within tens of meters of the ground surface.

1467

Lava flow scenarios and contingency planning for an eruption of Nyiragongo volcano

Dr Adalbert Syavulisembo Muhindo[1], Dr François Kervyn[2], Dr Moritz Lennert[3], Dr Caroline Michellier[2]
[1]Goma Volcano Observatory, Goma, Congo (the Democratic Republic of the), [2]Natural Hazards and cartography Service, Department of Earth Sciences, Royal Museum for Central Africa, Tervuren, Belgium, [3]ANAGEO/IGEAT, Université Libre de Bruxelles, Brussels, Belgium

During the last three eruptions, lava flows emitted by Nyiragongo volcano spread near Goma in 1977 and 2021, and within the city in 2002. During these three eruptions, the lava flows were very rapid and took hundreds of lives. This densely populated region remains at risk of further eruptions. In addition, it is expanding, both demographically and spatially, in areas where volcanic hazards could be a great danger in the future. While it is clear that the date, time, intensity and trajectory of the next eruption of Nyiragongo volcano are not known before its occurrence, we can anticipate the management of the volcanic crisis through scenarios. These scenarios, combined with other factors, will help to develop a coherent set of risk management protocols related to Nyiragongo lava flows for the prediction and effective management of crises and the promotion of sustainable development in the city of Goma. In this work, the susceptibility of opening eruptive vents is limited by the estimated density of volcanic cones and eruptive fissures in the entire Nyiragongo field. To identify lava flow scenarios in Goma, we started from estimates of lava flow trajectories. To determine the four lava flow zones, we grouped lava flow trajectories, thermal effect zones from possible gas station explosions, and areas enclosed by lava flows. Through the combined analysis of the lava flow hazard zones, we identified 15 lava flow scenarios that subdivide Goma into 40 possible areas outside the lava flow hazard zones. As with the other models, this is also a simplification, as one volcanic cone may correspond to several eruptions or several volcanic cones to one eruption, or one large volcanic eruption may cover several cones that would not have been visible in the density estimation. Tunnel lava flows were not studied in this work.

741

Aeromagnetic survey of Nishinoshima volcano by using drone in 2019

Dr Noriko Tada[1], Dr Hiroshi Ichihara[2,1], Dr Masaru Nakano[1], Dr Mitsuru Utsugi[3], Dr Takao Koyama[4], Dr Tatsu Kuwatani[1], Dr Kiyoshi Baba[4], Dr Fukashi Maeno[4], Dr Akimichi Takagi[5], Prof Minoru Takeo[4]
[1]Japan Agency For Marine-earth Science And Technology, Yokosuka, Japan, [2]Nagoya University, Nagoya, Japan, [3]Aso Volcanological Laboratory, Kyoto Univ, , Japan, [4]Earthquake Research Institute, The University of Tokyo, Tokyo, Japan, [5]Meteorological Research Institute, Tsukuba, Japan

Nishinoshima volcano in the Ogasawara (Bonin) island arc erupted in 1973-1974 for the first time since its discovery in 1702, and has intermittently erupted since November 2013. According to Iizuka et al. (1975), Nishinoshima volcano was formed after the last geomagnetic reversal event (~ 0.77 Ma) because all rocks obtained from Nishinoshima showed normal remnant magnetization. The volcanic island offers an opportunity to study island-forming eruption processes (Maeno et al., 2016) and formations of continental crust (Tamura et al., 2019). Thus, we have been approached these issues to measure total magnetic anomalies above the island by using the drone with the potassium magnetic sensor developed by Tierra Tecnica Ltd. (Tokyo, Japan).

The aeromagnetic surveys were conducted during the cruise of the Japan Meteorological Agency weather ship Keifu-Maru in June 2019, and covered an area of about 3 km x 3 km including the emergent part of Nishinoshima volcano. We extracted the magnetic anomaly induced by the magnetization structure from the observation data and estimated the magnetization structure from the anomaly by applying the 3D inversion (Utsugi, 2019), which combines L1 and L2 norm regularizations. We conducted a cross-validation procedure (e.g., Bishop, 2006) to simultaneously determine optimum values of a regularization parameter and a hyperparameter. We found that Nishinoshima volcano had an average magnetization of about 3.0 A/m and that two more strongly magnetized bodies existed as of 2019 beneath the volcanic vent at about 300 m below sea level and the northeast slope of the volcano at depths between 300 and 800 m below sea level. These features might be related to the evolution of this volcanic island. This study demonstrated the utility of this relatively safe and inexpensive observation method and this data analysis method for investigating the magnetic structure of remote volcanic islands.

1008

The role of irregular conduit geometry on the dynamics and seismo-acoustic radiation of scaled volcanic jets

Laura Spina[1], Dr Jacopo Taddeucci[1], Francesco Pennacchia[1], Daniele Morgavi[2], Piergiorgio Scarlato[1]
[1]*Istituto Nazionale Di Geofisica E Vulcanologia, Roma, Italy,* [2]*Dipartimento di Scienze della Terra, dell'Ambiente e delle Risorse (DISTAR), Università Degli Studi di Napoli Federico II, Napoli, Italy*

Laboratory experiments represent a test bench for creating a quantitative scheme of the interplay between process dynamics and geophysical markers in ideal and well-controlled conditions. They are indeed a fundamental tool for overcoming limitations arising from remote techniques such as not unique solutions for source properties, and mismatch of relevant spatial and temporal scale of interest for volcanological processes.

With the goal of investigating the role of conduit roughness on explosive volcanic activity we performed a series of laboratory experiments on scaled volcanic jets. Compressed air in the range of 2-8 bar was instantaneously released into home-build epoxy pipes (length 80 cm, mean inner diameter: 3 cm) with fractal dimension of the internal surface (proxy for conduit surface irregularity) of 2 (smooth), 2.18, 2.7 and 2.99, used as analogue conduits. The dynamics of the resulting subsonic to supersonic jets were observed using a high speed camera (50 KHz), synchronized with up to three monoaxial accelerometers (0.5 to 10 KHz) and one triaxial accelerometer (2 to 7 KHz) located along the conduit outer surface. An array of microphones (0.5-40 KHz), was distributed at the experimental conduit vent to cover different azimuthal and zenital directions.

Results show that increasing surface roughness of the conduit decreases the spacing between the Mach disks in the supersonic jets at the tube outlet, proxy for jet velocity, at all pressure differentials. This velocity decrease reflects in the features (amplitude, spectral properties) of the seismo-acoustic signals, and possibly in the coupling between conduit and gas and in the energy partition between seismic and acoustic radiation.

1000

Broken crystals at the edge of breaking magma

Dr Jacopo Taddeucci[1], Corrado Cimarelli[2], Michael Manga[3], Piergiorgio Scarlato[1]
[1]Istituto Nazionale Di Geofisica E Vulcanologia, Roma, Italy, [2]Department of Earth and Environmental Sciences, Ludwig-Maximilians-Universität München, Munich, Germany, [3]Department of Earth and Planetary Science, University of California, Berkeley, Berkeley , USA

Magma fragmentation is a key process in explosive volcanic eruptions. While numerical and experimental models have largely illuminated the consequences for volcano-scale principles, the mechanisms and record of fragmentation at the microscale remain elusive. A key challenge is that viscous deformation of melt, especially in low-viscosity magmas, may overprint some signatures of fragmentation in erupted pyroclasts. Conversely, solid crystals preserve features due to magma fragmentation. Scanning Electron Microscopy revealed broken crystals within the intact glass of pyroclasts from 13 explosive eruptions ranging from Strombolian to Plinian in style and from basanite to rhyolite in bulk magma composition. Increasing abundance of broken crystals in smaller pyroclasts and at their edges, their occasional association with sutured fractures in the melt, and nearly-identical features reproduced by high-temperature fragmentation experiments, reveal that the crystals are broken during fragmentation by the passage of brittle cracks through the magma. Subsequent viscous deformation of the magma then heals the cracks in the melt, effectively masking fragmentation and ultimately affecting the grain size distribution of eruption products. The features and abundance of broken crystals and associated micro-textures could be used to assess crack propagation and the state of magma at fragmentation. In lapilli-sized pyroclasts, local concentrations of broken crystals with large, empty cracks define ‘damage zones’. There, limited viscous healing of the melt suggests an origin relatively close to quenching temperature. Synchrotron X-ray computed tomography reveals cracks with plain, curved, and stepped surfaces, branching, multiple intersections, and almost ubiquitous connections with vesicles. Electron Back-Scatter Diffraction results show limited misalignment in the lattice of broken crystals, and large (up to 10°) misalignment in unbroken but bent surrounding ones, indicating stress accumulation in the magma (and crystals) and its release by cracks. All these observations suggest damage zones formed in narrow areas of a locally stressed and already vesicular magma.

553

Evaluation of fault activity in northeastern Japan and its relationship with magmatic activity

Ms Ayaka Tagami[1], Miu Matsuno[1], Tomomi Okada[1], Shin'ichi Sakai[2], Ohzono Mako[3], Kei Katsumata[3], Masahiro Kosuga[4], Yishiko Yamanaka[5], Hiroshi Katao[6], Takeshi Matsushima[7], Hiroshi Yakiwara[8], Satoshi Hirahara[1], Toshio Kono[1], Shu'ichiro Hori[1], Toru Matsuzawa[1], Shuutoku Kimurua[1], . Group for the aftershock observations of the 2011 off the Pacific coast of Tohoku Earthquake

[1]Research Center For Prediction Of Earthquakes And Volcanic Eruptions, Graduate School Of Science, Tohoku University., Sendai City, Japan, [2]Earthquake Research Institute, University of Tokyo, , Japan, [3]Institute of Seismology and Volcanology, Graduate School of Science, Hokkaido University, , Japan, [4]Graduate School of Science and Technology, Hirosaki University, , Japan, [5]Graduate School of Encironmental Studies, Nagoya University, , Japan, [6]Research Center for Earthquake Prediction, Disaster Prevention Research Institute, Kyoto University, , Japan, [7]Institute of Seismology and Volcanology, Faculty of Science, Kyushu University, , Japan, [8]Nansei-toko Observatory for Earthquakes and Volcanoes, Kagoshima University, , Japan

Introduction
Northeastern Japan is known as one of the typical volcanic island areas. Most of the Quaternary volcanoes are distributed in the inland area of Japan, but only a few are in the eastern margin of the Japan Sea (EMJS). In these areas, many old normal faults were initially formed at the backarc rifting and extensional stage in Miocene, and reverse faulting of them as tectonic inversion occurs under the current compressional stress field (Okamura, 2010). Also, newly developed faults are currently being formed.

This study investigated the relationship between the stress fields and the fault planes of several recent large earthquakes. It discusses the possibility that volcanoes affect seismic activity in such complex deformation area.

Data and methods
We use focal mechanism (moment tensor) data from the National Institute for Earth Science and Disaster Resilience (NIED) of Japan and focal mechanisms estimated from P-wave initial motions from Okada et al. (2022). For estimating the regional stress field, we deploy the stress tensor inversion method (Michael, 1984, 1987). For estimating the likelihood of slip, we use the Slip Tendency (ST) analysis (Morris et al., 1996).

Results
In the EMJS, the stress field determines the fault plane. In the inland area of Northeastern Japan, the fault planes that are hard to slip against the current stress field (i.e., inversion tectonics faults) are active.

Discussion

From the comparison between the fault and the volcanic distributions, the fault planes which are hard to slip against the stress field but which slipped are distributed near volcanoes. Several previous studies discussed that fault slipped due to the supply of interstitial fluid accompanying volcanic activity (e.g., Yukutake et al., 2011). We considered that the high pore fluid pressure associated with the volcanic activity is related to the inversion fault activity.

1294

How does it feel to be working under pressure in a volcano observatory during unrest?

Dr Benoit Taisne[1]
[1]Nanyang Technological University, Earth Observatory of Singapore, Singapore, Singapore, [2]Nanyang Technological University, Asian School of the Environment, Singapore, Singapore

How can someone appreciate the challenges of real-time interpretation or monitoring data? How to combine geodetic and seismic information together? How to have a quick assessment of where is the seismicity coming from? How to communicate the interpretations? All those questions were at the core of the thought process that went into designing a dynamic, flexible, real-time crisis simulation. As a teacher you can set the type of unrest you want, from deep chamber inflation, to shallow horizontal dyke migration and anything in between. This information will then be used by the program to generate time evolution of deformation patterns, on one screen, and increase likelihood to have seismicity where the deformation is taking place, on a second screen. As a teacher you can always include a tight cluster of distal volcano tectonic event to add a layer of complexity! How would the student see all this information? Well, this is an excellent question, isn't it? Depending on the level of your class, you can have a default monitoring network design that you know will capture the main characteristics of your unrest scenario…. Or you can let the students design their own network of GPSs and seismometers, and off course, they can request for InSAR information… if and when available. The level of complexity could range from budget constrain to communicating about the interpretation to fellow scientist, journalist, and stakeholder. I found this exercise valuable to generate collaborations between participants, improve their communication skills and for them to appreciate the challenges of interpreting monitoring data.

348

Eruptive quantity rates of ashfalls before and after the lava producing event of the 2018 Shinmoedake eruption in Kirishima Volcano

Dr Yasuhisa Tajima[1], Dr Setsuya Nakada[2], Dr Masashi Nagai[2], Dr Fukashi Maeno[3], Dr Jun Oikawa[3], Dr Masataka Kawaguchi[4], Dr Toshiaki Hasenaka[4]

[1]R&D, Nippon Koei, Tsukuba, Japan, [2]NIED, Tsukuba, Japan, [3]ERI Univ. Tokyo, Tokyo, Japan, [4]Kumamoto Univ., Kumamoto, Japan

A volcanic ash eruption at Shinmoedake, in Kirishima Volcano began on March 3, 2018. The volcanic ash producing event continued to March 5, and then lava flow was observed on March 6. After the lava producing event, volcanic ashfall eruptions continued until June 27. The amount of volcanic ashfall around Shinmoedake was observed and the volcanic ashfall volumes of each eruption were analyzed using the Ellipse-Approximated Isopach (EAI) method developed by Tajima et al. (2013).

First, ashfall quantities were calculated for the eruption period between March 1 and March 5, before the lava producing event. During this period, volcanic ash clouds were emitted continuously with occasional weaken. At times the amount of only one point of ashfall was observed in some cases during this initial period. In such cases, the distribution limit analysis described by Tajima et al. (2021) was used, which showed the detailed sequences. This quantity rate of this activity peaked on March 3, and then decreased until the afternoon of March 5. The quantity rate change inferred that the magma head had passed through an aquifer layer when compared with the subsurface structure by a geophysical survey. Following the lava producing event, the volcanic ash producing event became an explosive Vulcanian type eruption until June 27. During this period, each eruption was analyzed as possible as. Lastly, two different trends of eruptive quantity rate were found before and after the lava producing event.

315

Hazard evaluation change from stochastic to confident in the active phase, Kirishima Volcano, Japan

Dr Yasuhisa Tajima[1], Dr Testuo Kobayashi[2]
[1]R&D, Nippon Koei, Tsukuba, Japan, [2]DPRI, Kyoto University, Kagoshima, Japan

A revised hazard map for Kirishima Volcano has been in development since the 2000s. In the 2009 version, a conflict was evident between the map used by the local government, which designated an area with a 1-km radius as a possible vent area based on a long-term volcanic activity, and the Japan Meteorological Agency's (JMA) Volcanic Alert Levels, which did not designate a possible vent area. This difference has had a significant impact to the society and needs to be considered in a scientific context.

Recent surveys have revealed the presence of three active phases of concentrated magmatic eruptions in Shinmoedake. And a detailed analysis indicated that the magma pathway stabilized in the two completed active phases. Therefore, we observed whether the 2010–2011 and 2017–2018 magmatic eruptions would show the same pattern in the last active phase. In the 2010–2011 eruptions, small phreatic eruptions occurred on the western flank of Shinmoedake and the eruption vents gradually moved eastward in 2010. In the January 19, 2011, small phreatomagmatic eruption occurred from within the summit crater. Lastly the sub-Plinian eruption, which began on January 26, occurred at the Jan-19 vent. In 2011, lava erupted from the center of the summit crater following sub-Plinian eruption. Subsequently in March 2018, lava eruption slightly shifted northeastward in the summit crater compared to the 2011 eruption. In conclusion, the magma pathway was nearly identical throughout the current active phase. The hazard map was revised in 2019, and the possible vent area became more specific. In Shinmoedake, the indication style of the possible vent area has changed from the stochastic area in the quiet to the confident area in the unrest. In the end, Kirishima Volcano has used the confident area for the possible vent area of the hazard map.

347

A new series of the distribution map of large-volume ignimbrites derived from caldera-forming eruptions in Japan

Dr Shinji Takarada[1], Mr Ayumu Nishihara[2], Mr Hideo Hoshizumi[1], Dr Tadashi Yamasaki[1], Mr Yasuaki Kaneda[1,3], Dr Nobuo Geshi[1]
[1]Geological Survey of Japan, AIST, Tsukuba, Japan, [2]Kobe University, Kobe, Japan, [3]Ibaraki University, Mito, Japan

The low-frequency and large-scale geological events are getting important after the 2011 Tohoku Earthquake in Japan. Especially VEI 6 to VEI 8-class large-volume ignimbrites will provide catastrophic disasters in a large spatial area. Therefore, the Geological Survey of Japan (GSJ), AIST, has commenced releasing a new series of volcano maps titled the "Distribution Map of Large-volume Ignimbrite in Japan." The series provides details of the spatial distributions and characteristics of large-volume ignimbrites that erupted from caldera volcanoes during the late Pleistocene in Japan. This series aims to present the distribution and affected area by large-scale eruptions based on the reconstruction of ignimbrite distribution where the deposits are unexposed on the surface and eroded. The surface altitude and the thickness of the ignimbrite, the maximum size of pumice and lithic fragments in the ignimbrite, the preferred orientation of the pumice fragments, and the distribution of associated co-ignimbrite ash fall deposits are available for further usage in a variety of directions.

"Distribution Map of Ito Ignimbrite and associated deposits, Aira Caldera, Japan" (Takarada et al., 2022) has been released as the first publication of the series, which contains a 1:250,000 scale map of the distribution of the Ito ignimbrite in southern Kyushu. All PDF and GIS file contents are obtainable at the website: https://www.gsj.jp/Map/EN/lvi.html.

GSJ plans to publish distribution maps for the series in Japan, such as Shikotsu, Aso-4, and Aso-3 ignimbrites. These publications are expected to provide information about the possible extent of affected areas during future large-volume eruptions. This information could play a crucial role in disaster mitigation plans operated by national and regional governments and the construction of resilient infrastructure and is expected to place fundamental constraints on the impacts of large-scale eruptions that will help mitigate potential disasters in the future.

923

Molybdenum isotopic compositions in iguneous rocks from Izu arc

Mr Tatsuya Tamura[1], Dr Tetsuya Yokoyama[1], Dr Takeshi Kuritani[2], Dr Akira Ishikawa[1], Dr Ikshu Gautam[1]
[1]Tokyo Institute of Technology, Meguro-ku, Japan, [2]Hokkaido University, Kita-Ku, Japan

Molybdenum isotopic ratio (δ^(98/95)Mo) in arc lavas is an important geochemical tracer as it reflects various processes (e.g., dehydrations, crystallization) occurring beneath island arcs. Previous studies have demonstrated that δ^(98/95)Mo values in arc volcanic rocks became systematically lower from volcanic front (VF) to rear arc (RA), yet the data for RA samples are still lacking. The Northern-Izu Arc (N-Izu), consisting of a chain of volcanoes covering VF (Izu-Oshima) to RA (Niijima, Kozushima), is suitable location for better understanding the behavior of Mo isotopes associated with slab dehydration in subduction zones. Although most of the RA volcanoes in N-Izu are rhyolite in composition, small amount of basaltic enclaves were found in some rhyolitic lavas. Here we report δ^(98/95)Mo values of the Kozushima basalts, as well as those of basalts from Izu-Oshima and Niijima for comparison.

The δ^(98/95)Mo values of the samples were determined by a double-spike TIMS method. The Kozushima basalts have lower δ^(98/95)Mo values (–0.26 ± 0.13) than Niijima (–0.16 ± 0.02) and Izu-Oshima (+0.07 ± 0.07) . The higher La/Yb ratios of the Kozushima basalts than those of Izu-Oshima and Niijima basalts suggest that the primary magma for the Kozushima formed under conditions of lower partial melting in the RA region. Additionally, Kozushima basalts have lower Ba/Th and Pb/Ce ratios than those of Izu-Oshima lavas, indicating greater contribution of sediment component with lower contribution of aqueous fluid compared to VF lavas. Because the slab depth increases in the order of Izu-Oshima, Niijima, and Kozushima, the observed geochemical signatures including the lowest δ^(98/95)Mo value in the Kozushima basalts are considered to result from a progressive slab dehydration that continued to the slab depth below Kozushima. The dehydrated slab with such a low δ^(98/95)Mo value will eventually modify the Mo isotopic composition deep in the mantle.

671

Detection and characterization of seismic and acoustic tremor at volcanoes using machine learning

Darren Tan[1], David Fee[1], Társilo Girona[1], Matthew Haney[2], Alex Witsil[3], Aaron Wech[2]
[1]Geophysical Institute, University Of Alaska Fairbanks, Alaska Volcano Observatory, Fairbanks, United States, [2]U.S. Geological Survey, Alaska Volcano Observatory, Anchorage, United States, [3]Wilson Alaska Technical Center, University of Alaska Fairbanks, Fairbanks, United States

Volcanic tremor is a semi-continuous seismic and/or acoustic signal that occurs at time scales ranging from seconds to years, with highly variable amplitudes and spectral features. Having a fast, robust, automated method to detect and characterize tremor in high temporal resolution would be beneficial to eruption forecasting and monitoring efforts, as well as retrospectively building tremor catalogs for research purposes. As part of the NSF-funded PREEVENTS eruption forecasting project, we seek to test and develop a pair of machine learning algorithms (one for seismic, one for acoustic) that can detect tremor in near-real time and classify it according to its spectral signature (harmonic, monochromatic, broadband tremor, etc.). First, we manually label tremor time windows on single station seismic and low-frequency acoustic (infrasound) data from the August 2021-ongoing eruption of Pavlof Volcano, Alaska, and train selected open-source neural network and random forest algorithms on each data type. Then, we identify the most successful model features in detecting and classifying seismic and acoustic tremor, and compare temporal trends observed in our feature space alongside eruption chronologies compiled by the Alaska Volcano Observatory. We also implement a local network-wide weighting scheme to reduce false detections. Lastly, we validate and assess the transferability of our trained models by applying them on unseen data recorded from past eruptions at Pavlof and other Alaska volcanoes. We envision that our machine learning models will aid monitoring and research efforts related to tremor, and will contribute towards our understanding of the relationship between tremor and subsurface volcanic processes by making consistent tremor catalogs more accessible.

328

Multi-parametric observation of intermittent hydrothermal discharge at the west crater of Iwo-Yama volcano, Kirishima Volcanic Complex, Japan

Mr Harutou Tanabe[1], Prof. Takeshi Matsushima[2], Assoc Prof. Koki Aizawa[2], Dr. Dan Muramatsu[3]
[1]Graduate School of Science, Kyushu University, 744 Motooka, Nishi-ku, Fukuoka,, Japan, [2]Institute of Seismology and Volcanology, Faculty of Science, Kyushu University, Shinyama 2, shimabara,, Japan, [3]Earthquake Research Institute, University of Tokyo, Yayoi 1-1-1, Bunkyo-ku,, Japan

In the W4 vent at Iwo-Yama, Kirishima Volcanic Complex, Japan, the vent was repeatedly filled by hydrothermal water and subsequently dried up with a cycle of 14 to 17 hours during April to July 2021. One cycle was as follows: (i) steam effusion disappear 20–40 minutes before the hydrothermal discharge, (ii) the hydrothermal discharge occurs and generates hydrothermal water pool, (iii) steam discharge resume and gradually increase, (iv) drain back of the hydrothermal water occur 1–1.5 hours before the next hydrothermal discharge. We performed multi-parametric observation (camera, thermometer, electric self-potential (SP), seismometer, acoustic sensor, tilt meter) to investigate the cause of the cyclic hydrothermal discharge. In SP data, the change started approximately two hours before the hydrothermal discharge. However, when the amplitude of SP change was small, the hydrothermal discharge didn't occur. The temporal change in SP is possibly caused by groundwater flow through porous materials (e.g., Ishido and Mizutani 1981). Therefore, SP data suggest that preoperational groundwater flow occurred two hours before the hydrothermal discharge. The polarity of SP change suggests the groundwater flowed toward the vents. The seismic signals in the frequency range < 20 Hz started decrease 15–45 minutes before the onset of SP change. Similar seismic signals have been observed at geysers and thought to be caused by bubble collapse in the conduit (e.g., Kieffer, 1984). We interpret that the inflow of cold groundwater inhibited the boiling in the conduit and caused the cessation of the steam effusion and seismic activity. SP data suggests that the inflow of cold groundwater gradually decreased. Therefore, pressurization possibly occurred in the lower conduit by the continuous supply of steam bubbles and finally led to the hydrothermal discharge. We suggest that the inflow of cold groundwater into the conduit controls cyclic hydrothermal discharge at the W4 vent.

771

Lithospheric thermal structure from thermal data collection in and around Japan and its application

Dr Akiko Tanaka[1]
[1]Geological Survey Of Japan, Aist, Tsukuba, Japan

Knowledge of the lithospheric thermal structure is a fundamental understanding in regulating volcanism because the physical and chemical properties are strongly temperature dependent. Heat flow can be used for a proxy of lithospheric temperature distribution. A database “Thermal Data Collection in and around Japan”, which contains continuously updated heat flow since 1960’s, has been released in 2019 [https://www.gsj.jp/data/G01M/GSJ_MAP_TDCJ_2019.zip]. This also includes geothermal gradient data updated since 1999 and newly added thermal conductivity data. The compilation of global heat-flow data is currently under major revision by the International Heat Flow Commission (IHFC [http://www.ihfc-iugg.org/]), a commission of the International Association of Seismology and Physics of the Earth's Interior (IASPEI), which is co-sponsored by the International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI) and the International Association of the Physical Sciences of the Ocean (IASPO). A new database structure was launched in 2021 (Fuchs et al., 2021, https://doi.org/10.31214/ijthfa.v4i1.62), including 56 individual fields, grouped in four main thematic groups, heat-flow density, metadata and flags, temperature, and thermal conductivity. The significant improvement is an extended set of meta data fields, relevant to enable quality control, and supporting interoperability following FAIR (Findable, Accessible, Interoperable, and Reusable) and open data principles. In light of what is now known about the thermal related data, it is worthwhile to reassess the thermal state of the lithosphere along with other geophysical/geochemical constraints.

241

Numerical experiments for ground deformation due to volcanic hydrothermal system

Dr Ryo Tanaka[1], Dr Takeshi Hashimoto[1], Dr Shohei Narita[2]
[1]Institute of Seismology and Volcanology, Faculty of Science, Hokkaido University, Sapporo, Japan, [2]Graduate School of Science, Kyoto University, Aso, Japan

We performed numerical experiments for ground deformation due to volcanic hydrothermal systems, focusing on a permeability structure. The observations near craters have observed the ground deformation during the unrest period. Magnetotelluric surveys can image resistivity structure beneath craters. We are getting to reveal the relationship between resistivity structure and pressurization source. At some volcanoes, a bell-shaped caprock structure and hydrothermal fluid reservoir within the caprock have been imaged. The location of pressurization sources is estimated within the hydrothermal fluid reservoir. However, it remains unclear how a caprock structure influences ground deformation and how the location of the pressurization source, the Mogi source in many cases, reflects the activity of the hydrothermal system.

We follow the system's response and ground deformation for up to five years after giving perturbation to the hydrothermal system with the hydrothermal simulator and finite element method. The perturbations are an increase in hydrothermal input from the deep part of the system and a reduction of permeability at a certain depth in a conduit. Four different types of permeability structures are used in the experiments. Our numerical experiments demonstrate that 1) The thickness of the caprock influences the distribution of change in pressure, 2) The pressurization source (Mogi source) estimated by the synthetic data of ground deformation located deeper than the peak of the distribution of change in pressure. These suggest that the hydrothermal fluid flow and the permeability structure should be considered when one analyzes the ground deformation due to the hydrothermal system and compares between pressurization source and sources of other observations (e.g., hypocenter, magnetization source, etc.). Furthermore, we will try to calculate the change in a total magnetic field, estimate the magnetization source, and compare the locations of pressurization and magnetization sources.

859

August 2021 eruption of the Fukutoku-Oka-no-Ba Volcano, Izu-Bonin Arc: Understanding the eruption dynamics from rapid response seafloor surveys

Dr Kenichiro Tani[1], Osamu Ishizuka[2], Teruki Oikawa[2], Hiroki Minami[3], Masashi Nagai[4], Yoshiaki Suzuki[2], Hajime Katayama[2], Taketo Shimano[5], Iona M. McIntosh[6], Michihiko Nakamura[7], Fukashi Maeno[8], Takashi Sano[1], Tatsuki Mizuno[8], Taisei Ukita[7], Fumihiko Ikegami[9], Koji Ito[10]

[1]National Museum of Nature and Science, Japan, Tsukuba, Japan, [2]Geological Survey of Japan, AIST, Tsukuba, Japan, [3]Japan Coast Guard Academy, Kure, Japan, [4]National Research Institute for Earth Science and Disaster Resilience, Tsukuba, Japan, [5]Tokoha University, Shizuoka, Japan, [6]Japan Agency for Marine Science and Techonoloy, Yokosuka, Japan, [7]Tohoku University, Sendai, Japan, [8]The University of Tokyo, Bunkyoku, Japan, [9]University of Tasmania, Hobart, Australia, [10]Japan Coast Guard, Chiyodaku, Japan

Fukutoku-Oka-no-Ba (FOB) is an active submarine volcano located in the southernmost Izu-Bonin Arc, which erupted on August 13, 2021, according to satellite and aircraft observations. The eruption reached a plume altitude of 16 km at the tropopause, and satellite images showed that discolored water appeared below the sea surface at the onset of the eruption, followed by formation of pumice rafts and a new emergent island. The eruption continued for ~3 days with a terminal period of Surtseyan-style eruptions from the morning of August 14.

The pumice raft has been widely dispersed to the west of FOB volcano by ocean currents and wind. Pumice clasts started to arrive at the Ryukyu Islands from October, 2021, and to the shores of the main islands of Japan.

The volume of ejecta from this eruption is estimated to be more than 0.1 km3 and, considering the altitude of the plume, it is likely that this was a Plinian-type eruption with a Volcanic Explosivity Index of 4. This 2021 eruption of FOB volcano provides a crucial opportunity to understand the eruption dynamics and tephra dispersal mechanisms during an explosive shallow submarine eruption.

Following the eruption, we have conducted two rapid response research cruises in 2022 using R/V SHINSEI-MARU of JAMSTEC. The first cruise was conducted in April, and we were successful in obtaining sediment cores at 8 sites on the western foothill of FOB. The second cruise was conducted in August, and we were able to observe and sample the horizontal extension of eruptive materials on the distal/proximal sites using a remotely-operated vehicle.

We aim to understand the detailed time sequence of the 2021 eruption and the deposition mechanisms of the ejecta beneath the sea surface. In this presentation, we will introduce our latest results from the rapid response surveys.

308

Elemental partitioning between a hydrous melt and aqueous fluids: Origin of geochemical signature of arc basalts and their across-arc variation

Dr. Hajime Taniuchi[1,2], Dr. Takayuki Nakatani[2], Dr. Toshihiro Suzuki[2], Dr. Akihiko Tomiya[2], Dr. Akiko Tanaka[2], Dr. Osamu Ishizuka[2], Prof. Tatsuhiko Kawamoto[1]
[1]Shizuoka University, Shizuoka, Japan, [2]Geological Survey of Japan, AIST, Tsukuba, Japan

Geochemical signature of arc basalts and their across-arc compositional variation have been explained by the involvement of slab-derived fluids in the primary magma generation as well as elemental partitioning between subducting slab and the fluids (Elliott et al., 1997, JGR). Such slab fluids can be released as supercritical liquids and separate into aqueous fluids and hydrous melts during their migration (Kawamoto et al., 2012, PNAS). If this is the case, elemental partitioning between melts and aqueous fluids can partially contribute to the origin of geochemical signature of arc basalts. Here, we report new experimental results of partition coefficients between a hydrous dacitic melt and pure water or saline solutions for 26 trace elements at 1100°C, 0.3 and 0.7 GPa using internally heated pressure vessels.

Obtained experimental results show the followings: (1) High-field strength elements (HFSE), except Th, are hardly partitioned into aqueous fluids regardless of pressure conditions and aqueous fluid composition. (2) In contrast, partitioning of other elements varies dependent on fluid salinity. Dfluid/melt of large-ion lithophile elements (LILE) and U increases with salinity, while that of rare earth elements (REE) and Th decreases with salinity.

Slab-derived fluids can be saline fluids based on experimental and natural observation (Keppler, 1996, Nature; Kawamoto et al., 2014, Earth Planet Space; Joachim-Mrosko et al., 2022 Elements). Such slab-derived supercritical liquids can evolve to become richer in LILE and U and poorer in HFSE and REE through separating melt components during their ascent. If this is the case, it explains LILE- and U-rich, HFSE- and REE-poor characteristics of arc basalts based on the present experimental results. It also explains higher LILE/HFSE and LILE/REE ratios of frontal-arc basalts, which can be generated by addition of aqueous fluids after separating melt components at shallower depths than back-arc basalts generated by addition of supercritical liquids at deeper.

1340

Reconstructing the temporal evolution of the large Plinian Y5 Phase of the Taupo 232 CE Eruption (New Zealand)

Ms Sarah Tapscott[1], Prof. Gert Lube[1], Prof. Colin Wilson[2], Dr. Anja Moebis[1], Mr James Ardo[1], Miss Hannah Walters[1]

[1]Massey University, Palmerston North, New Zealand, [2]Victoria University of Wellington, Wellington, New Zealand

Initial investigations into the Y5 phase of the Taupo 232 CE eruption (New Zealand) determined that the event occurred as a single “ultraplinian” pyroclastic fall phase. More recent studies, however, have established up to 26 stratigraphical subunits within this phase based predominantly on granulometric variations and wall-rock clast abundances. In this study, we first investigate the lateral correlatability of bedform characteristics within the vertical profile of the Y5 fall deposit, focusing on both transient and pronounced boundaries (i.e., weak, or strong variations in grain-size or lithic abundance). We found that even the most defined boundaries cannot be confidently correlated between outcrops from dozens of meters to a few kilometres distance. Therefore, it is likely that such stratigraphical features are a result of sedimentation and gravitational instabilities in the umbrella cloud. With this in mind, we looked further into the vertical variation in physical properties of the deposit at a selected locality. Through granulometry, componentry and textural investigation, we discovered strong, yet vertically continuous variations in the pyroclast properties. Based on our interpretation, the Y5 eruption is characterised by three main transient phases: 1) Following an initial ash rich bed of complex fall-flow material, there is a ~30cm thick zone of peak lithic and obsidian abundance, with higher pumice densities (634±9kg/m^3) and ash content; 2) ~60cm where pumice density suddenly decreases (568±12kg/m^3), total lithic proportions show a strong steady decrease, and median grain-size and total pumice abundance increase with height, while the occurrence of juvenile agglomerate pumices peak; 3) ~70cm where total lithics increase, while pumice abundance and median grain-size decrease with height. We show that quantitative assessments of deposit features from large Plinian eruptions have implications for the reconstruction of the spatiotemporal evolution of eruptive behaviour which may be used for hazard modelling and assessment at many volcanoes globally.

356

Increased complexity in volcanic architecture along waning hotspots

Mr Al-Tamini Tapu[1], Dr Teresa Ubide, Professor Paulo Vasconcelos
[1]*The University of Queensland, Brisbane, Australia*

Mantle plumes are key drivers of intraplate volcanism. Variations in heat flux and resulting magma flux are expected within a plume’s lifetime; however, their impact on magma plumbing architecture, eruption products, and eruptive styles remain poorly constrained. Here, we combine geochemistry and geochronology on Earth's longest continental hotspot chain to assess the effects of waning magma flux on pre-eruptive magma transport and storage. We focus on Cenozoic age-progressive volcanoes across eastern Australia, which we divide into two groups. Northern volcanoes are older and "long-lived" (3.5–7 Ma activity) and erupted high volumes (>800 km3) of magmas with bimodal compositions (basalts and rhyolites); the basalts are relatively homogeneous and aphyric (~3 vol% phenocrysts). In contrast, the southern volcanic chain splits into two parallel tracks, where volcanoes become "short-lived" (~1.5 Ma or less), erupting <300 km3 of more evolved magmas with greater textural complexity (~12 vol% phenocrysts, zoned). The inflection point coincides with a change in plate motion and speed and voluminous volcanism. Our results suggest waning plume flux leads to increasingly complex feeder systems and enhanced magma differentiation. Similar trends in hotspot tracks globally suggest that plume and magma fluxes play a crucial role in the evolution of intraplate volcanoes.

810

The elevated 2021-2022 eruptive manifestation on Yasur possibly caused by a relative change of the source composition

Mr Dan Tari[1], Mr Ricardo William[1], Ms Estonia Meltetake[1], Mr John Ruben[1], Mr John Junior Niroa[1], Dr Philipson Bani[2]

[1]Vanuatu Meteorolgy and Geohazards Department, Port Vila, Vanuatu, [2]LMV - Centre IRD de Nouméa, Nouméa, Nouvelle Calédonie

Yasur volcano located in the southern part of the Vanuatu arc, is known for its ongoing strombolian activity since the first description in 1774. During the course of its activity, episodes of stronger events have been reported, including the 1988 event that caused significant damage, as far as to residents' gardens and coffee plantations in the centre of the island. A new elevated episode of strong activity was witnessed between October 2021 and May 2022. Heavy ash deposits has caused significant damage on the crops and contaminated drinking water reservoirs around the volcanoes. Real-time images of Yasur volcano show thick plumes of ash rising hundreds of metres above the cone and volcanic bombs were seen rolling down the flanks. Post-analysis of the seismic data showed an increase in volcano-seismic events since September 2021, with a peak of 55 000 events recorded in February 2022. The number started to decrease in May 2022. Satellite sensors have recorded a relative increased of SO2 emission between September 2021 and March 2022. The highest monthly SO2 value was recorded in January 2022 and it corresponds to 32 kt. The radiative power displayed in the Mirova has curiously decreased during this period of high activity. Ash samples collected during this event indicate a trachyandesite composition, indicating a change from the usual basaltic trachyandesite obtained in past works. All these results reflect changes in the reservoir and/or conduit that are yet to be constrained. One alternative hypothesis would be an increase in viscosity in response to the change in the composition of the source, which then led to pressure build-up and stronger explosions.

944

Volcanic Activity along the Tofua Volcanic Arc: Looking or Being in the Right Place at the Right Time.

Mr Paul Taylor[1], Dr Murray Ford[2], Mr Taaniela Kula[3], Mr Rennie Vaiomounga[3]
[1]Australian Volcanological Investigations, East Maitland, Australia, [2]University of Auckland, Auckland, New Zealand, [3]Ministry of Lands and Natural Resources, Nuku'alofa, Kingdom of Tonga

Frequent volcanic eruptions occur along oceanic island arcs. Many of these eruptive periods due to the nature may be entirely submarine and not result in any surface expression of the activity. Furthermore, in some localities the known centres of activity maybe somewhat remote from the inhabited islands and be rarely visited. When periods of activity do occur due to their remoteness they may not be observed or even known that an eruption has occurred.

One such island arc in the SW Pacific is the Tofua Volcanic Arc (TVA) that forms part of the Kingdom of Tonga. The TVA is located to the west of the Tonga Trench, about 30-40 kms west of the three main islands groups of Tonga. The TVA comprises both subaerial and submarine centres with Hunga Tonga Hunga Ha'apai, Tofua, Kao, Late and Fonualei representing permanent subaerial volcanic islands. However, recent seafloor surveys have indicated that submarine centres predominate. Over the past several decades numerous periods of activity have occurred with many eruptions being observed by passing ships/boats or the eruption columns being observed from the inhabited Tongan islands.

This paper will look at several submarine and subaerial eruptions that have occurred along the TVA that have only been noted more through accident rather than good planning. Periods of activity of this nature pose some degree of risk to both surrounding islands and maritime traffic that may be transiting the area. The importance of appropriate volcano surveillance in the region will thus be highlighted.

668

MYana Explorer: An App-Based Guide into Mt. Yana, an Eroded Stratovolcano in the Southern Cascades

Dr Rachel Teasdale[1], Dr. Andrew Harp[1], Evan Davis[1], Quinn Little[1], Henry Marine[1], Heidi Reynaga[1], Amy Robson[1], Erica Thompson[1], Tim Wright[1]
[1]*California State University, Chico, Chico, United States*

Mt. Yana is an approximately 3 Ma stratovolcano of the ancestral Cascades (1), located 40 km south of the Lassen Volcanic Center and 65 km from Chico, California. Erosion of Mt. Yana has made it difficult to recognize as a volcanic edifice, but the degree of erosion provides easy access to the internal structures of the volcano's eroded core. There are few publicly accessible resources that offer opportunities to investigate the growth and erosion of volcano interiors, so we developed the freely available MYana Explorer app to guide users on a geologic tour to explore the interior of this ancient volcano. MYana Explorer includes a series of hikes, each with multiple stops that explore processes of volcano growth such as feeder dike emplacement, lava flows, columnar jointing, and hyaloclastite deposits from magma-ice interactions. Erosional features include proximal and distal breccias deposited by debris flows. Stops in the city of Chico guide users in observing volcaniclastic breccia outcrops of the Tuscan Formation, which are distal breccias and conglomerates emplaced by debris flows from Mt. Yana (1). At each stop, MYana Explorer features images with short, informative explanations that guide users in making observations and interpretations about the outcrops, and offers options to pursue further information. The MYana Explorer app provides an opportunity for non-geologists to learn about an ancient volcano and the methods volcanologists use to investigate volcanoes and reconstruct their growth and erosional phases through geologic time. In doing so, the app actively engages the public in a scientific experience to help communicate scientific processes, contributing to scientific literacy and introduces users to a previously poorly-known local volcano. Development of the MYana Explorer was a collaborative effort by numerous students in geology, computer animation, marketing and more, making it an excellent professional experience. (1) Clynne and Muffler, 2017

868

Mush compaction and melt extraction in a silicic magma body: Aztec Wash Pluton, NV, USA

Elizabeth Teeter[1], Guilherme Gualda[1], Calvin Miller[1]
[1]*Vanderbilt University, Nashville, United States*

Compaction and melt extraction are key processes in the generation of eruptible magma bodies. Analyzing magmatic fabrics in the Aztec Wash Pluton (15.7 Ma, NV, USA) illuminates magma dynamics during the emplacement of a big (2 m diameter) felsic enclave (BFE) in a silicic magma body. We infer that the BFE settled at the boundary between crystal-rich and crystal-poor zones of the magma body at the time of impingement. Textural and compositional analysis by Scanning Electron Microscope (SEM) allows visualization of deformation of crystal-rich magma mush. Four thin sections sampled from the granite surrounding the BFE (three 0.25-0.5 m underneath, one 2.5 m to the side (far field)) show a change in the strength of magmatic foliation (revealed primarily by alkali feldspar) around the enclave. Backscattered Electron (BSE) imaging, Energy Dispersive Spectrometry (EDS), and Electron Backscatter Diffraction (EBSD) techniques show the textural and compositional differences between the samples located underneath the BFE and the sample from the far field granite, specifically the deformation of grains beneath the enclave. BSE images show multiple instances of broken feldspar grains underneath the enclave. Alkali feldspar crystals beneath the enclave have well-defined euhedral rims, while alkali feldspar grains in the far field sample have irregular overgrowths. These textures suggest compaction and melt extraction beneath the enclave and melt retained in the far field. EBSD data reveal a foliation defined by alkali feldspar grains beneath the BFE, but absence of foliation in the far field sample. This evidence suggests that mush was deformed during the emplacement of the BFE, reorienting alkali feldspars. Impingement of the BFE led to melt extraction, which caused the differences in rim textures. Analysis of textural and compositional differences between the irregular rims and the euhedral rims to constrain melt extraction is ongoing.

450

Evolving magma source during East Gondwana rifting to breakup

Dr Maria Luisa (Marissa) Tejada[1], Dr Osamu Ishizuka[2], Dr Takashi Miyazaki[1], Dr Lloyd White[3], Dr Qing Chang[1], Dr. Bogdan Vaglarov[1], Dr Eun Young Lee[4], Dr Hans-Jurgens Brumsack[5], Dr Bernhard Schnetger[5]

[1]Japan Agency For Marine-Earth Science And Technology (JAMSTEC)), Yokosuka, Japan, [2]National Institute of Advanced Industrial Science and Technology, Geological Survey of Japan, Tsukuba, Japan, [3]GeoQuEST Research Centre, School of Earth, Atmospheric and LifeSciences, University of Wollongong, Wollongong , Australia, [4]Department of Geology, University of Vienna , Vienna, Austria, [5]Institute for Chemistry and Biology of the Marine Environment (ICBM) Microbiogeochemistry , Oldenburg , Germany

Late Jurassic through Early Cretaceous rifting between Australia-Antarctica and Greater-India culminated in the breakup of the supercontinent Gondwana and opening of the Indian Ocean. Seafloor spreading was established at 132-133 Ma on the Perth Abyssal Plain, adjacent to the central part of the southwestern Australian continental rifted margin, and at 126-124 Ma to the west of the Naturaliste Plateau, on the southwestern part of the margin. The crust in the Mentelle Basin continued to extend during the intervening period. The presence of the nearby Kerguelen mantle plume was suggested to affect both the magmatic behavior of the rift and its uplift and subsidence patterns. Drilling on the eastern flank of Naturaliste Plateau bordering the western Mentelle Basin during the IODP Expedition 369 recovered a volcanic sequence at Site U1513. Up until this drilling expedition, no direct stratigraphic evidence corroborates the extensive volcanism that accompanied rifting and final breakup of Eastern Gondwana, which was inferred only from seismic reflection and dredging data. The volcanic sequence consists of several lava flow packages separated by volcaniclastic beds and intruded by dolerite dikes. Existing paleomagnetic data obtained from the overlying sedimentary sequence indicate emplacement at 130.9 Ma. The best ages obtained from dolerite dikes are 134 and 123 Ma. Trace elements obtained from the freshest samples from each flow package vary from light rare earth element (LREE) enriched transitional basalt to LREE-depleted tholeiitic basalt compositions toward the top of the section. This is coupled with a change from isotopically more enriched to depleted compositions toward the upper flows, suggesting evolving magma source. These observations possibly indicate thinning lithosphere from rifting to breakup of East Gondwana and increasing input from asthenospheric mantle source. Isotope data, coupled with large degree melting and high mantle potential temperature, corroborate involvement of the Kerguelen plume mantle.

228

Automating tephra fallout building impact assessment using deep object detecting and UAV-acquired optical imagery

Miss Eleanor Tennant[1], Dr Susanna Jenkins[1], Dr Victoria Miller[2,3], Dr Bihan Wen[4], Dr Benoit Taisne[1], Professor Thomas Wilson[5]

[1]Earth Observatory of Singapore and Asian School of the Environment, Nanyang Technological University, , Singapore, [2]The University of the West Indies Seismic Research Centre, , Trinidad and Tobago, [3]Montserrat Volcano Observatory, , Montserrat, [4]School of Electrical and Electronic Engineering, Nanyang Technological University, , Singapore, [5]University of Canterbury, Christchurch, New Zealand

In the aftermath of an eruption, it is important that information about building damage is collected as quickly as possible. This is primarily to enable the prompt distribution of aid and rehabilitation support to those that need it, but it also allows for the collection of perishable impact data that could otherwise be lost through rains, subsequent impacts and/or human activity. The use of satellite imagery enables wider spatial coverage in a shorter time frame than is typically required for traditional ground-based surveys, however this is currently largely limited to manual inspection, and can also be complicated by cloud cover and satellite revisit periods. Unmanned aerial vehicle (UAV) acquired optical imagery is a tantalising alternative. UAVs are able to cover a wide area rapidly, with a higher level of detail than satellite imagery and an increased number of viewing angles that may be used to resolve lower levels of damage. Using the extensive building damage dataset collected by The University of the West Indies Seismic Research Centre after the eruption of La Soufrière St Vincent in 2021, we have annotated over six thousand image frames which were applied to train a task-specific Faster-RCNN model that can detect damaged buildings. The trained detector has an average precision of more than 65% on the independent, on-island validation set. This is the first time that UAV data have been automatically processed for the purpose of volcanic impact assessment and has the potential to become an essential tool for governments and emergency managers during future eruptive crises.

730

Syn-eruptive melt unmixing in submarine basanites: new insights for nanolite crystallization in magmas

Dr Simon Thivet[1], Luiz Pereira[1], Nicolas Menguy[2], Pascale Besson[3], David Troadec[4], Kai-Uwe Hess[1], Donald Dingwell[1]

[1]Department of Earth and Environmental Sciences, Ludwig-Maximilians-Universität (LMU), Munich, Germany, [2]Institut de Minéralogie, de Physique des Matériaux et de Cosmochimie (IMPMC), Sorbonne Université, Muséum National d'Histoire Naturelle, CNRS, Paris, France, [3]Institut de Physique du Globe de Paris (IPGP), Université Paris-Cité, CNRS, Paris, France, [4]Institut d'Electronique de Microélectronique et de Nanotechnologies, Université de Lille, Villeneuve d'Ascq, France

Nanolites in volcanic rocks were firstly described in the 90's, but they have been drawing a lot of attention only in the last few years. They are thought to play important roles on magma properties and eruptive dynamics. However, their formation mechanisms and roles within the magma structures are not fully described and understood. Preliminary observations made on submarine basanitic lavas from the 2018-2021 Fani Maore eruption (Mayotte Island, France) revealed striking nano-structures, which are investigated by high-resolution imaging associated with chemical analyses. Scanning Transmission Electron Microscopy (STEM) allows the identification of different sizes, shapes, and compositions of nanolites. Some of which are interpreted to be induced by nano-scale melt unmixing. More specifically, melt unmixing is preferentially observed near pre-existing dendritic microlites. This fast crystallization may create a chemically contrasted zone around the microlites, in which the initial basanitic melt is separated into two immiscible zones, forming both bimodal and spinodal nano-structures. This phase separation induces the formation of nanolites. This formation mechanism of nanolite highly contrasts with the classic cooling mechanism, which is also identified in the studied lava groundmasses, and could represent an under-estimated mechanism for the nanolite nucleation and growth patterns, potentially revealing impactful physical and chemical processes for magma behavior.

1288

20 years of ground deformation patterns along Koa'e fault zone on Kīlauea volcano

Mr Bruce Enki Oscar Thomas[1], Prof. Dr. James Foster[1]
[1]*Institute of Geodesy, University of Stuttgart, Germany, Stuttgart, Germany*

Extreme long-term extensions are experienced along the Koa'e fault zone on Kīlauea volcano. Both tectonic motions of the south flank of the volcano, as well as magma storage and transport at the summit and along the rift zones create stresses and ground motion patterns across this fault zone. To assess the role this structure in these processes, and its contribution to hazard potential, this study investigates 20 years of survey GNSS data along a benchmark line running through the Koa'e fault zone. First results of the deformation data capture trends of inflation/deflation from the summit magma chambers during eruptive events, as well as transient local signals from both tectonic and magmatic processes, highlighting the complexity of the volcanotectonic processes active in and around Koa'e. Mapping the cumulative displacement over the last 20 years captures the response to the constant southeast seaward slip of the south flank which results in earthquake swarms, open fractures, intrusion of magma through shallow paths and the possible risk of eruptive fissures. Augmented by continuous GNSS data, InSAR images, earthquake activity and fault maps, this large dataset is being used to guide numerical models of the kinematic deformation of this area. We focus on the impact of the major events since 2003: the inflations in 2006 and 2009, the earthquake sequence in 2012, the dramatic 2018 summit collapse and lastly, the renewed eruption of Kīlauea in 2021. Final results highlight that brittle failure is clearly responsible for a significant portion of the ground deformation observed at the surface, rather than the continuous elastic strain that is assumed by standard analytical models of deformation. The discussion will thus examine the ratios of, and relationships between elastic and inelastic deformation and their significance for the evolution of Kīlauea and assessments of its seismic and volcanic hazard potential.

615

Assembling a Māori-centred Framework for Volcanic Impact Foresight in Taranaki, Aotearoa

Ms Kristie-Lee Thomas[1], Prof Tom Wilson[1], Dr Sarah Beaven[1], Prof Christine Kenney[2], Dr Acushla Sciascia[2]
[1]Te Whare Wānanga o Waitaha University of Canterbury, Christchurch , Aotearoa, [2]Te Kunenga ki Pūrehuroa Massey University, , Aotearoa

Indigenous Peoples have lived with active volcanoes and observed their processes over centuries (Gabrielsen et al., 2017; Niroa & Nakamura, 2022; Pardo et al., 2015). This knowledge has been acknowledged in international literature and by global strategies since the 1990s (Lambert & Scott, 2019; UNISDR, 2015; UNDRR 2022). However, a global challenge, and critical opportunity is how different domains and types of knowledge can borrow from one another in ways that respect indigenous sovereignty (Awatere et al., 2021; Kalland, 2000; Latulippe & Klenk, 2020). Recent attempts to bring together Mātauranga Māori and disaster risk science in Aotearoa have identified tensions in perception, language and process limiting deeper forms of analysis required to inform rangatiratanga over Māori well-being (Awatere et al., 2021; Harmsworth & Raynor, 2005). A Māori-centred impact assessment framework is required to foresee challenges and opportunities during future eruptions and to identify priorities for enhancing resilience (Awatere et al., 2021; King et al., 2013).

Taranaki Mounga has a 33-42% chance of eruption within the next 50 years (Cronin et al., 2021) and the potential impacts for Taranaki Māori are unknown. This doctoral project, led and guided by descendants of Taranaki Mounga proposes to use Kaupapa Māori and Taranakitanga Methodologies to:

- Produce an exploratory overview of international and Aotearoa-centric literature concerned with Indigenous and/or Mātauranga Māori and disaster risk assessment.
- Co-design a Māori-centred methodological framework founded from Mātauranga-a-Taranaki that incorporates elements of risk science to evaluate potential volcanic impacts.
- With tangata whenua approval, undertake a test-case study of value to Taranaki Māori.
- Produce recommendations regarding the adaptation of the framework for wider application.

This presentation will share dynamic learnings of a doctoral journey navigating the nexus between different knowledge systems seeking to understand the potential impacts of a Taranaki Mounga eruption.

991

Diverse mantle components with invariant oxygen isotopes; the 2021 and 2022 Fagradalsfjall eruptions, Iceland

Professor Thorvaldur Thordarson[1], Prof. Ilya Bindeman[2], Dr. Frances M. Deegan[3], Professor Valentin Troll[3], Prof. Ármann Ármann Höskuldsson[1], Dr. William Moreland[1], Dr. Edgar Zorn[4], Dr. Alina Shevchenko[4], Prof. Thomas Walter[4], Dr. Catherine R. Gallagher[1], Dr. Robert A. Askew[5], Ms Helga K. Torfadóttir[1], Ms Jacqueline Grech Licari[1], Ms Iðunn K. Valdimarsdóttir[1], Ms Lilja B. Pétursdóttir[1], Ms Jóna Sigurlína Pálmadóttir[1], Ms Diana B. D. S. G. Alvarez[1], Ms Méline Payet Clerc[6], Ms Lidia Stroganova[7]

[1]Faculty of Earth Sciences, University of Iceland, Reykjavík, Iceland, [2]University of Oregon, Eugene, USA, [3] Uppsala University, Uppsala, Sweden, [4]GFZ Potsdam, Potsdam, Germany, [5]Iceland Institute of Natural History, Reykjavik, Iceland, [6]University of Paris, Paris, France, [7]University College London, London, United Kingdom

Continuous high-resolution sampling of ongoing eruptions provides unprecedented insight into volcanic activity, magmatic evolution, and mantle processes that are extremely difficult to unravel when studying ancient deposits or pre-historic eruptions where younger and more voluminous products cover first erupted deposits. The Reykjanes Peninsula in Western Iceland is not only a volcanically active subaerial plate boundary functioning as the onshore extension of the Reykjanes Ridge, but also hosts about 70% of Iceland's population, including the Greater Reykjavík area, the Reykjanes geothermal power plant, and Keflavík international airport. The basalts of the 2021 Fagradalsfjall eruption were the first to be erupted on the Reykjanes Peninsula in 781 years and offer unique insights into the composition of the mantle underlying Iceland, in particular its oxygen isotope composition (δ18O values) and trace elemental ratios. The 2021 basalts show compositional variations in Zr/Y, Nb/Zr and Nb/Y values that span almost half of the previously described range for Icelandic basalt magmas and thus signal involvement of Icelandic plume (OIB) and Enriched Mid-Ocean Ridge Basalt (EMORB) in magma genesis. Remarkably, the 2021 Fagradalsfjall samples have invariable δ18O values (mean δ18O =5.4 ±0.3‰ 2SD, N=42) that are indistinguishable from "normal" MORB-type upper mantle, in contrast to significantly lower δ18O values reported for erupted materials from parts of Central Iceland for example. Therefore, despite differing trace element characteristics, the melts that supplied the 2021 Fagradalsfjall eruption show no evidence for 18O-depleted mantle or interaction with low-δ18O crust, and may thus represent a useful mantle reference value in this part of the Iceland plume system. At time of writing, a suite of samples from the nearby 2022 Meradalir eruption are being analysed, which will allow us to test for changes in the magma system over time.
Reference: https://www.nature.com/articles/s41467-022-31348-7

1442

Quartz-hosted Melt Inclusions as Windows Into Magmatic Assembly and Storage Processes in the Youngest Toba Tuff

Dr Casey Tierney[1], Dr Mary Reid[1]
[1]Northern Arizona University, Flagstaff, United States

Mineral phases can track the near-eruption assembly, storage conditions, and persistence of zoning within the magma reservoir(s) responsible for the enormous (>2800 km3) and compositionally zoned (68-77 wt. % SiO2) 74 ka Youngest Toba Tuff (YTT). Quartz serves as an effective monitor of melt domain processes due to ubiquity in YTT pumices and its ability to provide insights into melt temperature, storage pressure, and composition, however its use is limited by uncertainty over the affinity between crystals, host pumices, and matrix glasses.

Here we couple major and trace element compositions of quartz-hosted melt inclusions (n=107) with Ti-calibrated cathodoluminescence maps in crystals from five diverse YTT pumices to unravel mineral-scale complexities and assess YTT melt evolution in tandem with quartz crystallization. Based on feldspar-sensitive element concentrations and interelement ratios, we find melt inclusions define three distinct melt inclusion populations that each span a small fraction of the overall YTT compositional range. Modeling reveals 12-21% fractional crystallization. Eutectoid co-crystallization of quartz with sanidine and plagioclase can account for variations in more evolved low- and med-Ba populations whereas less evolved, high-Ba, populations crystallized under non-eutectic conditions.

Affinity between melt inclusion populations, host pumice and matrix glass compositions, and co-hosted phases indicate coexistence of spatially discrete parcels of magma within a more broadly zoned magma system. Evidence for growth timescales of 10s-1000s of years prior to eruption and a strong kinship between melt inclusion populations and host glasses indicate that quartz in the dominant portion of the magma system likely grew after extraction of their host melts from a mush. However, a small subset of chemically distinct crystal cores in the more crystal-rich, low-silica magmas may have been mush-derived. Collectively, the chemical zoning of the YTT appears to have developed prior to most quartz growth, likely “bottom-up” due to mush derived heterogeneity.

724

Searching for analogue volcanoes on global databases: the VOLCANS-PyVOLCANS suite

Dr Pablo Tierz[1], Vyron Christodoulou[1,2], John Stevenson[1], Eliza Calder[3], Susan Loughlin[1]
[1]British Geological Survey, The Lyell Centre, Edinburgh, UK, [2]The Data Lab, The Bayes Centre, Edinburgh, UK, [3]School of Geosciences, University of Edinburgh, Edinburgh, UK

Analogue volcanoes, or volcanoes that are considered similar enough as for data to be considered (partially) exchangeable amongst them, are increasingly being sought by volcanologists, especially in the context of volcanic hazard assessments. Data are scarce for many volcanoes worldwide, which significantly complicates the quantification of volcanic hazard, from eruption forecasting and frequency-magnitude relationships, to the spatiotemporal occurrence and intensity of hazardous phenomena (e.g. PDCs). One common practice when looking for analogue volcanoes has been to use expert knowledge, sometimes combined with ad-hoc searches in global databases, to identify small sets of best analogue volcanoes for a given volcanic system of interest.

We present an objective (data-driven), structured and reproducible strategy to derive customary sets of analogue volcanoes using global databases. VOLCano ANalogues Search (VOLCANS) is a groundbreaking approach to calculate a measure of total analogy (similarity) between any two volcanoes in the Volcanoes Of The World database (VOTW), based on a weighted-average combination of five volcanological criteria: tectonic setting, rock geochemistry, volcano morphology, eruption size and eruption style. PyVOLCANS represents the initial implementation of VOLCANS as an open-source, open-access Python package. Users are given full flexibility to derive their own sets of analogue volcanoes that fit their specific needs. Moreover, users can check the proportion of volcanoes in VOTW classified as better analogues (i.e. higher analogy) compared to their 'a priori analogues' (volcanoes considered good analogues by other means, e.g. expert knowledge). This makes PyVOLCANS strongly compatible and complementary with other methods and practices to derive analogue volcanoes, and will help enrich conversations around the 'why' and 'how much' behind analogues selection.

We hope that the VOLCANS-PyVOLCANS suite will facilitate the investigation of similarities and differences between volcanic systems worldwide, ultimately supporting activities ranging from fundamental research in volcanology, quantitative volcanic hazard assessment and even teaching and scientific outreach.

723

Coupling TITAN2D with a zero-censored emulator to explore the role of topography on pyroclastic density current hazard: Aluto volcano (Ethiopia)

Dr Pablo Tierz[1,2], Elaine Spiller[3], Ben Clarke[2,4], Firawalin Dessalegn[5], Yewubinesh Bekele[6], Elias Lewi[7], Gezahegn Yirgu[8], Robert Wolpert[9], Susan Loughlin[1], Eliza Calder[2]
[1]British Geological Survey, The Lyell Centre, Edinburgh, UK, [2]School of Geosciences, University of Edinburgh, Edinburgh, UK, [3]Department of Mathematical and Statistical Sciences, Marquette University, Milwaukee, WI, USA, [4]School of Geography, Geology and the Environment, University of Leicester, Leicester, UK, [5]CNCS, Wollega University, Nekemte, Ethiopia, [6]Geo-hazard Investigation Directorate, Geological Survey of Ethiopia, Addis Ababa, Ethiopia, [7]Institute of Geophysics, Space Science and Astronomy, Addis Ababa University, Addis Ababa, Ethiopia, [8]School of Earth Sciences, Addis Ababa University, Addis Ababa, Ethiopia, [9]Department of Statistical Science, Duke University, Durham, NC, USA

Aluto volcano is a peralkaline caldera located in Central Ethiopia, 180 km (137 km air distance) south of Addis Ababa, in an area where sparse settlements, densely-populated villages and critical infrastructure (e.g. flower industry and a geothermal power plant) are exposed to volcanic hazard. The most-recent, post-caldera volcanism at Aluto has been characterised by monogenetic-like, moderately-explosive eruptions that, among other volcanic products, commonly produced column-collapse pyroclastic density currents (PDCs). Through many tens of such eruptions, a complex volcanic edifice has been built, whose morphology possessess characteristics of both a caldera system and a stratovolcano. For instance, Aluto's present-day edifice has slopes (some steeper than 15°) dipping both outwards and inwards towards a central collapse-caldera floor.

Here, we present a modelling strategy, informed by background volcanological knowledge at Aluto, to explore, probabilistically, how the particular topography of Aluto influences PDC hazard. This strategy couples a widely-used physical model for PDCs (TITAN2D) with a novel statistical model to quantify uncertainty (a zero-censored Gaussian Process emulator). By interrogating the spatial location of eruptive vents as well as some general characteristics of the PDCs (e.g. size and mobility), we analyse how the probabilities of PDC inundation vary accordingly across the edifice. In particular, we focus on three spatial scales, depending on the distance between the eruptive vents and points along roads that traverse Aluto's edifice: proximal (0-3 km), medial (~2-5 km) and distal (considering vents within a ~20x20 km vent-opening domain). Our calculations indicate a complex interplay between the spatial and PDC (size-mobility) scales, with processes such as PDC channelisation having a more marked impact beyond the proximal scale.

The presented strategy can become very valuable for probabilistic hazard assessments as it optimises uncertainty quantification for complex physical models; addresses the zero-problem; and can readily be adapted to other volcanic systems and/or physical models.

452

If I Could Turn Back Time: A New Method to Map the Evolutionary Pathways of Igneous Rocks

Dr Christy Till[1]
[1]*Arizona State University, Tempe, United States*

How similar or different are the life stories of two igneous rocks? Each person reading this abstract would likely answer this question differently. From the questions we ask, to the data we collect, and the parts of the system we study, our expanding wealth of approaches have facilitated incredible insights into igneous processes and volcanic hazards. Nevertheless, we lack a shared, systematic method to map the sequence of igneous processes that form a particular igneous rock, or its 'evolutionary pathway', as well as examine changes in the pathway over time within a given trans-crustal magmatic system or compare it to common pathways in a particular tectonic setting. In this presentation, I will introduce a new method to map evolutionary pathways, from source to cooling, for igneous rocks. It maps magma evolution as a series of branching possibilities of igneous processes, beginning with the melting mechanism that formed the primary magma, through the processes that evolve the magma in the crust, and ending with the processes that cause final ascent and cooling. The method is built on the premise that the probability of a given process depends on the magma's characteristics, its prior history, and the state of the crust or lithosphere around it. This approach has similarities to the event trees and Bayesian networks used for hazard assessment, as well as the clades and phylogenetic trees used in biology and paleontology, but can be used without prior knowledge of probabilities. This method also necessitates utilizing multiple data types (e.g., major & trace element, isotopic, volatile & petrographic ± earthquake & remote sensing data) sensitive to different processes and intensive variables. Application of this method highlights anew the volumetric and energetic implications of different magma evolutionary pathways and is an excellent way to highlight key differences between interpretations or systems.

907

Complex Styles of Basaltic Explosive Volcanism from Fissure 17 of the 2018 Lower East Rift Zone of Kilauea

Caroline Tisdale[1], Bruce Houghton[1], Arianna Soldati[2]
[1]University Of Hawaii At Manoa, Honolulu, United States, [2]North Carolina State University, Raleigh, United States

Fissure 17 (F17), the longest fissure (470 meters) of the 2018 LERZ eruption of Kilauea, was the only fissure to have significant ranges in composition, a wider range than all the other 23 fissures combined. A combination of new and stored magma produced exceptional diversity of weak explosive activity occurring systematically and simultaneously along the fissure. At the eastern end (F17E), a lava fountaining vent built a c. 30 meter high cone and distal pumice blanket and fed fluid lava. A series of vents on the western side (F17W) erupted concurrently with F17E, displaying rapid and normal Strombolian behavior, ejecting meter-sized bombs that damaged two neighboring houses. The nature of the eruption, its weak intensity, and easy road access allowed for a wealth of data to be gathered. Samples of pyroclasts were collected and videography was captured on 14 May, one day after F17 began erupting. From the latter, through video and image analysis, we were able to quantify in-flight eruption parameters: fountain and jet heights, pyroclast exit velocities, in-flight grain size, and duration and frequency of pulses. Textural and geochemical analysis of the pyroclasts revealed that viscosity was systematically higher for F17W and the samples were andesite. Magmatic enclaves found in the F17W products closely resemble the magma erupted during of the 1955 LERZ eruption, from fissures adjacent to F17. F17E had no magmatic enclaves and erupted basalt to basaltic andesite. Here we will link in-flight eruptive parameters and magma composition to show how patterns of outgassing directly determined the eruptive style, but ultimately that the role of magma viscosity is the biggest control because it determined the form of outgassing and degassing.

573

Water driven eruptions: phreatic events from the fluid perspective

Dr Santina Chiara Stissi[2], Dr GIlda Currenti[2], Dr Dmitri Rouwet[1], Dr Micol Todesco[1]
[1]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Bologna, Bologna, Italy, [2]Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo, Catania, Italy

Phreatic events are sudden, magma-free explosions related to gas expansion that is fast enough to trigger rock fragmentation and the violent ejection of fragments. Triggering of such events is usually associated with the perturbation of shallow aqueous fluids, typically due to the ascent of magmatic volatiles and often involving water flashing into steam. However, not always sudden changes in pressure, temperature or gas composition are capable of an explosive outcome: depending on rock properties and system conditions, phase changes may occur gradually and expanding gases may discharge at the surface.

We focus on the hydrothermal system to explore which conditions may favor phase transition, increasing the generated overpressure and the speed at which it develops.

We considered two different volcanic systems: Poás (Costa Rica) and Vulcano (Italy). The first one is characterized by the presence of a crater lake and frequent events (hundreds in the last ten years), while the second features only a few phreatic events in the last centuries and hosts a widespread hydrothermal system that has been responsible for an unrest phase, ongoing since September 2021.

Data collection and numerical simulations were used to constrain pre-eruptive conditions. In particular, for the case of Vulcano we performed a parametric study simulating the injection of hot fluids in a shallow, warm aquifer. Results suggest that faster phase transition leading system pressurization require high injection temperature and flow rate and low permeability. The presence of non a non-condensable component, such as CO2 promotes phase transition and leads to higher pressures and temperatures, which are favorable conditions for triggering phreatic eruptions.

323

Analogous planetary environments for the development of inflated lava tubes: the La Corona system in Lanzarote (Canary Islands, Spain)

Dr Ilaria Tomasi[1], Prof Matteo Massironi[1], Dr Christine Marie Meyzen[1], Dr Francesco Sauro[2], Dr Riccardo Pozzobon[1,3], Tommaso Santagata[4], Prof Jesùs Martìnez-Frìas[5], Dr Elena Mateo Mederos[6]

[1]Department of Geosciences, University of Padova, Padova, Italy, [2]Department of BiGeA, University of Bologna, Bologna, Italy, [3]INAF-Astronomical Observatory of Padova, Padova, Italy, [4]Virtual Geographic Agency (VIGEA), Reggio Emilia, Italy, [5]Instituto de Geociencias, IGEO (CSIC-UCM), Madrid, Spain, [6]Geopark of Lanzarote, Cabildo Insular de Lanzarote, , Spain

Multidisciplinary efforts are currently boosted by an urgent need to better understand terrestrial and extra-terrestrial lava systems. Lava tubes are a peculiar variety of lava-driven caves. These roofed conducts are particularly effective thermal structures that allow channelised lava to be transported over great distances. The longest lava tubes are found on volcanic plateaus characterised by a gentle slope (<2°) or on volcanic islands (e.g. Hawai'i, Canaries, etc.). Skylights and roof collapses enable the identification of the tube path from the surface. Analogous configurations of aligned collapses have been seen on the surfaces of Mars and the Moon [1]. Given the similarities between basaltic volcanism on rocky bodies in the Solar System, lava tubes may have similar origins and morphologies to those on Earth.

Growing curiosity has resulted from this discovery since lava tubes could be suitable sites for future exploration or permanent human settlements.

Located in the northern region of Lanzarote (Canary Islands), the La Corona lava tube system, with 9.7km of cave development and a 20m avg. diameter, is one of the largest volcanic cave systems on Earth. The Canaries arose on a slow tectonic plate (<2cm/yr, during the last 30Ma [2]), characterise by long-term and spatially focussed volcanic activity. Accordingly to this environment the Canaries are considered as the best analogues of the Martian one-shell plate volcanism on Earth [3].

This inflated lava tube is made even more fascinating by the unique presence of a pyroclastic layer interspersed within the lava flows that the tube crosses. According to our assumption, the weak layer may have been crucial to the beginning of the inflation process [5]. The mechanisms found at La Corona may be extremely important for the formation of planetary lava tube systems because weak layers like regolith are a typical element of extra-terrestrial lava flows.

809

Geochemical and rheological characterization of the 1823 CE Keaīwa lava flow erupted from the Great Crack at Kīlauea Volcano

Miss Andrea Tonato[1], Mr Drew Downs[1], Dr. Thomas Shea[1]
[1]*University of Hawai'i at Mānoa, Honolulu, United States*

The Keaīwa or 1823 lava flow is located in the Southwest Rift Zone (SWRZ) of Kīlauea Volcano. The lava flow is the product of the first eruption recorded by an expedition of non-Hawaiian visitors through eyewitness accounts from local inhabitants. The uniqueness of the Keaīwa lava flow lies in its morphology and vent characteristics, although it has compositional similarities to other lava flows erupted from the SWRZ in the decades prior. The lava flow issued from a ~10 km-long open fissure known as the "Great Crack", and has a thin sheet-like morphology with a flow margin thickness between ~10 65 cm in proximal, and even distal areas.

Based on field relationships (e.g. drained back features), we propose that the Great Crack formed or at least significantly widened syn-eruptively during the eruption in 1823 CE. The fissure completely lacks in pyroclastic buildup, indicating that the eruption consisted of a sudden outpouring of relatively degassed lava as the structure unzipped. Moreover, there are ramp-up structures that climb ~3 m and higher over pre-existing tumuli and on the flanks of several cones ("Lava Plastered Cones"), which, together with the thinness of the flow indicate high effusion rates with low viscosity and unusual high flow velocities. Additionally, glass and bulk rock analyses showed homogeneous compositions (6.4±0.1 wt.% MgO) across most of the fissure, yielding eruption temperatures of 1152±15°C, and dismissing the possibility of unusual magmatic conditions for such rheological behavior. Ongoing petrological and rheological work will allow us to (1) understand processes underpinning this uncommon eruption style, and (2) better constrain petrogenetic linkages between the Keaīwa lava flow and other summit and rift zone eruptions from the same period. Equally, rheological models will help to develop velocity estimates from ramp up topography, thereby enriching our understanding of basaltic lava flows in the Hawaiian Islands.

390

Automatic generation and support vector classification of a large, labeled collection of explosion infrasound waveforms at Yasur Volcano, Vanuatu

Liam Toney[1], David Fee[1], Alex Witsil[2], Robin Matoza[3]
[1]Alaska Volcano Observatory and Wilson Alaska Technical Center, Geophysical Institute, University of Alaska Fairbanks, Fairbanks, United States, [2]Wilson Alaska Technical Center, Geophysical Institute, University of Alaska Fairbanks, Fairbanks, United States, [3]Department of Earth Science and Earth Research Institute, University of California, Santa Barbara, Santa Barbara, United States

Volcano infrasound data contain a wealth of information about eruptive patterns, for which machine learning is an emerging analysis tool. Although global catalogs of labeled infrasound events exist, the application of supervised machine learning techniques to local (<15 km) volcano infrasound signals has been limited by a lack of robust labeled datasets. Here, we automatically generate a labeled dataset of >7,500 explosions recorded by a five-station infrasound network at the highly active Yasur Volcano, Vanuatu (Toney et al., 2022). Explosions are located via backprojection and associated with one of Yasur's two summit subcraters. The labeled catalog exhibits trends in the relative contribution of south and north subcrater events that correlate with waveform characteristics, such as peak explosion signal amplitude. We subsequently apply a supervised machine learning approach (support vector machines) to classify the subcrater of origin using features extracted from the labeled waveforms. When trained and tested on waveforms from the same station, our chosen algorithm is >95% accurate; when training and testing on different stations, accuracy drops to about 75%. The choice of waveform features provided to the algorithm strongly influences classification performance. To maximize the potential for similar algorithms to generalize to new network configurations, future applications should train and test on multiple stations, and employ feature selection techniques to determine which waveform features are optimal.

Toney, L., Fee, D., Witsil, A., & Matoza, R. S. (2022). Waveform features strongly control subcrater classification performance for a large, labeled volcano infrasound dataset. The Seismic Record, 2(3), 167–175. https://doi.org/10.1785/0320220019

803

Multiscale spatio-temporal analysis of the value of "b" in the Sabancaya volcano (period 2013-2020), southern Peru

Ms José Luis Torres Aguilar[1], Dr. Rubén García-Hernández[2], Dr Luca D'Auria[2], Dr Marco Rivera[1]
[1]Instituto Geofísico del Perú, Arequipa, Peru, [2]Instituto Volcanológico de Canarias (INVOLCAN), San Cristóbal de La Laguna, España

We used a new algorithm called MUST-B (MUltiscale Spatial and Temporal estimation of the B-value) for a consistent calculation of the “b” value from seismic activity registered in the recent eruptive activity of the Sabancaya volcano. For this purpose, we recuperated 23,160 earthquakes signs detected by the IGP during the period from 2013 to 2020. The results allowed to evidence five zones of high "b" value during the pre-eruptive stage (2013-2016) and eruptive stage (2016-2020) on Sabancaya. In the pre-eruptive stage, three important anomalous zones are highlighted: A (“b” = 1.5 to 1.8), E (“b” = 1.0 - 1.5) and C (“b” = 1 - 2), located 15 km to the NW, E and N of the Sabancaya volcano. According to the temporal and spatial analysis of the “b” value, anomalies A and E would have been generated between March and July 2013, and anomaly C between June and August 2015, this period belongs when Sabancaya volcano were in unrest. We attribute this to the first intrusions of magma and/or circulation of magmatic fluids (less than 12 km deep), which would have caused a disturbance of the hydrothermal system, and the generation of confined phreatic explosions in August 2015. Regarding the eruptive stage, four anomalies of high “b” values are highlighted: C, B, A and D (“b” = 1.5 - 1.8), located between ~10 and 20 km W, NW and NE of the Sabancaya, which would have observed between January 2019 to June 2020. The presence of these anomalies is interpreted as a zone of accumulation of deep magma (less than ~12 km deep), where intense seismic activity would have been recorded, associated with two episodes of lava dome growth (visible on the surface of the crater), which would have been located between October to November 2019 and November 2020.

808

Preliminary data constraints on how moisture content in sediment influences physical and thermal responses during magma/sediment interaction

Miss Ivana Torres Ewert[1], Dr Alison H Graettinger[1], Dr Susan Sakimoto[2,3], Dr Ingo Sonder[2], Tabitha Tyler[1], Ramiro Flores[1]
[1]University Of Missouri-Kansas City, Kansas City, USA, [2]University at Buffalo, Department of Geology, Buffalo, USA, [3]Space Science Institute, Boulder, USA

Magma sediment interaction is strongly dependent on moisture content, grain size, and the composition of sediment in contact with the melt. These control the heat transfer, phase transitions, and resulting contact zone features.

To understand the influence of these three variables, four experiments using ~ 30 liters of remelted basalt were conducted at the University at Buffalo Geohazards Center. Basaltic melt at ~1300 °C was poured into a depression made in the top of a constructed sediment cone. We constructed cones of four different materials: dry well-sorted medium sand, dry poorly-sorted pebble gravel, dry lapilli scoria and wet poorly-sorted pebble gravel. From the base of the cone (0 cm) to the contact between the molten rock and the sediment (18 cm), five thermocouples were distributed vertically at 0 cm, 5 cm, 10 cm, 12 cm, 14 cm, 16 cm, and 18 cm. Three moisture sensors (two capacitive and one Time Domain Reflectometry “TDR”) were disposed at 5 cm (TDR) and two capacitive at 11 and 13 cm. Two experiments were disrupted with a metal rod to encourage melt to travel through the sediment pile, producing an intrusion and lava flow, four thermocouples were placed along the path of intrusions/lava flow.

Preliminary results indicated that higher sediment moisture content (14 - 19%) in contact with molten rock, form disperse “glued” grains at the contact, 1 cm of coherent "baked” layer bellow the contact with the molten rock, followed by 9 cm of dry sediment. On the other hand, under “dry” context (0 - 6%), more grains were glued to the pond/intrusion and lava flow, with some incorporating and partially absorbed. Observation of recent flows, like 2022 Fagradalsfjall eruption and experimental results, suggest that baked sediment in the rock records might indicate the presence of water during the emplacement of lava flow.

712

Health hazard generation via comminution and resuspension of tephra by vehicular activity in urban areas (Etna volcano, Italy)

Dr Ines Tomašek[1,2,3,4], Dr Pierre-Yves Tournigand[2], Dr Daniele Andronico[5], Dr Julia Eychenne[3,4], Prof Claire J. Horwell[6], Dr Ulrich Kueppers[7], Dr Jacopo Taddeucci[8], Prof Matthieu Kervyn[2]

[1]Analytical, Environmental and Geochemistry group (AMGC), Department of Chemistry, Vrije Universiteit Brussel, Brussels, Belgium, [2]Physical Geography group (FARD), Department of Geography, Vrije Universiteit Brussel, Brussels, Belgium, [3]Laboratoire Magmas et Volcans (LMV), CNRS, IRD, OPGC, Université Clermont Auvergne, , France, [4]Institute of Genetic Reproduction and Development (iGReD), Translational Approach to Epithelial Injury and Repair Team, CNRS UMR, INSERM, Université Clermont Auvergne, , France, [5]Istituto Nazionale di Geofisica e Vulcanologia (INGV), Osservatorio Etneo, Catania, Italy, [6]Institute of Hazard, Risk and Resilience (IHRR), Department of Earth Sciences, Durham University, , United Kingdom, [7]Department for Earth and Environmental Sciences, Ludwig-Maximilians-Universität (LMU) , Munich, Germany, [8]Istituto Nazionale di Geofisica e Vulcanologia (INGV), Sezione de Roma, Rome, Italy

Exposure to fine-grained particulate matter (sub-10 µm, i.e., PM10) is associated with adverse health effects. Compared to explosive eruptions, limited studies have been conducted on the products of low explosivity events (e.g., lava fountains, strombolian eruptions) as they generally generate rather coarse-grained deposits. Yet, reworking of tephra deposits by wind, traffic or other human activities can potentially alter the initial grain size distribution of a deposit, producing finer material. Remobilisation of such reworked deposits may affect ambient PM10 levels, generating increased exposure hazard.

We conducted in situ experiments on the slopes of Etna volcano, Italy, which frequently covers neighbouring urban areas with basaltic tephra. With a small SUV-type car, we drove over an area of a road that we covered with tephra and investigated the resulting grain size distribution by laser diffraction and concentration of PM10 in the air (by TSI DustTrak) as a function of 1) the number of car passages (between 10 and 70), 2) starting thickness of the tephra deposit (between 2 and 10 mm) and 3) vehicle speed (between 20 and 50 km/h). The results show that the grain size of the original tephra deposit decreases with the number of car passages, most notably with increasing vehicle velocity and deposit thickness. Similarly, airborne PM10 increased with increased numbers of car passages, increased tephra thickness and increased vehicle speed. We have shown that vehicles will change the grain size distribution of basaltic ash by comminution so local communities can expect that, after an eruption, concentrations of PM10 may increase with time and affect exposures close to roads.

711

Interdependence of source morphology and eruptive style at Stromboli volcano, Italy

Dr Pierre-Yves Tournigand[1], Dr Benoît Smets[1,2], Dr Tullio Ricci[3], Dr Riccardo Civico[3], Dr Ulrich Kueppers[4], Prof Matthieu Kervyn[1]

[1]Department of Geography, Vrije Universiteit Brussel, Brussels, Belgium, [2]Natural Hazards Service, Royal Museum for Central Africa, Tervuren, Belgium, [3]Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy, [4]Department of Earth and Environmental Sciences, Ludwig-Maximilians-Universität , Munich, Germany

Volcanoes with frequent explosive eruptions are highly dynamic geological features, displaying morphological variations on a broad range of timescales (from hours to years). Morphological changes at the vent can significantly influence the resulting volcanic activity's properties, such as eruption type and magnitude. Documenting the morphological evolution of crater area at active volcanoes over time is thus a crucial information to better understand the existing link between crater morphology and eruptive style. Considering that active volcanic craters are hazardous due to their instability, the possibility of eruptions and rapid evolution, unoccupied aircraft systems (UAS) represent an increasingly readily available technology allowing repetitive imaging and DEM reconstruction at centimeter-scale resolution from remote locations in between explosive eruptions.

In this study, we combined synchronized data sets from UAS (DJI Phantom 4 Pro) and ground-based cameras (GoPro) to characterize the evolution of the volcanic activity and crater morphology at Stromboli volcano, Italy, at high temporal resolution. To this end, detailed UAS imaging has been performed before and after individual eruptive events during two field missions over several days. The 4 months gap between the missions enabled us to quantify short- (few hours) and long-term (few months) morphological and eruptive evolutions. High-resolution DEMs (centimeter-scale) are produced using Structure from Motion Multi-View Stereo (SfM-MVS) photogrammetry and co-registered on a reference dataset, using a multi-epoch co-alignment method. Preliminary results highlight the capability of the approach to document Stromboli's vent area with high spatial accuracy in the short timing between two explosions and to document local morphological variations. Comparison with characteristics of the explosive events offers the potential to better decipher interactions between vent morphology and eruptive dynamics. Also, these high-frequency time series highlight the level of sensitivity reachable with SfM-MVS photogrammetry to measure morphological changes at active volcanic vents.

516

Timescales of Dike Growth and Chamber Deflation Constrain Magma Storage and Transport Pathways During Kīlauea's Lower East Rift Zone Intrusion

Meredith Townsend[1], Mong-Han Huang[2]
[1]*Department of Earth Sciences, University of Oregon, Eugene, United States,* [2]*Department of Geology, University of Maryland, College Park, United States*

The intrusion of magma into Kīlauea's lower East Rift Zone in May 2018 led to the largest eruption along this segment of the volcano in over 200 years. As magma drained from the rift zone, leading to the collapse of Puʻu ʻŌʻō, pressure at the summit initially remained elevated and dropped at a slower rate compared to historical intrusion events. The anomalously long timescale of summit deflation suggests that the dike was fed from multiple sources. Here we show that dikes can serve as "dipsticks" of magma reservoirs and that the co-evolution of dike growth and reservoir deflation constrains key magma transport parameters. Using coupled dike-chamber models constrained by ground deformation and seismicity, we test four configurations of magma plumbing in order to illuminate which reservoirs and transport pathways were activated during the intrusion phase (30 April to 3 May) of the 2018 event. Slow summit deflation relative to the rate of dike propagation is best explained by a model in which the dike initiates from a compressible magma reservoir in the East Rift Zone, which then drains magma upstream from the Halemaʻumaʻu reservoir through a shallow transport system. We use a Bayesian Markov chain Monte Carlo (MCMC) approach to estimate storage parameters for both reservoirs as well as the effective conductivity of the shallow magma transport system in the East Rift Zone, finding good agreement with independent estimates. Our results suggest that the rupture of reservoirs from within the East Rift Zone presents a unique hazard at Kīlauea.

1355

Relating chemical diversity and timings of eruptive processes across the last seven eruptions at Cumbre Vieja, La Palma, Canary Islands

Samantha Tramontano[1,2,3], Marc-Antoine Longpré[1,3], Franco Cortese[1,3], Fátima Rodríguez[4], Beverly Coldwell[4,5], Alba Martín-Lorenzo[4,5], Olivia Barbee[4], Matthew Pankhurst[4,5]

[1]City University Of New York - The Graduate Center, Staten Island, United States, [2]American Museum of Natural History, New York, United States, [3]City University of New York - Queens College, Forest Hills, United States, [4]Instituto Volcanológico de Canarias, , Spain, [5]Instituto Tecnológico y de Energías Renovables, , Spain

Refining our understanding of when volcanoes erupt is a critical goal for improving forecasting models and hazard assessment. To investigate processes that may influence eruption onset, we compare chemistries of erupted products to repose periods at Cumbre Vieja, La Palma, Canary Islands. Similarities in tephra whole rock (basanite-tephrite) and crystal records across seven historical eruptions are evidence that the evolutionary pathway to eruption is a repetitive process, despite large variations in repose (22 to 237 years). Olivine crystals are remarkably similar across eruptions: 70% of analyzed crystals (n=77) display a more evolved core composition (Fo80 ± 1.4), overgrown by a reversely zoned inner rim (Fo82 ± 0.9) and a steeply, normally zoned outer rim (as low as Fo73). The presence of Fo80 olivine cores implies the presence of relatively evolved melts beneath La Palma, consistent with eruptions of tephrite-phonotephrite lava (in 1585, 1949, and 2021). The ubiquitous presence of reversely-zoned crystals in historical tephras suggests that primitive melts entrain these evolved cores. The application of Fe-Mg interdiffusion chronometry to olivine chemical zones yields a wide range of recharge-to-eruption timescales from 6 days to >6 years, with eruption averages spanning 24 days to 1.2 years. Rhyolite-MELTS models show decreasing olivine Fo content upon decompression, mimicking the steep normal zoning observed at the outer rims, which we interpret as due to rapid-growth upon ascent. This is further supported by the presence of skeletal textures and a concave Fo–Ni relationship at the outer rim. Despite similarities between erupted samples, we find that the timings of primitive injections that precede eruptions at Cumbre Vieja are unrelated to the length of repose periods between eruptions. Instead, we postulate that repose periods are controlled by the rate of primitive melt generation and extraction in the upper mantle beneath La Palma.

1349

Monotonous mush built from diverse cryptic liquids modulates recent eruptions at Momotombo, Nicaragua

Samantha Tramontano[1,2,3], John Zayac[1,3,4], Eveling Espinoza[5], Silvio Aldebot[3], Cissy Ming[6], Maureen Feinemen[6], Peter La Femina[6], Armando Saballos[5], Brian Monteleone[7], Marc-Antoine Longpré[3,1]
[1]City University Of New York - The Graduate Center, New York, United States, [2]American Museum of Natural History, New York, United States, [3]City University of New York - Queens College, Forest Hills, United States, [4]Vassar College, Poughkeepsie, United States, [5]Instituto Nicaragüense de Estudios Territoriales, Managua, Nicaragua, [6]Penn State University, State College, United States, [7]Woods Hole Oceanographic Institute, Falmouth, United States

It is an important goal to understand the processes that diversify and homogenize the chemistries of volcanic-magmatic systems because of the impact of magma chemistry on eruption style and hazard assessment. We investigate the eruptive products at Momotombo, Nicaragua, focusing on the 2015–2016 eruption, to identify the dominant magmatic processes that modulate historic (1605 – present) eruptive history. Lavas and tephra glasses from the 2015–2016, 1905 and earlier eruptive episodes at Momotombo show monotonous basaltic-andesite (54 wt.% SiO2) compositions. Contrasting with bulk rock chemistry, matrix glasses, melt inclusions, and melt compositions (constrained from plagioclase–melt K2O partitioning and rhyolite-MELTS modeling) record a more extensive liquid line of descent from basalt (<51 wt.% SiO2) to dacite (63 wt.% SiO2). The high crystallinity of lavas (34-48 vol.%), the presence of glomerocrysts, and the wide range of plagioclase textures and compositions (An47 to An95) are evidence that Momotombo magmas are produced by disaggregation of crystal mush, which buffers the bulk rock composition. Low volatile saturation pressures and degassing models indicate that magma is active at shallow depths (1-2 km). The glass composition of ash — intermediate between bulk rock and melt inclusion compositions — and thin, reversely zoned rims of pyroxene crystals record an influx of new andesitic melt reaching shallow levels within days of the 2015-2016 eruption onset, with seismic records signaling unrest as early as 2013. The magnitude and style of eruptions at Momotombo may vary dramatically if mush modulation and interactions with the shallow hydrothermal system change in the future. Additionally, the evidence for the presence of cryptic silicic liquids beneath Momotombo, which overlap in composition with products erupted from the adjacent Pleistocene Monte Galán caldera, and potential shallow extension of the magmatic system beneath Momotombo serve as motivation for continued research and enhanced monitoring efforts in this area.

737

Application of MatMELTS, a Matlab-based MELTS batch processing tool, to petrological studies, thermomechanical magma chamber models, and magnetotelluric inversions

Professor Juliana Troch[1], Julien Cornet[1], Professor Chris Huber[1], Dr. Darcy Cordell[1]
[1]*RWTH Aachen University, Aachen, Germany*

Thermodynamic modeling can be coupled to thermo-mechanical models, geophysical inversions and petrological applications to provide additional constraints fundamental to modeling magmatic systems. Over the last decade, the thermodynamic modelling software package Rhyolite-MELTS (Gualda et al. 2012) has developed into a work horse of magmatic petrology by allowing easy and fast computation of thermodynamic phase equilibria between silicate melt, mineral assemblage and an exsolved H_2O-CO_2 fluid phase at various magmatic conditions. Here we show several examples of how thermodynamic constraints help to better constrain magma generation and storage conditions in a variety of model applications. Specifically, we developed MatMELTS, a Matlab-based fully-automated MELTS batch-processing script that works on both Mac and Linux. From created lists of compositions and run conditions, this tool generates MELTS input files and runs MELTS iteratively on each, allowing us to run hundreds of simulations overnight. We demonstrate the utility of this tool via three case studies that use MELTS batch-processing to better constrain magma generation and storage conditions: (1) Simulating the melting behavior of hydrothermally altered rocks in the Krafla volcanic field, Iceland, in order to investigate their role during the generation of low-δ^{18}O rhyolites; (2) Developing fully-differentiable expressions for H_2O and CO_2-dependent melting curves for typical rhyolite and basalt compositions as input for thermomechanical magma chamber models; and (3) constraining relationships between melt fraction, temperature, dissolved water and bulk resistivity from magnetotelluric inversion models. Next to the available stand-alone Rhyolite-MELTS with graphical user interface, the Excel-based version and access through a server-based web interface, MatMELTS provides yet another option for accessing MELTS. The application examples show how better flexibility in software platforms can facilitate integration of thermodynamic constraints into a variety of possible applications, allowing us to better link chemical and physical models of magma reservoirs in the future.

1004

Mantle source characteristics and magmatic processes during the 2021 La Palma eruption, Canary Islands

Prof James Day[1], Professor Valentin Troll[2], Prof Meritxell Aulinas[3], Dr Frances Deegan[2], Dr Harri Geiger[4], Prof Juan Carlos Carracedo[5], Dr Guillem Pinto[3], Prof Francisco Perez-Torrado[5]
[1]Scripps Institution of Oceanography, San Diego, USA, [2]Uppsala University, Uppsala, Sweden, [3]University of Barcelona, Barcelona, Spain, [4]University of Freiburg, Freiburg, Germany, [5]University of Las Palmas de Gran Canaria, Gran Canaria, Spain

The 2021 eruption of La Palma was the first subaerial eruption in the Canary Islands in 50 years and approximately 0.2 km3 of lava erupted from a basaltic edifice on the northwestern flank of the Cumbre Vieja volcanic ridge. Comprehensive sampling of the olivine- and clinopyroxene-phyric lavas over the eruption period reveals temporal changes in mineralogy and bulk rock geochemistry from tephrite to basanite. Initial tephrite lavas have low MgO (~6 wt.%) and elevated TiO2 (~4 wt.%) and contain amphibole crystals and gabbroic micro-xenoliths. In contrast, lavas with progressively more mafic compositions erupted to approximately day 20 of the eruption and thereafter remained as basanite (~8 wt.% MgO; 3.7 wt.% TiO2) until eruption termination. Temporal changes in lava chemistry reflect initial eruption of fractionated magmas that crystallized 5-10% olivine and clinopyroxene, as well as minor spinel, sulfide, and magnetite, followed by later eruption of deeper-sourced and more primitive magma. Vanadium-in-olivine oxybarometry indicates parental magmas were oxidized (fO2 = +1.5 to +2 FMQ) with 8.2 ±0.8 wt.% MgO and were generated from between 2.5-3% partial melting of a mantle source potentially containing a pyroxenite component (Xpx = 0.31 ±0.12). Day 1-20 tephrites have more radiogenic 187Os/188Os (0.143-0.148) and lower Pd, Pt, Ir and Os contents than post day 20 basanites (187Os/188Os = 0.141-0.145). Combined with available seismic data, the lavas provide a high-resolution record of eruptive evolution. Initial fractionated tephrite magma was stored in the upper lithosphere up to four years prior to eruption, consistent with pre-cursor seismicity and the presence of partially reacted amphibole and micro-xenoliths. The later lavas of the eruption were fed by more primitive basanitic parental magmas that were likely sourced from the deeper portion of the magma storage system that is underplating the island.

Reference: Day et al., 2022 Earth and Planetary Science Letters

361

Ancient oral tradition in Central Java warns of volcano–earthquake interaction

Professor Valentin Troll[1], Dr. Frances Deegan[1], Ms. Nadhirah Seraphine[1]
[1]*Department Of Earth Sciences, Uppsala, Sweden*

Merapi volcano in Central Java, Indonesia, is one of the most hazardous volcanoes in Southeast Asia, yet humans have inhabited the area around Merapi since ancient times. As a consequence, a rich but complex volcano-related folklore has developed. The local legends describe the interaction of the spirit kings that reside within Merapi volcano and the Queen of the South Sea, who resides in the Indian Ocean near Parangtritis, some 50 km SSE of the volcano (1). The royal palace in Yogyakarta is located half-way between Merapi volcano and Parangtritis beach and is believed to balance these opposing forces. In 2006 and 2010, Merapi erupted explosively and on both occasions, earthquakes shook the region and caused the eruptions to grow more intense. Notably, the 2006 earthquakes clustered along the Opak River fault system to the south of the volcano that reaches the sea at Parangtritis beach, the fabled residence of the Queen of the South Sea. We argue that local legends were used to rationalize the dynamic interaction between the volcano and the frequent regional earthquakes through the rich oral traditions and ceremonies in the districts around Merapi. These legends can thus be thought of as comprising an ancient hazard catalogue with respect to local eruptive behaviour and seismic phenomena. This realization is now finding increasing use in communicating volcanic hazard knowledge to diverse local resident and interest groups, including local primary schools. This expanded curriculum has led to measurable improvements in hazard awareness and crisis preparedness with school children in the affected areas around Merapi, which will likely reduce casualties in times of future volcanic crisis.

(1) Troll V.R., Deegan F.M., Seraphine N. (2021) Ancient Oral Traditions in Central Java warns of volcano-earthquake interaction. Geology Today, Vol 37: 100-109. https://doi.org/10.1111/gto.12350

231

Eruption dynamics of Shikabe Geyser in southern Hokkaido Japan, inferred from physical observations inside and outside of the conduit

Mr Ayuta Tsuge[1], Mr Hiroshi Aoyama[2], Mr Fujio Akita[3], Mr Kazuhiko Kato[3]
[1]Graduate School of Science, Hokkaido University, Sapporo, Japan, [2]Institute of Seismology and Volcanology, Faculty of Science, Hokkaido University, Sapporo, Japan, [3]AQUA Geotechno Co., Ltd, Sapporo, Japan

“Shikabe Geyser” is one of the most famous geysers in Japan, located in southern Hokkaido. We performed the pressure, temperature, video camera, ground tilt, and acoustic observations, to understand the physical background of controlling eruption processes and the variability of its eruption interval.

Shikabe geyser brings hot water and steam up to a height of more than 10 m, and its interval between eruptions is 10 to 12 minutes. The eruption cycle is composed of three phases, water recharge after the eruption, overflow, and vigorous eruption, as well as other geysers observed in previous studies.

Throughout the eruption cycle, the water temperature at 20 m depth exhibits approximately 114 ~ 115 ℃, which is lower than the boiling temperature at that pressure condition. However, immediately after the eruption begins, we found that many bubbles generated under 20 m depth from video observations. In addition, erupted water volumes measured on the ground are larger than estimated from the pressure drop inside the conduit, which indicates oversupply of water occurs during the eruption compared to the recharge processes.

Based on our observation results and the chemical composition of surrounding hot springs, we developed a conceptual model of the eruption process of the Shikabe Geyser. The video image inside the conduit suggests the presence of cracks and small cavities connected to the conduit wall. The eruption triggers the decompression boiling of water in the shallow part of the conduit, while in the deep part of the conduit and in the surrounding cracks, bubbles of carbon dioxide are produced due to decompression which may contribute to the oversupply of water from the cracks or cavities to the conduit. The observations indicate a new type of eruption model and a complex relationship between the eruption process and the plumbing system.

504

Measuring aerodynamic drag and lift of volcanic blocks in regards to the trajectory of ballistic blocks

Dr Kae Tsunematsu[1], Prof Kazuya Seo[2], Mr Takemi Shintani[3]
[1]*Yamagata University, Yamagata, Japan,* [2]*Kogakuin University, Shijuku, Japan,* [3]*Tohoku University, Sendai, Japan*

Running simulations of the trajectories of ballistic blocks is important in order to predict the hazardous zones around volcanic vents as ballistic blocks have a large landing energy which can cause serious damage to buildings and threaten human lives. It is difficult to define the values for drag of ballistic blocks as there are few measurement reports for the drag values while conducting numerical simulations. Therefore, we have measured the aerodynamic drag and lift of blocks from the eruptions of the Zao and Ontake volcanoes. We measured the drag by varying the wind velocity from 0.6 to 30.0 m/s with block sizes of 50%, 100% and 150% with 3D models of these blocks using a 3D scanner and printer. The drag values of the blocks diverge when the blocks are not rotated, while the drag values are within a small range when we rotate the blocks. The drag value is within 0.6-0.8. The drag value does not change when the block size varies. We also conducted numerical simulations in order to see the effect of drag and lift. When we vary the lift value within the measured range, the travel distances of blocks do not change. However, the variation of the drag value within the measured range affects the travel distances of blocks drastically.

620

Assessments of fundamental architecture of a pillar type seabed GNSS platform in Aira Caldera

Professor Tomoki Tsutsui[1], Professor Daisuke Miki[1], Professor Masato Iguchi[1]
[1]*Dpri, Kyoto University, Kagoshima City, Japan*

A development of a GNSS platform system will be presented, which can enhance geodetic observation for monitoring in flooded caldera volcanoes. The geodetic observations are one of the fundamental observations in the volcano monitoring. While it is easy to conduct geodetic observation on the land, the observation in water sector is much difficult. Many calderas include pressure source beneath their flooded central area, which are depressions as a result of huge magmatic eruptions. Water-bottom geodetic observation can contribute some improvement in sensitivity of the volcano monitoring. Iannaccone et al. (2018) challenged it in the Gulf of Pozzuoli.

A GNSS platform is developed for the purpose of monitoring in Aira Caldera, South Japan. Aira Caldera lies under about 100 m depth sea water. The caldera hosts Sakurajima Volcano at the south margin. Expected rate of vertical displacement is more than 1 cm/year in the marginal area. The caldera usually gets strong wind by flesh typhoons almost every summer to autumn.

Our system comprises GNSS at the top of rigid pillar shaft which is linked to the anchor with a universal joint.

Since the pillar shaft can tilt freely with external forces, such as wave and tide current, Kinematic method is applied as a method of the geodetic analysis. Following four problems occurred and needed inspections before the final design; Long-term stability of the method in comparison with the static method, consideration on methods of attitude detection, dynamic response of Kinematic method, and construction of attitude reduction algorithm.   Three of four were examined successfully on the test platform of miniature size on the land. Since plausible results are obtained through the inspections, GNSS antenna array system is applied to the final design of the actual platform.

1272

Boron isotopic composition of geothermal fluids in the Hatchobaru geothermal system, Kyushu, southwestern Japan

Ms Saki Tsutsumi[1], Ms. Yumi Kiyota[1], Professor Jun-Ichiro Ishibashi[2], Mr. Makoto Tanaka[3]
[1]*West JEC Co., Ltd., Fukuoka, Japan,* [2]*Kobe University, Kobe, Japan,* [3]*JOGMEC, Tokyo, Japan*

The Hatchobaru geothermal field is located in Kuju volcanic region, Kyushu Island, southwest Japan. The Hatchobaru geothermal power plant has been operating since 1977 by Kyushu Electric Power Co., Inc. and the current total output capacity is 112 MW.

Neutral-pH Na-Cl type fluid of meteoric origin dominates in the field, as demonstrated by Momita et al. (2000). On the other hand, discharge of acid fluid of pH=3-4 has been recognized at some wells in the southern part of the geothermal field Previous geochemical studies (Shimada et al., 1985; Matsuda et al., 2000) discussed formation mechanism of acid fluids. In this study, boron isotope composition was employed as a new indicator that could provide important information to solve this problem. In total 16 geothermal fluids were collected, and chemical and isotope composition were determined. While 15 geothermal fluids were classified as Cl type with neutral to slightly alkaline pH, one fluid (obtained from southern area) was Cl-SO4 type with slightly acid pH (pH=2.9). Boron isotope composition of the geothermal fluids was in a range of δ11B = -4.2 to -0.1 ‰, and δ11B value in the southern area is lower. Difference in gas composition was recognized between the geothermal fluids from two areas, while major element composition, and oxygen and hydrogen isotope compositions showed no significant difference. Based on trace gas composition, it is suggested that geothermal fluid in the southern area is more strongly affected by magmatic volatile. These results suggest that the regional difference of boron isotope composition would be attributed to contribution of magmatic volatile.

Acknowledgements: We are grateful to Kyushu Electric Power Co., for their permission of presentation. This study has conducted in the project financed by JOGMEC.

267

Better volcanic warnings as part of a global multi-hazard early warning system effort

Dr Andrew Tupper[1]
[1]*Natural Hazards Consulting, Melbourne, Australia*

One of the fundamental differences between volcanology and meteorology is that, in meteorology, it is impossible to operate effectively in isolation, because the physics of the atmosphere necessitate the sharing of observations before skilful predictions can be made. An outcome of this limitation is that meteorology has always prioritised international systems of cooperation, with remarkable effectiveness despite the challenges along the way. Further improvements in hydrometeorological warning systems are anticipated as part of the global push towards meeting Sendai targets.

How could operational volcanology use the resultant advances made in meteorology to help drive services for international and local stakeholders? Firstly, there are obvious science-based linkages that must be made to help provide services. These include the use of meteorological models for ash deposition modelling, rainfall forecasting, lahar risk analysis, gas dispersion modelling, and so on. Secondly, some global meteorological systems and principles can be directly applied to volcanological operations, including the free exchange of operational data and the principles of regional and global organisation for mutual assistance. Thirdly, and just as importantly, is the fundamental concept that stakeholders, including the general public, governments, emergency services, sector-specific groups, and the international aid and development communities, need and increasingly require a seamless service from technical agencies.

To achieve that means more than information exchange – it means global multidisciplinary cooperation and structured investment (including capacity development). Progress in this area may require resources and commitment but will be rewarded through the provision of better services and the trust, support and funding of governments and users. The talk will give examples of pathways forward in each of these areas.

1262

Some serious conversations about marine hazards – implications of the Hunga Tonga-Hunga Ha'apai eruption

Dr Andrew Tupper[1]
[1]*Natural Hazards Consulting, Melbourne, Australia*

Submarine volcanic hazards are some of the many natural hazards that the marine and coastal communities of the world face, including in the SW Pacific. The HTHH eruption occurred between the first and second phases of a major marine services training course led by the World Meteorological Organization, conducted virtually during late 2021 and in-person in Rarotonga, Cook Islands, September-October 2022. Forecasters from many SW Pacific countries participated in the course, and discussed, amongst other things, the importance of user engagement, seamless multi-hazard early warning services, and operations techniques.

During the 2022 phase of the course, participants discussed three case studies – a major tropical cyclone event (TC Harold), a widespread swell and coastal inundation event in July 2022, and HTHH. Each of these events caused significant damage. HTHH created shipping hazards from pumice and ashfall (reportedly disabling an Australian navy ship) as well as from the tsunamis. We learned many lessons from the case studies, including the need to bring warnings for volcanic risks more fully into global warning arrangements designed to protect lives and property at sea as well as on the land. To improve the provision of seamless warning services, we will continue to work on the operational cross-disciplinary relationships and arrangements required, including between the volcanological, tsunami, and meteorological communities.

1250

The filtering effect of volcanic plumbing systems on erupted melts. Implications for magma transport and storage across tectonic settings

Dr Teresa Ubide[1], Prof Gideon Rosenbaum[1], Dr Patricia Larrea[2], Dr John T Caulfield[3], Mr Jack Ward[1], Mr Dean Bennett[1], Ms Daniela Parra-Encalada[2], Prof Mike Sandiford[4]
[1]The University of Queensland, Brisbane, Australia, [2]Universidad de Chile, Santiago, Chile, [3]Queensland University of Technology, Brisbane, Australia, [4]The University of Melbourne, Melbourne, Australia

Our understanding of magma transfer and storage from source to surface is key to assess eruption hazards, crustal evolution, and economic mineralisation. The current paradigm of magma plumbing systems considers crystal-dominated mushes with transient eruptible melts. The complex architecture and dynamics of mush systems is reflected in the intricate disequilibrium textures and compositional zoning of minerals. However, less is known about the filtering effect of the mush on erupted liquids. This is partly because accessing melt compositions is challenging; whole rocks represent mixtures of liquids and entrained crystals, while mineral-hosted melt inclusions may be variably affected by post-entrapment modification.

Here we approach the architecture and dynamics of volcanic plumbing systems from the perspective of high-resolution petrology and geochemistry. We isolate the chemical signatures of discrete crystal zones and carrier melts to reconstruct pre- and syn-eruptive processes in ocean island and arc settings. In convergent margins, we identify links between geometric variations in the subducting slab and geochemical anomalies in erupted products. We discuss differences in the dynamics of magma transport and storage across tectonic settings, exploring the tipping mechanisms that trigger key geological processes, including mush destabilisation and eruption, and economic porphyry mineralisation.

537

Construction and future development of digital tephra fall distribution database in Japan

Dr Shimpei Uesawa[1], Dr Shingo Takeuchi[1], Mr Kiyoshi Toshida[1], Dr Hisatoshi Ito[1], Dr Kosuke Ishige[1]
[1]*Central Research Institute of Electric Power Industry, Abiko, Japan*

Probabilistic tephra fall hazard assessment using computational simulations can account for the uncertainty of eruption magnitude and wind direction. However, there are still issues with the determination of the appropriate model and range of parameters for using advection-diffusion modeling of volcanic ash-cloud dispersion. The large collection of tephra fall isopach maps in Japan (more than 500 to date) enables us to assess the tephra fall thickness hazard from geological record. As a prototype, the digital database was constructed by digitizing the isopach maps cataloged and interpolated by Suto et al. (2007). Based on the digital tephra fall data for the last 150,000 years, we can obtain the evidence-based mean annual frequency of exceedance (MAFE) curves of the tephra fall layer thickness in Japan (named “Isopach map-based tephra hazard analysis”: IB-THA). The MAFE is represented using the following equation:

$$MAFE = N/T$$

where N is the number of events exceeding the specific tephra fall thickness, and T is the term (year) of the used data. The MAFE shown in this study are the mean values and 95% confidence intervals of 15 MAFE curves for 10,000 to 150,000 yBP for temporal variation (each step is 10,000 years long). The exceedance hazard value may indicate a minimum estimate because the thickness of the tephra fall layers may be subject to erosion and compaction. We plan to update the database by collecting new tephra fall distribution maps (isopach as well as isopleth), observed point data, and eruption ages. The updated digital tephra fall distribution raster files will be created by applying more objective interpolation methods. We believe our digital tephra fall database will be the platform tool for evidence-based tephra fall hazard assessment in Japan, which can be iteratively improved by updating the datasets and interpolation method.

342

Particle Impacts and their Implications on the Hazard Potential of Pyroclastic Density Currents

Mr Daniel Uhle[1], James Ardo[1], Prof. Dr. Gert Lube[1], Prof. Dr. Jim Jones[1], Dr. Ermanno Brosch[1], Lucas Corna[1]
[1]*Massey University, Palmerston North, New Zealand*

Recently, direct but low-resolution measurements of pressure inside real-world PDCs, powder snow avalanches and large-scale experimental PDCs revealed that dynamic pressure forms wide spectra of pressure energies. These spectra are strongly skewed towards large dynamic pressures corresponding to the largest coherent turbulence structures and internal gravity waves. Importantly, these peak pressures exceed mean pressures, which are routinely estimated for hazard mitigation, by a factor of 3-5, raising concerns in current hazard planning routines.

Here, we present new high-resolution dynamic pressure data from large-scale PDC experiments. These show that energy spectra are considerably wider than originally thought, with peak dynamic pressures exceeding mean values by more than one order of magnitude. To explain these peak pressures, we calculated the spectra of dynamic pressure associated with the gas-particle mixture flow through independent measurements of flow velocity and density. This proved the original finding that the most extreme turbulent excursions in velocity and density exceed mean pressures considerably up to approximately five times. However, the considerably higher peak pressures cannot be explained as a 'fluid pressure' of the multiphase mixture. The peak pressures show marked and sudden onsets in <1 ms followed by an immediate pressure decline. Together with flow grain size and density data, this suggests that the peak pressures are associated with individual impacts of particles that are poorly to not coupled with the mixture flow. The number and amplitude of particle impacts decrease strongly with the flow height and length, which is well-explained through progressive sedimentation of large particles. The integral energy associated with these particle impacts accounts for up to 18% of the flow's total energy but reduces to <0.05% in distal reaches. These findings explain high-energy particle impact structures reported after eruptions. Particle impacts should find consideration to avoid underestimation of hazard impacts.

1212

Glass and phenocrysts reveal heterogenous magma sources drove the 15 January 2022 Hunga Volcano eruption

Dr Ingrid Ukstins[1], Alessio Pontesilli[2], Marco Brenna[2], Jie Wu[1], Shane Cronin[1], Joali Paredes-Mariño[1], Phil Shane[1], David Adams[1], Folauhola Latu'ila[3], Taaniela Kula[3]

[1]University Of Auckland, Auckland, New Zealand, [2]University of Otago, Dunedin, New Zealand, [3]Tonga Geological Services, , Tonga

On 15 Jan 2022, Hunga Volcano in the Tonga-Kermadec oceanic arc generated the most explosive eruption recorded in the last 140 years. The deposits are andesitic (whole rock SiO2 57 wt %) comprised of blocky, poorly vesicular glassy ash with subordinate vesicular pumice ash and fine lapilli. Phenocrysts (from 5-10% by volume) are plagioclase, orthopyroxene, clinopyroxene, and very rare olivine. They are commonly euhedral or fractured and are most abundant in the 500-1000 µm size fraction. Plagioclase phenocrysts have high-anorthite cores (~An90-93) surrounded by more sodic oscillatory-zoned overgrowths (~An80-85). Clinopyroxene phenocryst cores have average Mg# values of 79 (range = 68.0 to 87.5), and orthopyroxene cores have a mode at Mg# 75 (range = 63.4 to 82.7). Overgrowth mantles on pyroxene range from 100 to 300 microns and may be more or less magnesian than the cores, but rims are normally zoned, and the outermost edges are similar to groundmass pigeonitic pyroxenes. Preliminary thermobarometry estimates from equilibrium cpx-melt pairs indicate temperatures of ~1110-1130 °C and pressures of ~150-200 MPa for the modal cpx composition. Olivine crystals are euhedral with homogenous cores up to Fo93 and thin, normally zoned rims. Chondrite-normalized Rare Earth Element and primitive mantle-normalized trace elements in the glass are in similar to whole-rock values from the 2014/2015 Hunga eruption, with slightly lower incompatible element abundances. These data demonstrate assembly of heterogeneous magmas to drive this eruption and tap deeper parts of the magma system than ever seen before – likely due to extreme decompression. While there is no evidence for 'mafic magma recharge' immediately preceding eruption, phenocryst compositional variability, microlite texture contrasts, and ubiquitous mingling textures all indicate that different andesitic magmas mingled both before and during the eruption. This mingling may have driven development of extreme gas-pressure to trigger the very violent onset of this event.

1424

On Physical Meaning of Ionospheric Anomaly Immediately Preceding Tonga-Hunga Ha'apai Volcano Eruption on 15
January 2022

Professor Ken Umeno[1], Mr Yuta Tsusaka[1], Ms Minghui Kao[1]
[1]*Kyoto University, Kyoto, Japan*

Ionospheric Anomaly observed shortly before Tonga-Hunga Ha'apai volcano eruption on 15 January 2022 is discussed in connection with abrupt demagnetization due to magma rising.
To discuss a possible causal relation between demagnetization and ionosphere, we developed a theory of linear relation between a velocity change ΔV of traveling ionospheric disturbance and a change of Earth's geomagnetic field ΔB such that ΔV[m/s]=α ΔB[nT], where α=3.3 ✕ 10^9. Then we can observe ΔV=100m/s and its predicted change would be ΔB = 30 nT by the linear relation. The key issue about whether ΔB is really caused the demagnetization before the eruption or not is discussed from the view point of the magma uprising speed.

653

Conduit depressurisation through pyroclast-filled fractures: Insights from a large tuffisite at Húsafell central volcano, Iceland

Miss Holly Unwin[1], Dr Hugh Tuffen[1], Dr Fabian Wadsworth[2], Prof. Emrys Phillips[3], Prof. Michael James[1], Prof. Michael Heap[4], Dr Robert Cuss[3], Miss Annabelle Foster[2]

[1]Lancaster University, Lancaster, United Kingdom, [2]Durham University, Durham, United Kingdom, [3]The British Geological Survey, , United Kingdom, [4]Université de Strasbourg, Strasbourg, France

High pressure gas-pyroclast mixtures within erupting volcanic conduits can fracture the adjacent country rock. While open, these fractures are injected with gas and pyroclasts, preserving them as pyroclast-filled fractures called tuffisites. Tuffisites are thought to be a record of efficient gas escape pathways, perhaps able to dissipate sufficient conduit pressure to moderate eruption style. If particles deposited within these fractures are sufficiently hot they weld together through time, reducing fracture permeability and inhibiting gas escape. Despite their potential role in controlling eruption dynamics, the length of time that a tuffisite may remain permeable and the gas flux through tuffisites are poorly constrained.

Here we present a detailed characterisation of a large (0.9 m thick, 40 m long) tuffisite at Húsafell central volcano in Iceland. This tuffisite was injected along the near-horizontal contact between two ignimbrite units at ~500 m depth. The tuffisite has a complex internal structure, composed of multiple units that often contain sedimentary structures such as cross-lamination and graded bedding. These deposits record repeated erosion and deposition caused by multiple injections of ash-laden fluid along the fracture, potentially acting as a static, repetitive seismic source.

We interpret the tuffisite at Húsafell as a fossil record of the conduit fluid pressure fluctuations occurring during magmatic pathway evolution. Hydrofracture experiments that break the tuffisite host rocks with high pressure water indicate that an overpressure of a few Mpa would be required for initial fracture opening. The dimensions of the tuffisite units suggest fluid overpressures of ~1.9-3.3 Mpa would be needed to emplace each unit (0.1 m thick and 40 m long), with sintering timescales suggesting injections occurred every few hours. As sedimentary structures indicate tuffisite emplacement involved up to 20 fluid injections, we suggest that the tuffisite acted as an outgassing pathway for a few days before its activity ceased.

327

Interdisciplinary characterisation of flow dynamics within fossil dykes: A case study of the Reydarfjordur dyke swarm, eastern Iceland

Dr Stefano Urbani[1], Dr Janine Kavanagh[1], Miss Tegan Havard[1], Mr Dawid Rybak[1], Miss Katharine Gilchrist[1], Prof Andy Biggin[1], Dr Elisabetta Mariani[1], Dr Steffi Burchardt[2]

[1]Department of Earth, Ocean and Ecological Sciences, University of Liverpool, Liverpool, United Kingdom, [2]Department of Earth Sciences, Uppsala University, Uppsala, Sweden

Understanding the factors that control dyke propagation and emplacement is critical to define magma transport inside the Earth's crust and its eruption to the surface. In this regard, key insights can be obtained by studying exposed fossil dykes in extinct volcanic systems recording signs of the primary magma flow direction at the time of emplacement.

However, a suite of interlinked syn- and post-emplacement processes occurring during dyke propagation (e.g. crystallization due to cooling, chemical interactions with host rock, volatile exsolution) may partially overprint any evidence of magmatic flow, complicating its interpretation.

To reduce and overcome such limitations, we follow a multidisciplinary approach on a fossil dyke from the Reydarfjordur dyke swarm (eastern Iceland) which include detailed geometric data from drone surveying, rock magnetic, petrographic and structural laboratory analyses revealing microscopic magma flow indicators (e.g., magnetic fabrics and crystal alignment/distortion).

The dyke is exposed for ~ 500 m across the breadth in a ~ 100 m height span and comprises at least 3 main overlapping segments with variable thickness (0.5-2 m). Field mapping and photogrammetric analyses reveal an overall N-S trend of the dyke, a narrow and tapered tip geometry of the dyke segments which show subparallel walls.

We sampled the segments at different locations both across their thickness (i.e. cross section) and along their breadth (i.e. traverse section) for magnetic analysis including anisotropy of magnetic susceptibility (AMS) and anisotropy of anhysteretic remanent magnetisation (AARM). Comparison of the magnetic fabric with petro-fabric analysis of oriented hand samples (i.e. electron backscatter diffraction, EBSD) provides an additional and independent constraint on the reconstruction of magma flow direction.

Such interdisciplinary approach will increase the complementarity of different methods and techniques providing more reliable and transferrable insights on dyke propagation.

1055

Relationship between CO2 emissions and thermal anomalies in the crater of Poás volcano, Costa Rica

Ms Molly Urquhart[1], Dr. Maarten de Moor[2], Dr. John Stix[1], Dr. Margaret Kalacska[5], Carlos Andrés Vargas[3], Dr. J. Pablo Arroyo-Mora[4], Oliver Lucanus[5]

[1]McGill University, Department of Earth and Planetary Sciences, Montreal, Canada, [2]Observatorio Vulcanológico y Sismológico de Costa Rica, Heredia, Costa Rica , [3]Universidad Estatal a Distancia, San Jose, Costa Rica , [4]National Research Council Canada, Ottawa , Canada , [5]McGill University Department of Geography, Montreal , Canada

Mapping the extent of hydrothermal alteration and degassing can provide insight into the permeability of a volcanic system, and aid in understanding how hydrothermal alteration within a crater can influence different levels of volcanic activity. We conducted a field campaign in the crater area of Poás volcano, Costa Rica, from June 20th to June 23rd, 2022, to explore a collapse event on the eastern flank that occurred in April 2022. The goal of this work is to quantify the total CO2 output from the collapse area and beyond, and to determine if temperature anomalies can be correlated with enhanced CO2 outgassing. Ground data collected from the unstable eastern crater margin zone include CO2 flux measurements, temperature measurements, and mineralogical sampling. CO2 flux was measured at 8 locations within the crater, of which 7 were within a thermally anomalous area. The range of CO2 flux measured with the LI-830 CO2 LI-COR gas analyzer is from 43 to 757 µmol m-2 s -1 in moderate CO2 flux areas and 1434 to 1600 µmol m-2 s -1 in high CO2 flux areas. Temperatures measured using a thermocouple inserted ~ 10 cm into the soil ranged from 13.7 ^{o}C to 89.7 C in moderate temperature areas and 92.0 ^{o}C to 92.4 ^{o}C in high temperature zones. Background CO2 flux was close to zero with a temperature of 15.6 ^{o} C. Our preliminary findings suggest that there is a correlation between areas of high CO2 flux and areas of high temperature. Future work includes characterizing hydrothermally altered mineral samples collected in the collapse area using spectrometry and emissivity, and utilizing photogrammetry renderings and CO2 flux measurements to quantify volcanic CO2 flux of the thermally anomalous zones including the collapse area.

1385

Mechanisms of pressure buildup in magma reservoir: insights from numerical experiments

Dr Ivan Utkin[1,2], Dr Liudmila Khakimova[3,4], Prof Yury Podladchikov[3,4]
[1]ETH Zürich, Zürich, Switzerland, [2]Swiss Federal Institute WSL, Zürich, Switzerland, [3]University of Lausanne, Lausanne, Switzerland, [4]Lomonosov Moscow State University, Moscow, Russia

Understanding mechanisms leading to volcanic eruptions is of fundamental importance in geology and volcanology. Prerequisite to a volcanic eruption is the generation of sufficient overpressure in a magma reservoir, enough to exceed the strength of the rock, potentially triggering the eruption. In geological models the pressure buildup in magma reservoir is often linked to magma recharge and volatile exsolution. Another mechanism, that is often overlooked in conventional geological models, is related to the isochoric rise of gas bubbles in almost incompressible magma saturated with volatiles. Predicting volcanic eruptions using numerical models is complicated by the need to solve coupled physical processes spanning multiple temporal and spatial scales.

We present a coupled thermo-chemo-hydromechanical mathematical model for predicting the pressurisation of a magmatic reservoir. The model predicts porous and free convection of partially crystallised magma due to thermal and compositional heterogeneities, and compaction of crystals due to density difference between solid and liquid phases. We describe thermodynamic equilibrium and thermo-mechanical properties of phases using the nonlinear equation of state obtained through direct Gibbs energy minimisation. We resolve the multi-scale processes within magma reservoir using the high-resolution numerical modelling based on supercomputing.

We demonstrate through numerical experiments that the two mechanisms, volatile exsolution due to retrograde boiling, and rising of gas bubbles in a closed system, could lead to pressure buildup in magma reservoir, sufficient to exceed rock strength. We study systematically the relative importance of these mechanisms in a simplified problem setup.

1042

A MEMS Semi-absolute Pendulum Gravimeter for Volcanology

Miss Phoebe Utting[1,2], Mr Abhinav Prasard[2], Mr Giles Hammond[2], Mr Richard Middlemiss[1,2]
[1]James Watt School of Engineering, University of Glasgow, , United Kingdom, [2]Institute for Gravitational Research, School of Physics and Astronomy, University of Glasgow , , United Kingdom

Gravimetry is a geophysical method that can be used to infer density variations beneath the ground. Therefore, it has many potential applications for volcanology. It could provide geological discrimination and insight into subsurface processes related to the hydrothermal and magmatic systems of volcanoes. If applied in array format, then temporal changes could also be monitored.

Existing gravimeters are costly and heavy, but this is changing with the utilisation of MEMS – (Microelectromechanical-systems). A team at the University of Glasgow has already developed a MEMS relative gravimeter and is currently collaborating with multiple European institutions to make a gravity sensor network around Mt Etna - NEWTON-g. A second generation of the MEMS sensor is now being designed and fabricated in the form of a semi-absolute pendulum gravimeter. Gravity data for geodetic and geophysical use were provided by pendulum measurements from the 18th to the 20th century. However, scientists and engineers reached the limit of fabrication tolerances and readout accuracy approximately 100 years ago. With nanofabrication and modern electronics techniques, it is now possible to create a competitive pendulum gravimeter again.

In this presentation the design of a new MEMS pendulum gravimeter will be outlined. The design comprises a pendulum, with a thermal enclosure and isolation platform. Data collected from laboratory testing will be presented, demonstrating the progression being made towards a prototype field device for volcanological research. This data will include measurements of the influence of tilt-sensitivity and the seismic and shadow sensor noise floors. Altitude tests of the free-air effect will be presented to demonstrate the current sensitivity of the device. If semi-absolute values of gravity can be measured, then instrumental drift concerns are reduced. Additionally, the need for calibration against commercial absolute gravimeters may not be necessary. This promotes improved accessibility of gravity measurements at an affordable cost.

1304

On geomagnetic total intensity variation associating with eruptions of Shinmoe and Iwoyama volcanoes in the Kirishima volcano group, SW Japan

Professor Makoto Uyeshima[1], Dr Takao Koyama[1], Prof Koki Aizawa[2], Prof Tsuneomi Kagiyama[3]
[1]Earthquake Research Institute, the University of Tokyo, Tokyo, Japan, [2]Institute of Seismology and Volcanology, Faculty of Science, Kyushu University, Fukuoka, Japan, [3]Aso Volcano Museum, Kumamoto, Japan

The Kirishima volcano group is located in the southern part of the Kyushu Island, SW Japan, and is composed of many Quaternary andesitic strato-volcanoes occupying about 600 km². Among more than 20 volcanoes in the Kirishima volcano group, Mt. Shinmoe-dake (SM) and Mt. Iwo-yama (IW) are the recently most active volcanoes. Since moderate volcanic activities in 1991-1992, we have performed continuous monitoring of geomagnetic total intensity (F) at several sites in the vicinity of SMZ to detect temporal variation due to thermal magnetic effect. In this presentation, we want to show temporal variation of F associating series of volcanic activities at SM and IW, from 2010 to 2018. After moderate eruptions in summer of 2010, the sub-Plinian eruption occurred at the SM crater on Jan. 26, 2011. Then we first estimated position and size of the thermally demagnetized area in association with volcanic activities of SM in 2010-2011 based on F time series. Appearance of the time series both of F and GNSS looks very similar. But the demagnetized area was located juts near the SM crater, whereas mechanical inflation and deflation source was about 5km apart from SM. After these activities in the vicinity of SM until 2011, number of volcanic tremors increased in the vicinity of IW from winter in 2013, and, later, the activity accompanied the inflation ground motion, which led to a small phreatic eruption at the IW summit on Apr. 19, 2018. Almost in the same duration, SM was also reactivated from a small summit eruption in Oct. 2017, and intense phreatomagmatic eruption accompanying lava flow occurred from Mar. 2018. In order to discuss thermal process associating series of volcanic activities both at IW and SM, we show subsequent geomagnetic total intensity time series and compare them with the GNSS observations and seismic activities.

544

A slippery slope? (Mu)sings on the friction characteristics of PDC-ice interactions

Miss Amelia Vale[1], Professor Jeremy Phillips[1], Professor Alison Rust[1], Dr Geoff Kilgour[2]
[1]*University of Bristol, Bristol, United Kingdom,* [2]*GNS Science, Taupo, New Zealand*

When PDCs flow over ice, they generate steam and melt that can be incorporated into the flow, causing transformation into an ice-melt lahar. These particle-particle and particle-interface interactions with melt, steam, and frozen substrates alter the frictional regime of the flow. We use laboratory experiments to quantify and characterise the melting and frictional regime changes that occur when PDCs interact with an ice substrate.

Static and inclined plane experiments are presented using three particle types, including glass ballotini, crushed pumice, and Ruapehu andesite lapilli/ash. Static experiments quantified heat transfer rate, and mass of melt and steam when a layer of hot particles was emplaced onto a horizontal ice substrate. Melt and steam increased with increasing particle mass and temperature, but different particle types showed distinct sensitivities to particle temperature for any given layer thickness. Localised steam escape, fluidisation, capillary action, and particle sinking were observed to aid the incorporation of melt into the particle layer.

Inclined plane experiments measured the displacement and thickness of particle flows of varying temperature across several inclination angles, to obtain insights into frictional regimes. Experiments revealed complex interactions with the ice substrate, melt, and steam, heavily influencing flow dynamics and character. Steam was observed to fluidise particles resulting in greater flow mobility. Melt exerted varying controls on flow rate depending on the quantity produced. Limited melt decelerated particles, but with sufficient meltwater slurries formed, accelerating the flow front away from the bulk flow. Measurements of flow height and front speed show that some flows reached steady state suggestive of a Coulomb friction regime, but flows with significant fluidization or melt generation are likely controlled by granular or fluid frictional regimes.

These experimental data will be used to formulate hazard models for PDC runout and lahar generation, which will be tested at Mt. Ruapehu, New Zealand.

244

Emplacement of pyroclastic deposits at phreatomagmatic Ubehebe Crater (Death Valley, California, USA) and hazards implications

Professor Gregory Valentine[1], Judy Fierstein, James White
[1]*University At Buffalo, Buffalo, United States*

Deposits of the ~2.1 ka, phreatomagmatic Ubehebe Crater form four main facies. Lapilli- and block-dominated beds occur within several hundred meters of the crater and transition outward into discontinuous lenses of lapilli and blocks; they are interpreted to have been deposited by ballistic processes associated with crater-forming explosions. Thinly bedded lapilli tuff/ash is found mainly within several hundred meters and laminated and cross-laminated ash extends at least 9 km from the crater center. Thinly bedded lapilli tuff and laminated and cross-laminated ash are interpreted to record multiple pyroclastic surges (dilute pyroclastic currents) sourced by phreatomagmatic explosions. Dune-form data provide possible constraints on the relationships between suspended load sedimentation and bed load transport that are consistent using two independent approaches. Massive lapilli ash/tuff beds occur in drainages below steep slopes and can extend up to ~1 km onto adjacent valley floors beneath large catchments. Although they are massive in texture, their grain size characteristics are shared with laminated and cross-laminated ash facies, with which they are interbedded. These are interpreted to record concentrated granular flows sourced by remobilized pyroclastic surge deposits, either during surge deposition or shortly after. These concentrated flows followed drainages independently of the pyroclastic surges. Ubehebe Crater has the dimensions of a typical maar (~800 m diameter), and there is no reason to suspect that its explosions and pyroclastic currents were somehow unique. Preservation of their thin distal deposits at distances up to 9 km is due to the arid setting, suggesting that hazard assessments for volcanic fields should use larger potential surge footprints than has been previously done. The deposits of surge-derived granular flows with their independent flow paths also represent a potential hazard at similar maars in areas with complex terrain.

1445

Pulsatile lava activity at El Reventador volcano, looking through ground-based infrared and optical cameras

Dr Silvia Vallejo[1], MSc Patricio Ramón[1], MSc Stephen Hernandez[1], Gerardo Pino[1], Eng Marco Almeida[1], MSc Freddy Vásconez[1,2], Eng. Jorge Córdova[1], Eng. Iván Tapa[1]
[1]Instituto Geofísico - Escuela Politécnica Nacional, Quito, Ecuador, [2]Laboratoire Magmas et volcans, Clermont-Ferrand, France

Volcanic activity in El Reventador andesitic volcano (Ecuador), since its reactivation in 2002, has ranged from explosive to effusive, generating more than eighty different lava flows of diverse composition, duration and volume. These lava flows units have been identified through field campaigns, monitoring flights over the volcano and ground-based infrared and optical cameras. Since May, 2021 this volcano has produced continue lava emissions emplaced along the northern and northeastern flanks of the volcano. From ground-based infrared and optical cameras (2.8 km northeast of the crater) that send images every 10 minutes by telemetry to the IG-EPN offices in Quito and from seismic signals, it has been possible to better constrain the understanding of the dynamics, emplacement, duration and characteristics of this lava flows. By analyzing the temperatures of the thermal anomalies distributed along the flanks of the volcano corresponding to the vent, the lava flow unit and its front since May 2021, it was possible to determine on one side, that the vent has been active since then with an average temperature of 80°C. On the other side, three lava flow pulses were identified corresponding to: Pulse one, mid-May to late October 2021 (Ta=94°C); Pulse two, early October to early June 2021 (Ta=86°C); Pulse three, early July 2022 to present (September, 2022) (Ta=82°C). These estimates were based on measuring the temperatures of lava flow pulses zones, by observing their variation in time and subsequently their cooling. Additionally, in order to determine the activity of this pulsatile lava, we also analyzed thermal anomalies given by FIRMS data to see how these two methodologies provide agreement in the characterization of superficial volcanic activity.

485

Understanding the Kilauea caldera collapse infrasonic and seismic tremor source

Mr Leonardo Van Der Laat[1], PhD Zack Spica[1], PhD Corentin Caudron[2]
[1]*Department of Earth and Environmental Sciences, University Of Michigan, Ann Arbor, United States,* [2]*Université Libre de Bruxelles, Bruxelles, Belgium*

The Kilauea caldera collapse in 2018 was accompanied by seismic and infrasonic tremors during the phases of (1) lava lake draining and steady subsidence; and (2) small periodic collapse events and explosions. In this work, we seek to understand the source of these signals. In order to locate the seismic source, we train a regression model based on seismic amplitudes and precise local earthquake locations. We obtain a source position at a few hundred meters NW of the Halema'uma'u crater and about 1 km deep, which coincides with the position of the summit magma reservoir determined in other studies. We also analyzed the infrasonic tremor which is sourced at the active vent. We conceptualize the tremor in analogy to the speech source-filter model, where the magma reservoir acts as the generator while the overlying conduits and cavities act as the acoustic filter. We modeled the draining magma flux rate from a system of cracks based on the gliding of the tremor spectral notches.

658

Lava-water interaction produced an ash-poor, electrified plume at the onset of the December 2020 summit eruption of Kīlauea Volcano, Hawai'i

Dr Ryan Cahalan[1], Dr Larry Mastin[1], Dr Alexa Van Eaton[1], Dr Shaul Hurwitz[2], Adam Smith[3], Josef Dufek[4], Stephen Solovitz[5], Matthew Patrick[6], Johanne Schmith[6], Carolyn Parcheta[6], Weston Thelen[1], Drew Downs[6]
[1]U.S. Geological Survey, Cascades Volcano Observatory, Vancouver, United States, [2]U.S. Geological Survey, California Volcano Observatory, Moffett Field, USA, [3]Gemini Observatory/NSF's NOIRLab, Hilo, USA, [4]Department of Earth Science, University of Oregon, Eugene, USA, [5]Washington State University, Vancouver, USA, [6]U.S. Geological Survey, Hawaiian Volcano Observatory, Hilo, USA

The appearance of a water lake in Kīlauea's Halema'uma'u crater in 2019 accelerated concerns of violent magma-water interaction akin to historical activity at the volcano's summit. However, the eruption beginning 20 December 2020 was unusual in many respects. Lava effusion into the water lake sent a lightning-rich volcanic plume to 11–13 km above sea level. This plume height is among the tallest on record for Kīlauea and would suggest a high mass eruption rate, yet boiling of the lake and the subsequent plume did not produce a measurable fall deposit, nor did it generate infrasound signals consistent with impulsive, high-energy explosions. Analyses of satellite, webcam astrometry, and weather radar data show that the volcanic plume was rich in water and ice but contained no detectable ash – certainly less than expected from its maximum height. Despite this, we cannot rule out the possibility that undetectable amounts of airborne ash still posed a hazard to aircraft. Ground-based webcams captured four lightning flashes, three of which were also measured by the satellite-based Geostationary Lightning Mapper onboard GOES-17. Volcanic lightning was confined to freezing altitudes of the upper cloud, suggesting that ice formation (not ash particle collisions) drove electrification in the plume. The low acoustic energy of the lava-water interaction points to a weakly explosive style of hydrovolcanism, most likely from boiling of the crater lake over ~90 minutes. Heat transfer calculations explain how inefficient lava-water mixing could provide enough energy to boil the 9.16×10^5 m3 water lake within this timeframe without triggering explosive fragmentation. Overall, our findings shed light on an unconventional style of volcanism in which lava-water interaction transferred most of its energy into steam generation rather than particle fragmentation, generating a high-altitude plume from weakly explosive activity.

392

Volcanic lightning from the 15 January 2022 eruption of Hunga Volcano, Tonga

Dr Alexa Van Eaton[1], Dr. Sonja A. Behnke[2], Dr. Jeff Lapierre[3], Dr. Christopher J. Schultz[4], Dr. Chris Vagasky[5]
[1]U.S. Geological Survey, Cascades Volcano Observatory, Vancouver, USA, [2]Los Alamos National Laboratory, Los Alamos, USA, [3]Earth Networks, Germantown, USA, [4]NASA's Short-Term Prediction and Research Transition Center, Marshall Space Flight Center, Huntsville, USA, [5]Vaisala, Inc., Louisville, USA

The climactic eruption of Tonga's Hunga Volcano on 15 January 2022 produced the most intense lightning storm ever measured. How did this volcanic plume become so strongly electrified, and what does it reveal about the dynamics of the submarine eruption? We examine how magma-seawater interaction, plume microphysical processes, and umbrella cloud dynamics influenced the evolution of lightning from this extraordinary event. Lightning observations have been combined from three ground-based networks: (a) Vaisala's Global Lightning Dataset and (b) Earth Networks' Total Lightning Network, which includes data from (c) the World Wide Lightning Location Network. Results yield an astonishing amount of lightning produced on 15 January (>196,000 flashes), with peak rates exceeding 2,500 flashes per min. GOES-17 satellite observations show an initial volcanic plume before 4:00 UTC, but the first-detected pulse of lightning did not occur until the plume rose high enough to freeze (>8–9 km above sea level). In map view, the lightning locations detected by ground-based networks reveal successive, radially expanding rings of lightning activity. The first, largest, lightning ring initiated ~4:25 UTC and expanded at a rate commensurate with the upper umbrella cloud. An intriguing observation is that the optical Geostationary Lightning Mapper onboard GOES-17 stopped detecting this lightning while the plume was sustained above ~30–35 km asl. We infer the upper umbrella was optically thick enough to obscure the prolific lightning detected by ground-based systems. These findings suggest that most of the lightning occurred below 30 km asl, which was much lower than the maximum height of the umbrella and its overshooting top. Integrating our observations with previous simulations of large-scale 'wet' eruptions, we speculate that intense magma-seawater interaction sustained a mixed phase microphysical zone in the volcanic plume, injecting ash, ice, graupel, and liquid water well into the stratosphere.

562

Quantitative analysis of morphometric evolution through degradation of subduction arc composite volcanoes

Ms. Roos Marina Johanna van Wees[1], Dr. Daniel O'Hara[1], Dr. Gabor Kereszturi[2], Dr. Pablo Grosse[3,4], Dr. Pierre Lahitte[5], Dr. Matthieu Kervyn[1]
[1]Department of Geography, Vrije Universiteit Brussel (VUB) , Brussels, Belgium, [2]Volcanic Risk Solutions, School of Agriculture and Environment, Massey University, Palmerston North, New Zealand, [3]Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), , Argentina , [4]Fundación Miguel Lillo, Tucumán, Argentina , [5]GEOPS, CNRS, Université Paris-Saclay, 91405 Orsay, France

The topography of composite volcanoes is inherently a cumulative product of eruptive, intrusive and erosion processes throughout time. Previous studies show that volcano erosion patterns evolve from umbrella-like drainage networks with multiple narrow gullies to a few large valleys widening towards the edifice centre. However, the processes, that dictate long-term volcano degradation, as well as their controlling factors, are still poorly understood. This study aims to quantify the patterns resulting from long-term volcano degradation and analyse how different controlling factors manifest in the eroded edifice morphologies.

We compile a morphometric dataset of volcanic geomorphologies for more than 80 conical composite volcanoes across the Indonesian and Japanese island arc systems. In particular, we quantify both landform-scale edifice morphologies and the geometries of edifice drainage basins using 30 m TanDEM-X Digital Elevation Models. For each volcano, chronology of eruptive activity, climate and tectonic context are also documented. Multivariate statistical approaches (e.g. Principal Component Analysis) are used to investigate the links between the edifice morphologies, age, climate and tectonic context on erosion rates and patterns.

Results highlight that the irregularity index correlates negatively with the height/basal width ratio and drainage density. Drainage density decreases when the volcano gets older and basins become wider with increasing volcano age. The normalized number of basins increases with higher elevation. Overall, Indonesian and Japanese composite volcanoes show similar morphometric trends, however, the correlations between the morphometric parameters are stronger for Indonesian volcanoes. These arc-scale variations show consistent trends that give insight into the main controlling factors of volcano erosion and morphology.

560

Insights into volcano degradation from analogue modelling: how volcano shape and size influence runoff erosion and morphology

Ms. Roos Marina Johanna van Wees[1], Dr. Engielle Paguican[1], Dr. Daniel O'Hara[1], Dr. Gabor Kereszturi[2], Dr. Pablo Grosse[3,4], Dr. Pierre Lahitte[5], Dr. Matthieu Kervyn[1]

[1]Department of Geography, Vrije Universiteit Brussel (VUB) , Brussels, Belgium, [2]Volcanic Risk Solutions, School of Agriculture and Environment, Massey University, Palmerston North, New Zealand, [3]Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), , Argentina , [4]Fundación Miguel Lillo, Tucumán, Argentina , [5]GEOPS, CNRS, Université Paris-Saclay, 91405 Orsay, France

Composite volcanoes have diverse morphologies due to their inextricably intertwined eruption, intrusion, and degradation histories. Surface runoff, a major erosional process involved in volcanic degradation, is dominantly controlled by climatic, lithologic, and topographic factors. Analogue models offer the opportunity to examine rainfall-induced erosion on a scaled volcano cone with the advantage of a well-constrained initial shape, homongenous lithology and controlled precipitation. In this study, we aim to document the morphological evolution and quantify eroded volumes and rates on variously-shaped analogue volcanic cones.

The experiments were carried out at the VUB volcanology analogue laboratory. Analogue volcanic landscapes were built from a combination of granular material consisting of silica sand, silica flour and kaolin. Cone shapes were scaled based on simplified measurements (height, base width, and slope angle) of natural pristine composite volcanoes; cones both with and without summit craters were analysed. Rainfall-induced erosion was simulated with four atomizer sprinklers. Using four DSLR cameras, photogrammetry-derived digital elevation models with sub-millimetre spatial resolutions were computed at regular time intervals during the experiments, allowing to estimate volume loss, which was compared to the measured sediment yield. Morphometric and drainage parameters of the eroding cones were then obtained with the automated MorVolc and DrainageVolc algorithms, previously used on natural volcanoes.

The resulting drainage network and morphological features of the analogue models mimic those occurring at natural volcanoes with different ages and climatic settings. Our results emphasize the importance of the initial cone morphometry on its subsequent morphological evolution by degradation processes. The next step will be to compare the main morphometric evolution with what is observed on natural volcanoes.

1375

Transitions between different eruptive regimes: deciphering precursors in a complex system

Dr Nick Varley[1]
[1]*Universidad de Colima, Colima, Mexico*

The most recent activity at Volcán de Colima, Mexico was characterised by frequent transitions between contrasting regimes: rapid dome-building effusive phases transformed into periods of recurrent Vulcanian explosions; very slow magma emplacement terminated with multiple larger explosions, which produced dangerous pyroclastic density currents. The underlying cause of these transitions reflects a complex plumbing system, though the composition showed very little variation during the period, evidence points to periodic shifts in the volatile-contents and temperature of the magma resulting in changes in viscosity, and hence transitions in eruption style.

Clear geophysical and geochemical precursors preceded some events during the 1998 – 2017 period of activity, however, others, such as the complex effusive/explosive eruption in 2015, arrived largely unannounced and generated significant hazards. The monitoring strategy at persistently active and complex volcanoes, such as Volcán de Colima, needs to be comprehensive, with rapid analyses and interpretations. Decisions that are part of risk mitigation plans need to consider hard quantitative evidence, but experience from previous crises can also play an important role, the correct balance between the two often being difficult to achieve. Predefined tools, such as a clearly defined alert level system and hazard zonation maps can be invaluable for unbiased decision making.

Volcán de Colima has shown minimal signs of activity during the last 5 years. The question still exists to whether a new catastrophic sub-Plinian to Plinian eruption is imminent, given the observed 100-year cycle, the most recent event occurring in 1913. A precise interpretation of any fresh precursory signals to sudden explosive events is vital for timely and pertinent decisions regarding mitigation actions in the surrounds population centres.

571

What is the origin of shear thinning in crystal-bearing magmas?

Dr Jeremie Vasseur[1], Dr Fabian Wadsworth[2], Prof. Donald Dingwell[1]
[1]LMU, Munich, Germany, [2]Durham University, Durham, United Kingdom

Crystal-bearing magmas are assumed to be intrinsically non-Newtonian with only qualitative or empirical descriptions of apparent shear-thinning behaviour. Similarly, the threshold for brittle fracture for these materials remains poorly constrained. Here, we compile existing data for the rheology of high-temperature synthetic silicate crystal-bearing magmas across a wide range of conditions, in order to test microphysical models for the real origin of shear-thinning effects. Our hypothesis is that shear thinning in these materials arises from unrelaxed shear thinning in the melt phase or viscous heating, or both. In order to test this, we define a 'lever' function L which scales for the amplification of strain rate in the melt phase between crystals. We show that when the strain rates are amplified by the L factor, a validated shear-thinning law for the melt phase accounts for the observed non-Newtonian behaviour. We then use the Brinkman number Br to demonstrate that some existing data are also subject to viscous heating, which can manifest as apparent shear thinning. Taken together, our results provide a theoretical framework that predicts a microphysical mechanism for shear thinning. This implies that crystal-bearing magmas may in fact be Newtonian except for when the scaled conditions for viscous heating are met, or when the strain rates in the melt phase approach the inverse of the structural relaxation timescale. Additionally, these results imply that shear thinning due to non-Newtonian behaviour in the melt between crystals occurs only very close to the brittle threshold, and that it is therefore an effect that may be closely associated with failure, rather than being intrinsic or pervasive during magma ascent. Our analysis provides constitutive laws that can be upscaled to magma ascent conditions.

1084

Signatures of sediment input and mantle heterogeneity recorded in melt inclusions from the Lesser Antilles

Dr Swetha Venugopal[1], Dr. Severine Moune[2], Dr. Giancarlo Tamburello[3], Vincent Robert[4], Dr. Thomas Christopher[4], Dr. Glyn Williams-Jones[5], Dr. Erouscilla Joseph[6]

[1]NASA JSC/LPI, Houston, United States, [2]Institut de Physique du Globe de Paris, Paris, France, [3]Istituto Nazionale Geofisica e Vulcanologia (INGV), , Italy, [4]l'Institut de Recherche pour le Développement (IRD), , New Caledonia, [5]Montserrat Volcano Observatory, , Montserrat, [6]Simon Fraser University, , Canada, [7]Seismic Research Centre, The University of the West Indies, , Trinidad & Tobago

The Lesser Antilles Arc is formed by the slow (2-3 cm yr^{-1}) and oblique westward subduction of the South American Plate beneath the Caribbean Plate. Notable along-arc variations in geochemistry, volcanic activity, seismicity, and crustal structure are attributed to the age and velocity of the subducting plate, however both are virtually uniform along the arc. In contrast, a likely candidate is the north to south variability in the amount and composition of the sediment veneer atop the subducting plate. Here we evaluate the role of sediments on the along arc transition from tholeiites to high magnesian basalts along the arc by using olivine-hosted melt inclusions from arc basalts. We analysed olivines from St. Kitts (Fo70-80), Guadeloupe (Fo64-78), and Dominica (Fo75-79), and compiled literature data from St. Vincent (Fo84-90), to ensure north to south coverage along the arc. Across the arc, there is no dependence of mobile/immobile trace element ratios on olivine composition and low Sr/Y implying insignificant crustal contamination. Similarly, the generally low Nb/Y (<0.15) suggests large degrees of partial melting across the arc. Elevated Zr/Nb (>20) values beneath all centres supports a depleted source that has been modified by subduction components. All centres have constant Nb/Ta and Zr/Hf values (~13 and ~31 respectively), similar to global marine sediment values (14.2 and 35). Positive correlations between La/Sm and Yb/Sm signal the presence of incoming Pacific clays beneath St. Kitts and Guadeloupe, while similar correlations between Ba/La and La/Sm highlight the unique presence of biogenic sediments beneath Dominica and St. Vincent. Preliminary mixing models suggest that melts generated by up to 15 % of sediment melting plus a depleted mantle can account for the melt inclusion compositions. This study provides new insights into the role of subducting sediments in providing unique trace element signatures in arc basalts.

855

Using images to improve understanding of volcanic hazards using VolFilms and the photo collection of the Smithsonian's Global Volcanism Program

Mr Edward Venzke[1], Dr. Benjamin Andrews[1], Dr. Janine Krippner[1], Dr. Sarah Brown[1]
[1]*Smithsonian Institution, Washington, United States*

Images are one of the most effective tools for communicating geoscience and hazards information. Comprising over 5,000 volcano photos organized in topical and volcano galleries, and more than 8,500 images included in volcanic activity reports, the collection provided by the Smithsonian's Global Volcanism Program (GVP) is a reliable resource that can be effectively utilized by a wide variety of users, including researchers, communities, and decision-makers. The curated theme galleries have been restructured to align with the VolFilms topics for volcanic hazards and processes, impacts, and experiences videos.
Over the past few years every caption for gallery photos has been professionally reviewed and updated, evaluated for inclusion in the new gallery topics, and assigned keywords. Beyond volcanic hazards and processes, additional galleries present volcanic types and features, new satellite imagery, and specific photographers. Almost 150 keyword galleries provide supplement the broad topical collections. New photos were solicited from currently active volcanologists and professional photographers, adding xxxx high-quality images that complement the older collections.

A collaboration between GVP, the U.S. Geological Survey, U.S. Agency for International Development, and Bristol University has resulted in four new VolFilms (Volcano Monitoring, Health Hazards of Volcanic Ash, Debris Avalanches and Landslides, and Human Experience: Lava Flows), each available in eight language versions (US English, UK English, Spanish, French, Italian, Indonesian, Tagalog, Japanese). The entire collection of 120 videos is available through the GVP website galleries.

Understanding the complexity and variety of volcanic and other natural hazards is challenging, for both professionals and the public. Regardless of the audience or medium, combining photo and video elements with other informational content will improve audience attention and communication. It is hoped that this resource will be used in a wide variety of efforts around volcano education.

854

Eruption histories in the Volcanoes of the World database expanded with episodes and events

Mr Edward Venzke[1], A. Elizabeth Crafford[1], Dr. Benjamin Andrews[1], Ms. Sally Sennert[2], Ms. Kadie Bennis[1]
[1]Smithsonian Institution, Washington, United States, [2]United States Geological Survey, Washington, United States

Organizing eruption data presents many challenges, which the Smithsonian's Global Volcanism Program (GVP) has been working on for the past 50 years. For classification purposes, the guideline for defining an eruption in the GVP Volcanoes of the World (VOTW) database is ejection of fragmental rocks or effusion of liquid lava at a volcano with no pauses longer than three months. Previous versions of the database included eruption "phases" (in a very limited way) and "characteristics" (as simple check-box data). Starting with VOTW v.5 (public in late 2022), eruption histories will include dated "Episodes" and "Events" in addition to the current overall start and stop dates. Episodes are used to group related events, and can distinguish activity taking place within a specific time period or simultaneously from different vent locations. Events such as significant explosions, lava flows, lahars, or ashfall are linked to each Episode, with associated dates and explanatory descriptions. This structure to track and document activity is especially useful for complex and long-lasting eruptions at volcanoes such as Kilauea or Etna.

In recent years GVP has been updating eruption data to use this Eruption / Episode model and be more consistent with our stated guidelines. Thousands of dated events have been added to eruptions beginning in 2010 or later. These data are sourced from the Smithsonian / USGS Weekly Volcanic Activity Report and the Bulletin of the Global Volcanism Network, which in turn are narrative descriptions based primarily on reports from volcano observatories and other reliable contemporary sources. This eruptive history for each volcano is presented online with expandable drop-down sections, and as downloadable files with unique eruption, episode, and event identifiers. Designed for flexibility to accommodate a wide range of volcanism, we hope that this organizational structure can provide a useful data model for volcanology researchers.

534

Regional seamounts in Southeast Asia: A hazard perspective

Dr Andrea Verolino[1], Ms Su Fen Wee[2], Professor Susanna Jenkins[1,2], Professor Fidel Costa[1,2,3], Professor Adam Switzer[1,2]
[1]Earth Observatory Of Singapore, Nanyang Technological University, Singapore, Singapore, [2]Asian School of Environment, Nanyang Technological University, Singapore, Singapore, [3]Institut de Physique du Globe de Paris, Paris, France

Volcanic seamounts are a common physiographic feature of Earth. Still, only a few of them have been studied in any detail. Commonly hard to physically access, they can be investigated through geospatial techniques that can reveal useful information for more focused studies and for submarine eruptions and volcano-tsunami risk assessments. Southeast Asia hosts over 750 active or potentially active volcanoes, and according to the Global Volcanism Program only 4 of them are fully submerged. In contrast, a recent global seamount dataset shows that there are ~450 of them in Southeast Asia that have been identified but not studied. The new availability of medium-resolution global bathymetry data (Gebco 2022, ~450-m/pixel), and more localised higher-resolution multibeam ship tracks (NOAA, 90-m/pixel), provides an opportunity to conduct a first-time characterisation of some of these volcanoes in Southeast Asia, based on their morphologies. We conducted this assessment through quantitative (e.g. slope angles, height) and qualitative (e.g. seamount morphology, presence of landslide morphological features) analyses. Using this dataset we describe the likely type of hazard(s) they might have produced in the past and may produce in the future, in case of eruption. The results show that the majority of the seamounts (~53%) are composite edifices that likely experienced several stages of growth (e.g. ridges/massifs with multiple vents) and destruction (e.g. presence of landslide scars and asymmetric flanks); some are simple pointy cones (~5%) and flat-topped edifices (~2%), providing clues about their relative age; a few show evidence of past explosive activity (calderas with steep inner walls, ~1%); while a relevant number (~39%) could not be classified using the currently available resolution. These initial results suggest that medium-resolution bathymetry data can be a valuable resource in preliminary hazard studies, and highlight sites in Southeast Asia where high-resolution bathymetry is needed for more quantitative hazard and impact analysis.

576

Indirect boundary integral modelling and paleoseismology provide insights into fault rupture triggered by rhyolite eruptions, Okataina Volcanic Centre, New Zealand

Dr Pilar Villamor[1], Dr Rafael Benites[1], Dr Geoff Kilgour[2], Dr Kelvin Berryman[3]
[1]GNS Science, Lower Hutt, New Zealand, [2]GNS Science, Warakei, New Zealand, [3]Berryman Research and Consulting, Porirua, New Zealand

Within the Taupō Volcanic Zone (TVZ), New Zealand, faults have ruptured on tectonic segments in association with prehistoric eruptions sourced from the Okataina Volcanic Centre (OVC), a magmatic segment of the TVZ. In both the Whakatāne and Ngakuru tectonic segments, north and south of the OVC, respectively, fault rupture occurred during the 9.5 cal. ka BP Rotoma eruption. We use published field data from fault trenches and numerical modelling to illustrate possible triggering.

The method we use for modelling is an indirect boundary integral numerical scheme based on point, single-force regular distribution over the closed surface of the prescribed magma reservoir, and Green's function representation of each single-force contribution to the overall deformation.

The Rotoma eruption occurred in the Haroharo Volcanic Complex (HVC), one of the two active volcanic lineaments within the OVC. The total eruptive volume was 8 km3 and the eruptions occurred at three different vents aligned along 12 km of the lineament. Three distinct magma compositions erupted from distinct vents. These published data on the Rotoma eruption are used to define possible magma reservoir sizes and locations for the modelling. Surface faulting on the Paeroa and the Whirinaki Faults, (N45°E striking, 60°NW dipping normal faults in the Ngakuru segment) was associated with the eruption, at least 24 and 31 km distant from the nearest Rotoma vent. Several co-eruptive surface ruptures have also been identified on the Manawahe Fault (N70°E striking, 60°SE dipping normal fault located in the Whakatane segment) at least 7 km from the closest Rotoma vent. Published paleoseismic data are used to explore the magma reservoir conditions that could generate the appropriate stresses at the fault that are capable of triggering rupture.

276

Lahar risk awareness and preparedness among Mount Rainier, USA, communities

Dr Lauren Vinnell[1], Dr Emma Hudson-Doyle[1], Prof David Johnston[1], Dr Julia Becker[1], Lucy Kaiser[1], Professor Michael Lindell[2], Professor Ann Bostrom[2], Professor Chris Gregg[3], Maximilian Dixon[4], Brian Terbush[4]
[1]Joint Centre For Disaster Research, Wellington, New Zealand, [2]University of Washington, Seattle, United States, [3]East Tennessee State University, Johnson, United States, [4]Washington State Emergency Management Division, Camp Murray, United States

Communities living near snow-capped volcanoes are often at a high risk of lahar and other debris flow impacts, with several devastating events in recent global history such as the loss of over 23,000 lives in Colombia in 1985. One such volcano which poses a significant lahar risk is Mount Rainier, Washington, United States which has a large amount of glacial ice and snow. Over 150,000 people live near this volcano and are at risk from potential impacts. In order to reduce the likelihood of negative outcomes for these communities, it is important to understand how they perceive and prepare for this risk. An online survey (N = 830) found differences based on demographic, social, and behavioural factors which could have implications for communication and engagement with these communities. For example, men saw themselves as more prepared and had weaker intentions to prepare, self-perceptions of preparedness as well as likelihood of having an emergency kit were highest among those who neither live nor work in a lahar hazard zone, and self-efficacy and intentions to evacuate appropriately were better among those who had practised drills and evacuation. These findings demonstrate the importance of considering and understanding the particular context of communities at risk of volcanic impacts when determining how to communicate that risk and how to encourage preparedness actions.

1448

Volcano-tectonic interaction on the Reykjanes Peninsula, Iceland involving repeated magma intrusions, intense seismic swarms and volcanic eruptions during 2019 –2022

Dr Kristín Vogfjörd[1], Dr Michelle M. Parks[1], Benedikt G. Ófeigsson[1], Dr Freysteinn Sigmundsson[2], Dr Halldór Geirsson[2]
[1]Icelandic Meteorological Office, Reykjavik, Iceland, [2]Institute of Earth Sciences, University of Iceland, Reykjavík, Iceland

The Mid-Atlantic ridge enters land along the Reykjanes Peninsula oblique rift in SW Iceland, where sub-parallel volcanic fissure swarms, trending NE-SW interact with N-S striking parallel strike-slip faults distributed across the length of the peninsula. Repeated volcano-tectonic interaction events have occurred on the peninsula, but prior to the two recent eruptions in 2021 and 2022, the last eruption occurred 800 years ago. Earthquake activity however is frequent, with events up to M6 occurring on the N-S faults. A few such medium-size events have occurred over the last several decades as well as repeated seismic swarms in the volcanic fissure swarms. Plate spreading of 1.9 cm/yr has been recorded by GNSS and InSAR over two decades.

Duration of the current sequence is from December 2019 to August 2022. The activity started with an earthquake swarm at Fagradalsfjall and propagated west to the Svartsengi geothermal area. High-precision relocation of seismicity revealed activation of many short, mostly N-S faults in an area surrounding 3 magmatic sill intrusions emplaced at shallow depth, during January-July 2020. A fourth sill was intruded in the same location in May 2022. in July 2020 a sill was also intruded in the Krísuvík geothermal area. The sills' locations and volumes were constrained by modeling of InSAR and GNSS data. An intense seismic swarm at Fagradalsfjall during February-March 2021, including over 60 $M_w \geq 4$ earthquakes and accompanied by significant surface deformation marked the intrusion of a 9 km-long 34 km^3 vertical dyke , which ended in a volcanic eruption lasting 6 months. A second intrusion occurred along the dyke's southern part in December 2021 and a third in July/August 2022, along the northern section, ended in an eruption from a small fissure just north of the initial eruption site. A few cm slip, along the plate boundary accompanied the dyke intrusions.

1402

Open access to volcanological data and products at the Icelandic Volcano Observatory

Dr Kristín Vogfjörd[1], Gunnar B. Gudmundsson[1], Hildur M. Fridriksdóttir[1], Dr Sara Barsotti[1], Ríkey Júlíusdóttir[1], Sigurlaug Hjaltadóttir[1], Hanna Blanck[1], Benedikt G. Ófeigsson[1], Dr Bergrún A. Óladóttir[1], Esther H. Jensen[1], Kjartan A. Jónsson[1], Matthías Pétursson[1]
[1]*Icelandic Meteorological Office, Reykjavik, Iceland*

The Icelandic Volcano Observatory operates within the Icelandic Meteorological Office (IMO), which is responsible for monitoring and research of all natural hazards in Iceland, and for providing warnings and forecasts of these hazards to society as well as to both Civil Protection and Aviation authorities. Furthermore, the IMO's role includes archiving and preservation of data on long-term developments of natural processes, including seismicity, crustal movements and volcanic activity. To fulfill these responsibilities, the institute operates multidisciplinary monitoring systems, recording a wide variety of geophysical, geological and volcanological data. The data are mainly recorded for monitoring purposes but must also fulfill requirements for sufficient quality to sustain IMO's current and future research.

To meet requirements for more open data access, the IMO is taking measures to upgrade and quality check its multidisciplinary data archives. The data, presently stored in a variety of different file structures, data bases, and formats, are being moved to community standard formats, data bases and structures where they can be easily Findable, Accessible, Interoperable and Re-usable (FAIR) by outside users. Through over a-decade-long participation in EPOS (the European Plate Observing System) and as Iceland's representative in the EPOS ERIC consortium, IMO has already created several new API services providing open access to quality checked volcanological data, both at the IMO data hub and through the EPOS Volcano Observations Thematic Core service (VO-TCS). These services were populated by more multidisciplinary data from recent volcanic events in Iceland under the recently completed H2020 EUROVOLC project, and further upgraded in the ongoing EPOS-Iceland (epos-iceland.is) national infrastructure project. The services, data and products from the Bárdarbunga 2014-15 unrest and eruption and the ongoing Reykjanes peninsula volcano-tectonic events will be presented

1379

Effusion Rates as a Control for Transitional Lava Morphologies: A Case Study from the 2014–2015 Holuhraun Lava Flow-Field, Iceland

Ms Joana R. C. Voigt[1], Dr Christopher W. Hamilton[1], Dr Ármann Höskuldsson[2], Dr Ingibjörg Jónsdóttir[3], Dr Thorvaldur Thordarson[3]

[1]Lunar and Planetary Laboratory, University of Arizona, Tucson, United States, [2]Faculty of Earth Sciences, University of Iceland, Reykjavik, Iceland, [3]Institute of Earth Sciences, University of Iceland, Reykjavik, Iceland

Lava morphologies can be used as a powerful tool to unravel emplacement dynamics and reconstruct conditions of past eruptions on Earth and other planetary bodies. The 2014–2015 fissure-fed Holuhraun eruption in the highlands of Iceland presents a unique study site to explore the link between lava morphology and effusion rate, as a controlling parameter. The lava flow-field was emplaced onto a flat-lying glacial outwash plain, the chemistry remained constant during the eruption (Halldórsson et al., 2018), and the eruption was well monitored including pre, -syn, - and post-eruption datasets (Pedersen et al., 2021). The Holuhraun lava flow-field is dominated by three lava morphologies (i.e., facies), namely rubbly (57%), spiny (26%), and undifferentiated rubbly–spiny (10%; Voigt et al., 2021), which together cover 93% of the entire flow. Here, we utilize a 1:800 scale lava facies map in combination with a novel chronological map and two independently derived Time Average Discharge Rate datasets (TADR; Bonny et al., 2018 and Coppola et al., 2017) to evaluate the correlation between lava morphologies and effusion rates. Our results show that in the beginning, the lava morphology is controlled by the effusion rate at the vent and with a more evolved lava flow-field, the transport system and thus local effusion rate exerts a stronger control. Further, rubbly lava is formed under high local effusion rates with pulsating lava supply, reflected in a high variance of the TADR. In contrast, spiny lava was emplaced under lower local effusion rate with a steadier lava supply (low TADR variance).

Bonny et al., 2018, Journal. of Geo. Res.: Solid Earth. Coppola et al., 2017, Geology. Halldórsson et al., 2018, Contrib. Mineral. Petrol., Voigt et al., 2021, J. Volcanol. Geotherm. Res.

793

Trachydacite Magma Storage and Ascent Before the 1257 Eruption of Mt Samalas: Insights from an Experimental Study

Miss Annika Voigt[1], Dr Michael Cassidy[1], Prof Jonathan Castro[2], Prof David Pyle[1], Prof Tamsin Mather[1], Dr Christoph Helo[2], Dr Mirzam Abdurrachman[3], Dr Idham Andri Kurniawan[3], Dr Katherine Dobson[4], Prof Atsushi Toramaru[5]

[1]Department of Earth Sciences, University of Oxford, Oxford, United Kingdom, [2]Institute of Geosciences, Johannes Gutenberg-University Mainz, Mainz, Germany, [3]Faculty of Earth Sciences and Technology, Bandung Institute of Technology, Bandung, Indonesia, [4]Department of Civil and Environmental Engineering, University of Strathclyde, Glasgow, United Kingdom, [5]Department of Earth and Planetary Sciences, Kyushu University, Fukuoka, Japan

In 1257, Mt Samalas volcano on Lombok island, Indonesia, produced one of the most explosive and sulphur-rich eruptions recorded in the last 1000 years. The Samalas eruption products are of intermediate alkaline composition, similar to other powerful volcanic events (e.g., Tambora 1815, El Chichón 1982), yet this type of magma is still relatively understudied.

In this project, we performed partial equilibrium experiments on natural trachydacite pumice of the 1257 Samalas eruption to investigate magma phase relations at different P-T conditions and the final magma storage conditions before the eruption. The experiments were run under water-saturated conditions and at P-T conditions between 850-1000°C and 25-200 MPa and an oxygen fugacity fO_2 of NNO(+1) log units. A second set of experiments is composed of decompression experiments simulating magma ascent in the volcanic conduit towards the surface. Water-saturated experiments are decompressed at different rates, starting from magma storage P-T conditions, in order to study volatile saturation and bubble nucleation behaviour during trachydacite magma ascent.

Textural and geochemical changes in the equilibrated experimental matrix glass and minerals were analysed and compared with data from the natural pumice to identify potential magma reservoir conditions. Experimental matrix glass and mineral compositions between 875-930°C and 100-150 MPa (4.5 ± 1 km depth) replicated the natural results, indicating likely reservoir conditions. Initial H_2O contents in experimental glasses (FTIR) at equilibrium propose relatively high H_2O solubility (about 3.73 wt.% at 50 MPa) in trachydacite magma.

The relatively limited and shallow storage pressures (100-150 MPa) indicated by our experiments suggest that intermediate alkaline magma causing highly explosive eruptions can accumulate in one place rather than be extracted rapidly from a vertically-extensive, transcrustal magma system. A potentially high volatile solubility, suggested by our initial results, might have implications for increased explosivity of trachydacite systems.

566

Comparative geomorphometric classification of terrestrial and Martian scoria cones

Fanni Vörös[1], Dávid Karátson[2], Balázs Székely[3]
[1]Doctoral School of Earth Sciences, ELTE Eötvös Loránd University, Pázmány P. sétány 1/C, H-1117 , Budapest, Hungary,
[2]Department of Physical Geography, ELTE Eötvös Loránd University, Pázmány P. sétány 1/C, H-1117, Budapest, Hungary,
[3]Department of Geophysics and Space Science, ELTE Eötvös Loránd University, Pázmány P. sétány 1/C, H-1117 , Budapest, Hungary

Classic scoria cone morphometric research began in the first half of the 20th century: field surveys and various resolution maps provided its basis. With the advent of new imaging technology, new processing tools were needed: nowadays, various analysis modules and plug-ins are becoming increasingly common in GIS software. The combination of digital terrain models (DTMs) and appropriate processing software allows the automated processing of areas abridged many of the difficulties of classical surveying: 1) large areas can be processed 2) even extraterrestrial fields can be studied 3) relatively cost-effectively 4) objectively 5) and in timely manner.

In our research, on the one hand, we examined the classic parameters, now based on DTMs (which frequently give significantly better results than formula-based ones), and additionally, we also apply newly introduced methods.

Classical parameters of 501 terrestrial (from four different volcanic areas) and 14 Martian scoria cones were examined. Beside the classical parameters, we intended to study the (a)symmetry of the cones. To this end Polar Coordinate Transformed (PCT) maps were created and the ellipticity of the shapes were also studied by computing the Spatial Elliptic Fourier Descriptors (SEFD). This approach can be used to study the direction and extent of elongation of scoria cones, whereas a truncated Fourier approximation can be used to estimate the complexity of the studied shapes. For the evaluation of the higher-order parameters further studies are required.

Our results show various levels of asymmetry for both terrestrial and Martian cones. Previous research found that parameters - especially cone width - are significantly bigger for Martian cones. This could be due to the lack of rain, vegetation, or human influence, less significant erosion, or different gravity values. However, as the parameters calculated here do not differ significantly from their terrestrial counterparts, further studies of this kind are encouraged.

550

Extending the range of electrical activity to low-explosivity basaltic volcanic eruptions

Dr Caron Vossen[1], Dr Corrado Cimarelli[1], Dr Alec J. Bennett[2,3]
[1]Department of Earth and Environmental Sciences, Ludwig-Maximilians-Universität München, Munich, Germany, [2]Bristol Industrial and Research Associates Ltd (Biral), Bristol, United Kingdom, [3]Department of Electronic and Electrical Engineering, University of Bath, Bath, United Kingdom

Previous studies on electrical activity in volcanic plumes generally focused on intermediate- to high-silica volcanoes producing ash-rich explosive eruptions with VEI ≥ 2, as these are typically associated with lightning activity. Very little is known, however, about the electrification of basaltic explosive eruptions, in particular those of low intensity generally characterising mafic volcanoes. The lower-intensity electrical activity associated with mild explosions is invisible to VHF antenna networks conventionally used to monitor thunderstorm lightning events at the regional scale and therefore requires dedicated monitoring instruments.

We used an ELF electrostatic lightning detector (100 Hz sample rate) to detect electrical activity associated with the mafic explosive eruptions at Stromboli, Cumbre Vieja and Etna during 2019-2021, spanning a wide range of eruptive styles. At Stromboli, generation of charge and electrical discharges were detected during single events characterising ordinary Strombolian, major and paroxysmal explosions (2019-2021). At Etna, volcanic lightning discharges were measured during a series of paroxysmal events (June-September 2021) characterised by the transition from Strombolian activity to sustained lava fountaining. At Cumbre Vieja, continuous recording (October-December 2021) showed changes in the electrical signature in response to the transition of eruptive styles.

Our results show that the fragmentation of hot and low viscosity magmas generates sufficient charging to result in measurable electrical discharges, albeit with a substantially smaller charge moment magnitude than thunderstorm lightning. Duration and number of electrical discharges correlate with the intensity of pyroclast ejection as well as eruption magnitude. Other electrical signals include movement of charge with respect to the sensor, marking the inception of impulsive eruptions in real-time, and ash fall impacting the instrument. Correlation of the electrical signature with the explosive style and other geophysical observations allows for the interpretation of changing eruptive conditions, further improving remote volcano monitoring.

552

The occurrence of volcanic lightning in basaltic explosive eruptions at Stromboli volcano, Italy

Dr Caron Vossen[1], Dr Corrado Cimarelli[1], Dr Alec J. Bennett[2,3], Dr Markus Schmid[1], Dr Ulrich Kueppers[1], Dr Tullio Ricci[4], Dr Jacopo Taddeucci[4]

[1]Department of Earth and Environmental Sciences, Ludwig-Maximilians-Universität München, Munich, Germany, [2]Bristol Industrial and Research Associates Ltd (Biral), Bristol, United Kingdom, [3]Department of Electronic and Electrical Engineering, University of Bath, Bath, United Kingdom, [4]Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy

Volcanic lightning is a common phenomenon during ash-rich explosive eruptions with VEI ≥ 2, typically associated with more silicic magmas. Lightning has also been observed during basaltic explosive eruptions producing large plumes (>1 km), but the electrification of smaller-scale mafic explosions remains understudied. We narrow this gap in knowledge by presenting the electrical signature of the explosive activity (VEI ≤ 1) of Stromboli volcano, Italy, recorded by an electrostatic thunderstorm detector measuring within the extremely low frequency range at a sample rate of 100 Hz.

Stromboli is well-known for its persistent eruptive activity of Strombolian explosions, which is occasionally interrupted by larger-scale major explosions and paroxysmal events. This provides the opportunity to study the electrical effects of basaltic explosive eruptions for a variety of eruption dynamics and source parameters.

Here, we present electrical observations of “normal” Strombolian explosions, three major explosions and unprecedented measurements of the 3 July 2019 paroxysm. Measurements of Strombolian activity, where variable amounts of ash, lapilli and incandescent bombs are ejected up to tens of metres, testify that these events generate sufficient charge to produce measurable electrostatic field variations relative to the sensor as well as very low voltage electrical discharges. The three major explosions showed apparent similarities, where the inception is marked by a strong movement of charge resulting from the ejection of charged pyroclasts, followed by tens of electrical discharges. The electrical signals from the 3 July 2019 paroxysm exceeded those from the major explosions in amplitude, discharge rate, and complexity, displaying characteristic variations during different phases of the eruption.

These results show that also impulsive lower-magnitude explosions generate detectable electrical activity, which holds promise for monitoring low VEI activity at mafic volcanoes.

1301

Local to national scale volcanic hazard to risk science delivered through partnership in Ethiopia

Dr Charlotte Vye-Brown[1], Dr Susan Loughlin[1], Dr Getnet Mewa[2], Prof Gezahegn Yirgu[2], Dr Elias Lewi[2], Yewub Bekele[3], Muluken Orione[4], Dr Pablo Tierz[1], Dr Ben Clarke[5], Prof Eliza Calder[6], Dr Susanna Jenkins[7], Dr Julia Crummy[1]

[1]British Geological Survey, Edinburgh, United Kingdom, [2]Addis Ababa University, Addis Ababa, Ethiopia, [3]Geological Survey of Ethiopia, Addis Ababa, Ethiopia, [4]National Disaster Risk Management Commission, Addis Ababa, Ethiopia, [5]University of Leicester, Leicester, United Kingdom, [6]University of Edinburgh, Edinburgh, United Kingdom, [7]Earth Observatory of Singapore, Singapore, United Kingdom

Long-term research over the last 15 years in Ethiopia has produced multi-disciplinary insights and a significant improvement in our scientific understanding of the drivers and processes of past and current magmatism and volcanism in the Main Ethiopian Rift and the Afar Depression. Despite these efforts, there remains particularly low data availability, high uncertainty and little/no dedicated volcano monitoring with which to adequately characterise eruption history and current activity status of the 59 Holocene volcanoes in Ethiopia. Yet, over 42 million people within 100 km of a volcanic centre are potentially exposed to the impacts of volcanic hazards in Ethiopia.

Through our partnership we have developed volcanic hazard assessment methodologies within the challenges of this data poor environment at local to national scales. These approaches have included expert elicitation, event trees, probabilistic hazard assessment including the selection of analogue volcanoes and process modelling using statistical approaches for conditions of high uncertainty.

Building on increasing awareness of the significance and cumulative impacts of geohazards at local, regional and national scales in Ethiopia, we present the progress achieved through transdisciplinary partnership with colleagues across observatories and responsible in-country institutions including: Addis Ababa University, the Geological Survey of Ethiopia, the National Disaster Risk Management Commission, government ministries, and stakeholders. We highlight the challenges in bringing the volcanic hazard science and risk management communities in Ethiopia together which will help to focus attention on next-steps towards implementation and making most effective use of the collective knowledge now gained through this work.

1296

Development of a volcanic hazard assessment methodology in low-data environments: Ascension Island, South Atlantic

Dr Charlotte Vye-Brown[1], Dr Julia Crummy[1], Dr Susan Loughlin[1]
[1]British Geological Survey, Edinburgh, United Kingdom

Knowledge of the character, frequency, magnitude and impacts of previous eruptions from historical records and geological data is in many cases insufficient to enable comprehensive volcanic hazard and impact assessments. Volcanic islands often have only sparse geological data due to a combination of poor exposure, poor deposit preservation, remote location, small physical size of the island, or a lack of resources to carry out the required fieldwork. Inhabitants of small isolated islands, such as the UK Overseas Territories in the South Atlantic, are exposed to multiple natural hazards and the effects of climate change, leading to increasing risks. However, there are limited options for early warning or timely self-evacuation in the event of a crisis. We present the development of a volcanic hazard assessment methodology for low data environments using an analysis carried out for Ascension Island in the South Atlantic as a case study. Using a combined approach of the available geological data, co-development of scenarios with the Ascension Island Government, expert elicitation, consideration of uncertainties, and the application of an eruption analogue to parameterise hazard models, we have carried out probabilistic vent-opening and tephra fall hazard analyses, as well as lava flow modelling. The probabilistic hazard maps form the evidence base to enable discussions with stakeholders on potential future volcanic activity and impacts.

1103

From pyroclasts to lava: Silicic volcanism and explosive-effusive transitions

Dr Fabian Wadsworth[1], Prof. Edward Llewellin[1], Dr Jeremie Vasseur[2], Dr Hugh Tuffen[3], Ms Annabelle Foster[1], Ms Holly Unwin[3], Prof Jonathan Castro[4], Dr Ian Schipper[5], Prof James Gardner[6], Dr David Damby[7], Dr Iona McIntosh[8], Prof Michael Heap[9], Dr Jamie Farquharson[9], Prof Donald Dingwell[2], Dr Kayla Iacovino[10], Dr Shane Rooyakkers[11], Dr Alexandra Kushnir[12], Dr Lucille Carbillet[9], Dr Jackie Kendrick[2], Prof Yan Lavallée[2], Dr Madeleine Humphreys[1], Prof Bettina Scheu[2], Dr Joshua Weaver[2], Dr Anthony Lamur[2], Dr Richard Brown[1], Dr Ben Ellis[13]

[1]Durham University, Durham, United Kingdom, [2]Ludwig-Maximilians-Universität, Munich, Germany, [3]Lancaster University, Lancaster, United Kingdom, [4]Johannes Gutenberg Universität, Mainz, Germany, [5]Victoria University of Wellington, Wellington, New Zealand, [6]Jackson School of Geosciences, Austin, United States, [7]United States Geological Survey, , United States, [8]JAMSTEC, Tokyo, Japan, [9]University of Strasbourg, , France, [10]Jacobs-NASA Johnson Space Center, Houston, United States, [11]GNS Science, , New Zealand, [12]EPFL, , Switzerland, [13]ETH, , Switzerland

Silicic volcanic eruptions range in style from gently effusive to highly explosive and may switch style unpredictably within a single eruption. Direct observations of subaerial rhyolitic eruptions (Chaiten 2008, Cordón Caulle 2011-2012) challenged paradigms of explosive and effusive eruptive styles and led to the formulation of new models of hybrid activity. The processes that govern such hybrid explosive–effusive activity remain poorly understood. Here, we bring together observations of silicic eruptions and their products, including: (1) textures from all products of the well-studied Cordón Caulle eruption; (2) textures and lithofacies from eroded silicic intrusions throughout the upper crust; and (3) petrological and petrophysical information from a growing global database of silicic lavas and fall deposits. We infer that all of the activity – explosive, effusive, and hybrid – is ultimately fed by fragmentation at moderate depth, and that effusive behaviour arises from sticking, sintering, and compaction in the shallow vent region, of the clastic products of deeper, cryptic fragmentation. We use scaling approaches and numerical models to determine that there is sufficient time available during lava assembly and flow for diffusive pyroclast degassing and sintering to produce a degassed plug that occludes the shallow conduit, feeding clastogenic, apparently effusive, lava-like rheomorphic deposits. We further argue that hybrid explosive–effusive activity is driven by episodic gas-fracking of the aggrading lava plug, fed by the underlying pressurized ash- and pyroclast-laden region. The presence of a pressurized pocket of ash-laden gas within the conduit provides a mechanism for generation of harmonic tremor and for syn-eruptive sill or laccolith intrusion, both of which occur during silicic eruptions. We conclude that the cryptic fragmentation model is more consistent with available evidence than prevailing models for effusion of silicic lava that assume coherent non-fragmental rise of magma from depth to the surface without wholesale fragmentation.

480

Constraining the magmatic plumbing system of the Snake River Plain volcanic province, USA: contributions from crystal mush fragments

Dr Clara Waelkens[1], Professor Francois Holtz[1], Dr Renat Almeev[1], Professor John Shervais[2]
[1]Leibniz University Hannover, Hannover, Germany, [2]Utah State University, Logan, United States

The Snake River Plain (SRP) volcanic province, located in the western United States, is a prime example of a continental hotspot. It records 12 million years of bimodal volcanism, with early rhyolite caldera complexes covered by extensive younger basaltic flows. The ICDP Snake River Scientific Drilling Project (HOTSPOT) completed three drill holes in the SRP, which combined offer an overview of the entire volcanic sequence.

The Kimana drill core samples 1912 m of continuous basalts, which were erupted over a time span of 6 million years. The basalts generally consist of mm- to cm-scale macrocrysts of plagioclase and olivine, interpreted to be entrained mush fragments, in a glassy to fine-grained groundmass of plagioclase, olivine, pyroxene and oxides. Anorthite contents vary up to 25 % within single plagioclase macrocrysts, and both glomerocrysts and individual macrocrysts exhibit complex zoning patterns, with single plagioclase crystals regularly recording different types of zoning (normal, reversed, oscillatory, patchy), resorbed cores and repeated internal resorption surfaces. This indicates a complex magmatic system, in which plagioclase crystals which formed in different environments were entrained by ascending magma and erupted together.

We present an overview of textural and compositional data from the plagioclases within the Kimana core and a classification of the complex zoning types. By grouping plagioclases with a similar history and measuring compositional changes within the crystals, we can constrain the pre-eruptive storage conditions of the magma by proposing a sequence of events (changes in P and T, recharge events, magma mixing). This allows us to reconstruct how the magma was stored and entrained, how separate reservoirs were connected and how P and T in the system changed, thereby enabling us to build a model for the magmatic plumbing system of the SRP basalts.

1163

A numerical and analytical investigation of the emplacement of Pavonis Fossae

Nick Wagner[1], Peter James[1]
[1]*Baylor University, Waco, United States*

Circumferential dike complexes commonly occur on Earth. They are also seen on other planets such as Venus and Mars. On Mars there numerous circumferential graben and dike complexes surrounding most of the enormous volcanic edifices. Pavonis Mons is an interesting case study, as it hosts the most dramatic example of intruded circumferential dikes, named Pavonis Fossae. Most of the circumferential features on the flanks Pavonis Mons have been attributed to volcanic burial of the lower flanks to induce radial tension. However, Pavonis Fossae is located distally from the flanks of Pavonis, and its location was plausibly controlled by the stress state of the surrounding areas of Pavonis. In this study, we use a combination of an analytical thick- and thin-plate calculation of lithospheric flexure to evaluate the stress state in addition to a 2D finite-element thermomechanical numerical model that replicates magma intrusion from a basaltic volcanic body in the subsurface. We vary the location of the magmatic body in our numerical models, as other studies suggest that off-centered magmatic bodies can be deflected towards topographic loads, and the elastic thickness of the lithosphere in the analytical models. These represent the main parameters we chose to vary, but we also investigated changing the density and viscosity of the crust, mantle, and magma within accepted values. Numerical models predicting the location of Pavonis Fossae will be used in tandem with the flexural models to diagnose the elastic state of the lithosphere. This will have implications for the elastic and thermal state of the lithosphere at the time of dike intrusion and emplacement as these properties are poorly constrained using other methods.

296

Making and shaping South Greenland: unravelling crustal growth in the Ketilidian Orogen, a Paleoproterozoic continental arc

Professor Tod Waight[1], Rikke Vestergaard[1], Dr Andreas Petersson[1]
[1]*Department of Geosciences and Natural Resource Management, University of Copenhagen, Copenhagen K, Denmark*

Elucidating the mechanisms of silicic crustal growth and preservation is essential to understanding the geochemical differentiation of our planet. The Ketilidian Orogen crops out over ca. 30,000 km^2 in South Greenland representing a continental arc bordering Archean crust of the North Atlantic Craton (NAC), and part of the Great Proterozoic Accretionary Orogeny along the margin of the supercontinent Columbia/Nuna. It is subdivided into the Central Domain – dominated by high-K, calc-alkaline I-type monzogabbro to granites of the 1.85-1.80 Ga Julianehåb Igneous Complex (JIC), and the Southern Domain – representing forearc sediments metamorphosed to amphibolite and granulite facies at 1.79-1.76 Ga and subsequently intruded by rapakivi granites of the Ilua Suite (1.75-1.73 Ga). Gold mineralization occurs at the Central-Southern Domain boundary. New geochronological data indicate the JIC grew in two geographically and chronologically discrete events, with most JIC granites in SW Greenland emplaced at 1.81-1.80 Ga, and older (1.85 Ga) granites dominating to the east. Nd and Hf isotope compositions of the 1.8 Ga JIC are predominantly mildly suprachondritic, and O isotope compositions of zircon in the JIC are primarily mantle-like, indicating juvenile crustal growth. Negative Hf and Nd in some samples close to the NAC suggest some older crust may be involved towards the boundary. Detrital zircons in the Southern Domain metasediments are dominated by ages and Hf isotope compositions similar to JIC, consistent with sediments derived by erosion of the JIC continental arc – however discrete and minor populations of older zircons (up to 2.8 Ga) indicate likely lateral input from older crustal sources. Zircons in the Southern Domain metasediments have relatively heavy O isotope compositions ($\delta^{18}O$ = +8-10), consistent with interaction with meteoric water. Zircons from the younger Ilua Suite granites also have heavy O isotope compositions, suggesting these formed in part through reworking of Southern Domain metasediments.

728

Volcanic Emissions of Environmentally Reactive Trace Elements in the 2021 and 2022 Fagradalsfjall Eruptions

Miss Laura Wainman, Dr Evgenia Ilyinskaya[1], Dr Anja Schmidt[2,3,4], Gerdur Stefansdottir[5]
[1]School of Earth and Environment, University of Leeds, Leeds, United Kingdom, [2]Yusef Hameid Department of Chemistry, University of Cambridge, Cambridge, United Kingdom, [3]Institute of Atmospheric Physics (IPA), German Aerospace Center (DLR), Oberpfaffenhofen, Germany, [4]Meteorological Institute, Ludwig Maximilian University of Munich, Munich, Germany, [5]Icelandic Meteorological Office, Reykjavik, Iceland

The 2021 and 2022 eruptions of Fagradalsfjall in Iceland resulted in the sustained emission of volcanic pollutants, including SO_2 gas, fine particulate matter (PM2.5 and PM1) and environmentally reactive trace elements (ERT) into the atmosphere. Based on observations from Kilauea in 2018 it has been proposed that the dispersion patterns and lifetimes of trace elements within volcanic plumes vary according to element volatility and solubility, with more volatile elements being depleted in the plume faster than refractory elements. Nonetheless, this relationship has yet to be investigated in relation to the recent Icelandic eruptions, which also offer the opportunity to study trace element plume dispersion behavior under lower temperature background atmospheric conditions. The dispersion of the volcanic aerosol plume varied according to wind strength and direction and thus resulted in spatially variable but sustained environmental exposure over the course of both 2021 and 2022 eruptions. Air quality stations suggest the presence of the plume in far-field locations up to 300km away.

Through the use of ground and drone-based sampling methods we report the concentrations of volcanic gases and ERT within the volcanic plumes for both 2021 and 2022 Fagradalsfjall eruptions. Samples include at-crater, downwind and far-field measurements which allow us to trace the compositional and chemical evolution of the plume with distance from the vent. Precipitation datasets are also included allowing us to investigate the wet deposition of ERT from the volcanic plume. Understanding the behavior of ERT elements within volcanic plumes and through both air and water-borne pathways during sustained eruptive events has critical implications for understanding additional longer-term volcanic hazards, where chronic exposure to environmentally reactive and potentially toxic elements such as Pb, As, Mo, and Cd may be associated with severe effects on both human health and the environment.

838

Utilizing a Multi-Proxy Model Comparison to Constrain the Eruption Season and Regionally Heterogeneous Impacts of the Mt. Samalas 1257 Eruption

Miss Laura Wainman[1,2], Dr Lauren Marshall[3,4], Professor Anja Schmidt[4,5,6]
[1]School of Earth and Environment, University Of Leeds, Leeds, United Kingdom, [2]Department of Earth Sciences, University of Cambridge, Cambridge, United Kingdom, [3]Department of Earth Sciences, Durham University, Durham, United Kingdom, [4]Yusuf Hamied Department of Chemistry, University of Cambridge, Cambridge, United Kingdom, [5]Institute of Atmospheric Physics (IPA), German Aerospace Center (DLR), Oberpfaffenhofen, Germany, [6]Meteorological Institute, Ludwig Maximilian University of Munich, Munich, Germany

The Mt. Samalas eruption, thought to have occurred between 1257 and 1258, ranks as one of the most explosive sulfur-rich eruptions of the Common Era. However, the precise year and season of the eruption remains unconstrained with both summer 1257 and early 1258 being proposed as potential eruption dates. Widespread surface cooling and hydroclimate perturbations following the eruption have been invoked as contributing to a host of 13th century social and economic crises, although regional scale variability in the post-eruption climate response remains uncertain. In this study we run ensemble simulations using the UK Earth System Model (UKSEM) with a range of eruption scenarios and initial conditions in combination with a globally resolved multi-proxy database. This allows more-precise constraints on the year and season of the Mt. Samalas eruption to be placed as well as investigating the regionally heterogenous post-eruption climate response. Using a multi-proxy to model comparison, we are able to robustly distinguish between July 1257 and January 1258 eruption scenarios. The July 1257 ensemble simulation achieves considerably better agreement with spatially averaged and regionally-resolved proxy temperature reconstructions which suggest the onset of significant cooling across Asia and Europe in 1258, and thus support the plausibility of inferred historical connections. Model-simulated temperature anomalies also point to severe cooling across the Southern Hemisphere with as of yet unknown historical implications for impacted civilizations. The multi-proxy to model comparison employed in this study is shown to have significant potential in constraining uncertain eruption source parameters.

987

The PDC Flow Units Problem: Deposit heterogeneity from varying cohesive behaviour and sediment flux.

Miss Nemi Walding[1], Dr Rebecca Williams[1], Dr Natasha Dowey[2], Dr Peter Rowley[3], Professor Dan Parsons[4]
[1]University Of Hull, Hull, United Kingdom, [2]Sheffield Hallam University , Sheffield , United Kingdom , [3]University of Bristol, Bristol, United Kingdom , [4]Loughborough University, Loughborough, United Kingdom

Pyroclastic Density Currents (PDCs) are rapidly moving, high-temperature currents of heterogeneous volcanic material and gas that can surmount topographic barriers and can form extensive deposits (ignimbrites) far away from source. Flow units are interpreted as deposits of individual PDCs and are defined by markers of hiatus in activity (such as ash fallout, reworking or paleosols). However, it has been shown that the arrangement of flow units can vary spatially within a deposit, recording a contradictory picture of PDC activity during a single eruption at different locations[1].

The stratigraphic record of flow units within an ignimbrite may have been influenced by a number of factors, such as current unsteadiness or syn-depositional processes. Formation of ash within a PDC can be from magma fragmentation and/or by comminution processes as the current propagates. Entrainment from both internal and external environments can decrease temperatures and introduce water vapour. This will likely affect cohesive and frictional behaviours within the flow causing internal variations affecting both the current dynamics and resulting deposits.

This project investigates how cohesive and frictional behaviours within a PDC may impact its ability to transport, deposit and erode material. Thus, impacting the flow unit record and determining the extent to which single pulsatory currents can be misinterpreted as separate flow events during major eruptions. Flume experiments[2 3] explore the significance of cohesion in influencing flow dynamics and resulting deposit behaviours, by exploring the role of fines and water vapour. Fieldwork will be undertaken to consider bedform and stratigraphic relationships of flow unit marker beds to ground-truth the experiments. This research will improve our understanding of the dynamics of PDCs, how they react to variations in internal and external conditions and factors that control the depositional record of PDCs.

1. Smith, N. J. (2012)
2. Smith et al (2020)
3. Walding (2022)

986

Cohesional behaviours in volcanic and analogue material and the consequent implications on deposit architecture.

Miss Nemi Walding[1], Dr Rebecca Williams[1], Dr Natasha Dowey[2], Dr Peter Rowley[3], Professor Dan Parsons[4]
[1]University Of Hull, Hull, United Kingdom, [2]Sheffield Hallam, Sheffield , United Kingdom , [3]University of Bristol, Bristol , United Kingdom, [4]Loughborough University, Loughborough, United Kingdom

During Pyroclastic Density Current (PDC) propagation, entrainment from both internal and external environments can decrease temperatures and introduce water vapour (e.g. exsolving juvenile magma, external hydrological factors, combusting plant matter, water-laden sediment). As a PDC flows away from source the comminution of grains will lead to fragmentation and subsequent higher ash content. These factors are expected to affect cohesive and frictional behaviours within the flow and the resulting deposits. Fluidisation within PDCs plays a substantial role in their high mobility and is accepted as an outcome of excess pore pressure from exsolution and entrainment[1]. Defluidising material may alter the profile of a deposit by remobilising grains through gas escape structures (i.e. elutriation pipes) and can cause secondary hydroeruptions in a deposit[2]. The ability for gas escape to reorganize the deposit will be affected by the mechanical properties of the deposit, which will include cohesion.

Experiments investigating the cohesive behaviour of analogue and ignimbrite material have been undertaken to explore how static packs of sediment respond to gas escape under a range of conditions. Material properties including angle of repose, bulk and tapped density and fluidisation behaviour have been recorded under varying moisture content conditions to better understand the static and dynamic behaviours of these materials.

Results show that just small amounts of moisture (0.25 – 0.50%) greatly affect the behaviour of analogue and volcanic material. Increasing moisture content results in higher angle of repose and minimum fluidisation velocity values. As materials become fluidised, cohesional variations within the deposit affect bubble and channel formations and can create vertical pressure profiles. These results begin to explore the impact of capillary cohesion and its implications for PDC dynamics, deposit architecture and validity of different analogue materials in experimental modelling.

1. Branney and Kokelaar (2002)
2. Gilbertson et al (2020)

679

Changes in andesite genesis owing to variable basalt flux over 3 m.y. at the Goat Rocks volcanic complex, Cascade Arc

Dr Kellie Wall[1], Anita Grunder[2]
[1]U.S. Geological Survey, Vancouver, United States, [2]Oregon State University, Corvallis, United States

We investigate the 3-m.y. compositional evolution of a major Cascades andesite locus. The Goat Rocks volcanic complex, southeast of Mount Rainier in Washington State, consists of several composite volcanoes built between 3.1 Ma–100 ka. The first, Tieton Peak volcano, was constructed between 3.1–2.6 Ma along the margin of the inferred Devils Horns caldera (3.2 Ma). Lava flows of Tieton Peak range in composition from basaltic andesite to rhyolite. Later, the Bear Creek Mountain volcano (1.6–1.1 Ma) erupted a compositionally restricted suite of alkalic andesite-trachyandesite, including two far-travelled lava flows (74 and 52 km long; Gusey et al., 2018, GSA Special Paper 538). The last eruptions of Bear Creek Mountain overlap with the emergence of Lake Creek volcano (1.1 Ma–450 ka). Lake Creek compositions were initially indistinguishable from those of Bear Creek Mountain, then evolved to more silicic (dacitic) over time. Finally, Old Snowy Mountain (and satellite vents) erupted between 440–100 ka. Earlier Old Snowy Mountain compositions were more like those of Lake Creek, and later eruptions were dominantly less alkalic and more mafic.

The Magma Chamber Simulator (MCS) was used for thermodynamic modeling of magma evolution, testing possible parent magma compositions selected from bulk-rock major and trace element analyses (including local coeval basalts). MCS results largely explain diverse Tieton Peak compositions by fractional crystallization (FC) of basalt ± assimilation of crustal melts. Significant recharge and FC are required to reproduce the alkalic, trace element-enriched Bear Creek Mountain suite, signaling increased basalt flux. Waning recharge and more FC explain the Lake Creek suite. Finally, the less evolved, less incompatible element-enriched Old Snowy Mountain suite is well reproduced by fractional crystallization (without significant recharge), suggesting waning basalt flux. These results are complemented by Fe-Ti oxide and zircon thermometry, which record highest temperatures for Bear Creek Mountain and early Lake Creek magmas.

678

Timescales of magmatic events in the San Francisco Volcanic Field, Northern Arizona, USA

Dr Kellie Wall[1], Emily Johnson[1], Mark Stelten[2], Michael Ort[3], Wendy Stovall[1], Carmen Jaimes-Viera[4], Michael Poland[1]

[1]U.S. Geological Survey, Vancouver, United States, [2]U.S. Geological Survey, Menlo Park, United States, [3]Northern Arizona University, Flagstaff, United States, [4]University of South Florida, Tampa, United States

This project investigates the recent magmatic history of the San Francisco Volcanic Field (SFVF), near Flagstaff, Arizona, USA. The SFVF comprises several hundred volcanic vents that formed between ~6 Ma and 1 ka. Volcanic features include basaltic scoria cones, lava flows, and pyroclastic deposits; felsic lava flows and domes; and composite volcanoes like San Francisco Mountain. Recently (<200-300 ka), eruptions have occurred primarily in the northeastern part of SFVF, north and northeast of the city of Flagstaff. This project aims to better quantify potential hazards of SFVF and supports a broader effort to constrain hazards of distributed volcanic fields in the US and globally. The primary goal is to better quantify eruption timescales, including ages of eruptions, durations of clustered eruptive episodes, and magma storage and ascent timescales. Field work and initial compositional and geochronological analyses are underway in 2022. More than 20 recent (younger than ~200-300 ka) volcanoes/volcanic events are the target of this study. This selection is based on prior mapping and age data, LIDAR, satellite imagery, and field observations of cone and lava morphology. For many of these vents, existing ages are uncertain (e.g. only K/Ar data), and several have not yet been dated. For more robust age determinations of the young, dominantly mafic units, we will use a combination of 40Ar/39Ar dating, cosmogenic surface exposure dating (3He and 36Cl), and paleomagnetic analysis. Diffusion chronometry will be applied to zoned phenocrysts such as olivine and pyroxene to determine residence time between magma mixing events and eruption. In addition, we will explore relationships between these temporal data, petrologic processes, and eruptive behavior. Here we will present preliminary age and diffusion chronometry results, and whole-rock and mineral compositions, to build a more complete model of recent SFVF magmatic processes and their timescales.

378

Cycling of sulfur in subduction zones and implications for arc magma redox state and Cu content

Paul Wallace[1], Michelle Muth[2]
[1]University of Oregon, Eugene, United States, [2]Smithsonian Institution, Washington DC, United States

Arc magmas are oxidized relative to MORB, but the cause of this is debated. Some evidence indicates that arc magmas evolve towards oxidizing conditions during storage in the crust, whereas other evidence points toward the influence of oxidizing slab-derived material in the mantle source. Slab-derived sulfur has the potential to be a powerful oxidant in the mantle wedge, yet the cycling of sulfur through subduction zones is poorly understood. We used olivine-hosted melt inclusion data from 32 arc segments globally to characterize S contents of magmas from a variety of subduction zones and identify key processes that control S content in arc magmas. Primitive and more evolved magmas in both hot- and cold-slab subduction zones commonly have higher S contents than MORB. Correlations between magma S and Cl concentrations and S/Dy and Th/Yb ratios in the global data set confirm that substantial S is recycled from the subducting plate.

Comparing melt inclusion S contents to solubility limits imposed by sulfide saturation, 88% of arc magmas in our compilation require fO2> QFM during melting. Using electron exchange and mass balance models, we explore the relationship between slab-derived S and magma oxidation state. We find that oxidized slab-derived S causes increases in magma oxidation state that mirror those observed in natural data and that the upper limit for fO2 in arc magmas is likely controlled by S-Fe redox interactions.

Mass transfer of S from the slab can maintain sulfide saturation in the mantle wedge even in oxidizing conditions and can thus reconcile the MORB-like Cu contents of arc magmas with evidence for oxidizing conditions during sub-arc mantle melting. High Sr/Y ratios in primary arc magmas are correlated with high S and oxidizing conditions. This relationship may help to explain the association between high Sr/Y magmas and the formation of porphyry Cu deposits.

424

From pumice cones to lava domes: Deciphering eruption dynamics of two juxtaposing active caldera systems in the East African Rift

Dr Paul Wallace[1], Petra Godec[1], Victor Otieno[2], Ruth Njoroge[3], Monicah Tubula[4], Lorenzo Cappelli[1], Purity Kamau[3], Prof Nicholas Mariita[3], Prof Karen Fontijn[1]

[1]Université libre de Bruxelles, Department of Geosciences, Environment and Society, Brussels, Belgium, [2]Kenya Electricity Generating Company PLC, Olkaria, Naivasha, Kenya, [3]Dedan Kimathi University of Technology, Geothermal Training and Research Institute, Nyeri, Kenya, [4]Olkaria, Naivasha, Kenya

The longstanding volcanological dilemma on whether magma will flow or blow has resulted in a plethora of multidisciplinary datasets. However, such data has been overwhelmingly derived from well monitored subduction-related calc-alkaline systems preventing the direct application of subsequent models to other tectonically/chemically distinct systems, such as poorly monitored East African Rift (EAR) volcanoes where alkali-rich magmas dominate. Recent evidence from field-based deposit descriptions, degassing surveys and remote sensing techniques have revealed many EAR volcanoes are active, raising future concerns on eruptive activity and hazards. Particularly in the Kenya Rift, volcanoes are experiencing episodic deformation and CO_2-degassing indicative of the presence of shallow magmatic reservoirs. Here, we focus on two active juxtaposing systems that reveal evidence for a range of post-caldera eruption styles: the Greater Olkaria Volcanic Complex (GOVC) and Longonot. GOVC is a young multicentred caldera complex consisting of pumice cones and domes produced by the eruption of peralkaline rhyolites, while Longonot is a trachytic caldera hosting a central summit cone, situated 3 km east of GOVC, with pumice and ash eruptions being a dominant feature, both systems likely fed by an inherent parental source. We present results from three field campaigns (carried out in Nov. 2020, Jul. 2021 and Jul. 2022) to characterise the overlapping eruptive histories of the two systems through integrating tephrostratigraphic field observations, geochronology, geochemistry, petrology and textural analyses of tephra deposits. Eruptive frequency-magnitude relationships have been constrained from >30 explosive sequences, revealing at least 1 moderate-large explosive eruption every ~450 years, consistent with Ethiopian Rift volcanoes. Petrological modelling reveals extensive fractional crystallisation (>92%) of a H_2O-poor alkali basalt (<0.5 wt.%) is required to generate trachytic melts (~880°C) stored within the mid-upper crust, followed by an additional ~72% FC to form the peralkaline rhyolites (~760°C) that likely pond in multiple reservoirs at <5km depth across GOVC.

725

Role of CO2 flushing on amphibole reaction rim development: Experimental insights into pre-eruptive magmatic processes

Dr Paul Wallace[1], Dr Sarah De Angelis[2], Prof Jessica Larsen[3], Prof Luca Caricchi[4], Prof Yan Lavallée[5]
[1]Université libre de Bruxelles, Department of Geosciences, Environment and Society, Brussels, Belgium, [2]Tornillo Scientific, Liverpool, UK, [3]University of Alaska Fairbanks, Geophysical Institute, Fairbanks, USA, [4]University of Geneva, Department of Earth Sciences, Geneva, Switzerland, [5]Ludwig Maximilian University of Munich, Department of Earth and Environment, Munich, Germany

Volatiles are a central ingredient to the evolution of magmatic systems; changes in their concentration may exert an important control on the physicochemical state of magma, thus acting as the driving force for eruptive activity. Disequilibrium textures of magmatic minerals have highlighted the feasibility to track pressure and temperature changes, along with volatile fluctuations, within volcanic systems, permitting interpretation of ascent dynamics and eruption trigger mechanisms. Amphibole and their reaction rims have formed the basis for such descriptions owing to their sensitivity to pre-eruptive conditions. Studies have traditionally assumed ascent-driven decompression to be the main cause of rim formation, while recent work has demonstrated that heating can be similarly impactful. Other causes have been postulated (e.g., CO_2 flushing), but remain experimentally unexplored. A lack of calibrated data on such intrinsic variables makes interpretation of pre-eruptive processes problematic. As such, amphibole stability in magmatic systems experiencing continuous/episodic CO_2 flushing remains elusive, precluding an accurate interpretation of natural rim formation, previously assigned to decompression or heating. Here, we performed high-temperature (830°C), high-pressure (120 MPa) experiments to investigate the effects of XCO_2 (0.3–0.7) on amphibole reaction rim development in H_2O saturated magmas in shallow volcanic systems, providing new insights for interpreting amphibole rim textures. Our results show CO_2 causes reaction rim growth in <24hrs, opposed to >48hrs after heating (+50°C) and >120hrs following decompression (SSD to 65 MPa). Rim microlite textures reveal each process can be differentiated primarily through crystallographic orientation and shape/size analysis, with rim thickness and mineralogy alone proving insufficient. CO_2-triggered microlites are consistently smaller (<10µm), acicular (AR ≤35) and preferentially orientated with the host amphibole, which become more apparent with increasing CO_2. These new results quantify the importance of CO_2 on amphibole stability and indicate that it should not be neglected when interpreting disequilibrium textures formed during magma ascent.

670

Prototype proposal for a FAIR tephra data information system

Mrs Kristi Wallace[1], Dr. Kirsten Lehnert[2], Dr. Marcus Bursik[3], Dr. Steve Kuehn[4], Dr. Andrei Kurbatov[5], Dr. J. Douglas Walker[6]
[1]US Geological Survey, Anchorage, United States, [2]Lamont-Doherty Earth Observatory of Columbia University , Palisades, USA, [3]SUNY Buffalo, Buffalo, USA, [4]Concord University, Athens, USA, [5]University of Maine, Orono, USA, [6]University of Kansas, Lawrence, USA

Based on an extensive tephra community engagement process, we present a vision for a community-based information system that will enable FAIR (Finable, Accessible, Interoperable, Reusable) tephra data in support of the wide range of future scientific research that requires its discovery, access, and re-use. We envision a system that 1) Makes it easy for researchers to input chemical and physical data on tephra; 2) Provides human and machine-actionable interfaces to publish, share, access, and re-use data; 3) Provides tephra deposit analysis, characterization, and correlation tools for comparison and matching of unidentified tephras with known tephras; 4) Ensures rapid but controlled access to new information, while individual investigators control intellectual property ownership and receive credit for data; 5) Adopts transparent data workflow monitoring; 6) Facilitates comprehensive metadata archiving for thorough documentation; and 7) Is based on recently published community-developed best practice recommendations (https://doi.org/10.1038/s41597-022-01515-y).

Rather than invent new tools and repositories from scratch, we envision building upon existing resources (e.g., EarthChem, SESAR, StraboSpot, Sparrow, GeoDiva, TephraBase), and creating interoperable data pipelines between existing systems. The end user will interact with the tephra information system through a central portal seamlessly accessing services provided from an array of data systems. The benefit of linking and aggregating distributed resources is that it allows users choices in data archiving, along with the ability to run models and workflows that access required information. The system will ingest data and maintain links to additional resources (e.g., figures, references, models, methods, tools, and workflows). The system will work as a template for other scholarly communities. The tephra community serves as an ideal seeding and testing ground, as it comprises a relatively small number of diverse projects in a variety of disciplines that are spread around the globe and commonly use multiple types of data.

802

The Quartz Kerfuffle: A closed system test of the multiple proposed Ti-in-quartz diffusivities

Dr Blake Wallrich[1], Dr. John Ayers[1]
[1]*Vanderbilt University, Nashville, United States*

Monitoring of volcanic hazards is largely dependent on our understanding of the processes occurring within the subsurface. Therefore, it is critical that we accurately identify and constrain the processes that signal eruption triggering events and their associated timescales from a petrological perspective to inform the monitoring approach. One widely applied petrologic method used to constrain timescales is Ti-in-quartz geospeedometry. This method is dependent on the rate of Ti-diffusion in quartz. Therefore, it is imperative that the diffusivity of Ti-in-quartz be well constrained.

Two recent studies (Jollands et al. 2020; Audetat et al. 2021) used an external Ti source to demonstrate experimentally that the diffusivity of Ti-in-quartz may be orders of magnitude slower than indicated by the widely accepted results of Cherniak et al. (2007). If the diffusivity is indeed slower, current interpretations of the timescales associated with magmatic processes in silicic systems (e.g. decompression, rejuvenation) and eruption may be underestimated. In this study, we evaluate the available Ti-in-quartz diffusivities by using a closed system (internal source) diffusion experiment to further understand this hotly disputed topic.

We extracted quartz from a single large pumice from the Late Bishop Tuff. A control group (unheated) was imaged in cathodoluminescence (CL) to characterize the average initial diffusive state of the CL boundary of interest. A second quartz split was heated in a furnace at 1300ºC. CL imaging showed no change in zoning profiles of heated crystals relative to the control group after 16 days.

Our results suggest that the diffusivities of Cherniak et al. (2007) are orders of magnitude too fast. Due to the limitations of our experimental setup we will conduct additional experiments at 1.5 GPa that will allow higher-temperature experiments on quartz separates to see if our method yields diffusivities that are consistent with the low values recently reported.

846

The internal structure of Öræfajökull, Iceland imaged by local earthquake tomography

Dr Braden Walsh[1,2], Dr. Ari Tryggvason[1], Dr. Dave McGarvie[3]
[1]*Simon Fraser Univeristy, Burnaby, Canada,* [2]*Uppsala University, Uppsala, Sweden,* [3]*Lancaster University, Lancaster, UK*

Öræfajökull is Iceland's largest and potentially one of its most dangerous volcanoes, that has erupted twice in historic times, once in 1362 which was Iceland's largest recorded eruption, and another in 1727. Half of Öræfajökull is completely covered in ice, and at the summit there is a 5x3 km caldera containing ~550m of ice. These factors have led to a lack of detailed knowledge about the structure of the volcano. Öræfajökull's eruptions are variable in location, composition, volume, and explosivity, thus any unrest is a matter of concern and an opportunity to gain vital information about the relatively unknow internal structure. Between 2017-2019 seismicity increased from ~5 earthquakes with magnitudes greater than 1.5 to over 4000 per year. The increased seismicity at Öræfajökull allowed for the use of a local earthquake (LE) tomography study. LE tomography uses P- and S-wave traveltimes to simultaneously solve for earthquake locations and velocities of the subsurface using 17 three-component seismic stations installed on and around Öræfajökull. Results of the LE tomography show a network of centralized earthquake locations between the surface to about 8 km depth below sea level (bsl) directly beneath the caldera, with scattered earthquake sources down to depths of ~14 km bsl. The LE tomographic structure of Öræfajökull depicts a high velocity zone <2 km depth bsl, high Vp/Vs ratios in a low velocity zone ranging between 2-6 km depth bsl, and a higher velocity/low Vp/Vs region below 6 km bsl directly under the caldera. The interpretation of the tomography results are proposed as a geothermally active system at shallow depths (<2 km bsl), a melt or mush zone between ~2-6 km depth bsl, and the presence of high velocity cumulates below, with a sharp velocity contrast starting ~7-8 km depth bsl, which could indicate the start of the plutonic basement.

722

Constraining mass flow properties with real-time gravimetry: Implications for channelized mass flow modeling and monitoring

Dr Braden Walsh[1], Antonina Calahorrano-Di Patre[1], Dr. Daniel Andrade[2], Glyn Williams-Jones[1]
[1]*Simon Fraser Univeristy, Burnaby, Canada,* [2]*Instituto Geofísico, Escuela Politécina Nacional, Quito, Ecuador*

Lahars and other mass flows have large impacts through environmental change and destruction of human society. This has increased the importance of estimating the properties of these flows to not only understand the internal dynamics, but to improve risk assessment and warning systems. One of the most important inputs for mass flow prediction modelling and hazard assessment is the true mass and energy of the flow as it progresses down channel, and thus the need to physically measure these properties in real-time. Here, we show exploratory research on use of a gravimeter to record a lahar at Cotopaxi, Ecuador, and the implications for numerical modeling and mass flow monitoring. At 18:30 UTC on 13 January, 2016, a rain induced lahar occurred on the western slope of Cotopaxi and flowed down the Cutzualo channel passing the seismic monitoring station BNAS. Located about 100 m form the active lahar channel, BNAS consisted of a 3-component Guralp GMG-40T broadband seismometer and, for the day, a continuously-recording Scintrex CG5 gravimeter. The lahar took approximately 1 hour to flow completely past the monitoring station with an estimated peak discharge of 55 m3/s. The gravimeter showed a significant increase in the gravitational signal (~1000 µGal) as the lahar passed the monitoring station which was highly correlated (r=0.85) with the seismic signal. Furthermore, the differences between the recorded and theoretical gravitational signals (calculated from the known channel dimensions and treating the lahar as an infinite line of mass) were analyzed as additional evidence for the gravimeter recording the mass of the lahar. The outcomes of this research will help to better constrain the energy, mass, and type of a mass flow event, which in turn can be used for more accurate hazard and forecast modeling.

935

Late Permian volcano-sedimentary succession description and basin filling characteristics in Sichuan Basin

Wenhua Wang[1]
[1]Jilin University, Changchun, China

As a product of mantle plume activity, Permian Emeishan Large igneous province is widely distributed in Sichuan Basin. Compared with the extensive research on volcanic rocks around the world, the research on volcanic rocks in Sichuan Basin is still in its infancy. Previous studies have shown that uplifting mantle plumes can usually cause large-scale crustal uplift and the formation of dome-like uplift features, and control regional paleogeographic pattern and sedimentary facies distribution. The surface uplift caused by mantle plume uplift, differential denudation of existing sediments, changes of sedimentary facies and lithofacies paleogeography must profoundly affect the paleogeomorphology and eruption mechanism of volcanic rocks in Permian Emeishan Large igneous province before eruption. This study constrains the temporal sequence of different regions and types of volcanic rocks in the Permian Emeishan Large Igneous Province, combines the spatial distribution patterns of different types of volcanic rocks, paleogeomorphology and eruption environment before eruption, reduction of volcanic eruption to build process, established above the cycle and lower cycle of 2 major eruption cycle of 4 stages of the volcano-sedimentary succession description, The filling characteristics of Permian basin in Sichuan Basin are also discussed.

371

Simulation of caldera collapse with coupled ring fault dynamic rupture and magma flow

Mr Taiyi Wang[1], Eric M. Dunham[1], Lauren S. Abrahams[1], Lukas Krenz[2], Paul Segall[1]
[1]Stanford University, Stanford, United States, [2]Technical University of Munich, , Germany

Basaltic caldera collapse is often episodic, with each collapse producing up to ~ Mw 5 very long period (VLP) earthquakes. Wang et al. (2022) demonstrated, with a lumped-parameter model, that, the dynamics of collapse events are controlled by mechanical interactions between ring fault slip (assumed uniform on a vertical fault) and magma chamber pressure (assumed spatially uniform). However, in nature, caldera collapse likely initiates when rupture nucleates at a highly stressed region on the ring fault and propagates around the caldera block. The movement of the caldera block then induces time-dependent magma flow in the underlying chamber, resulting in non-uniform normal and shear tractions on the chamber wall (due to dynamic pressure changes and viscous drag). Therefore, two sets of questions remain unanswered: 1. how does the dip of the ring fault (inward or vertical), bulk rheology of the magma (e.g. compressibility, viscosity), and geometry of magma chamber (prolate vs. oblate spheroid) impact the magnitude and time dependence of collapse? 2. what does near-field ground motion imply about the orientation of the ring fault and the geometry/rheology of the underlying magma chamber?

We investigate these questions through a self-consistent model using SeisSol (www.seissol.org), capturing dynamic rupture on a ring fault, magma flow in the chamber, as well as the associated ground motion in the near field. At the current stage, we approximate magma with acoustic fluid (compressible, inviscid). In the future, we will consider viscous effects by implementing frequency-dependent attenuation. We will present preliminary results on the variability of caldera collapse duration and magnitude as a function of aforementioned factors. Future work will compare synthetic seismic waveforms with near-field observations to gain insight into the time dependence of ring fault rupture and transient magma flow in the underlying magma chamber.

1180

Forecasting Eruptions Using Analogues and Multivariate Renewal Processes

Dr Ting Wang[1], Professor Mark Bebbington[2], Professor Shane Cronin[3], Mr Joel Carman[1]
[1]*University Of Otago, Dunedin, New Zealand,* [2]*Massey University, Palmerston North, New Zealand,* [3]*University of Auckland, Auckland, New Zealand*

Forecasting future destructive eruptions from re-awakening volcanoes remains a challenge, mainly due to a lack of previous event data. This sparks a search for similar volcanoes to provide additional information, especially those with better compiled and understood event records. However, we show that some of the most obviously geologically comparable volcanoes have differing statistical occurrence patterns. Using such matches produces large forecasting uncertainties. We created a statistical tool to identify and test the compatibility of potential analogue volcanoes based on repose-time characteristics from world-wide datasets. Selecting analogue volcanoes with compatible behaviour for factors being forecast, such as repose time, significantly reduces forecasting uncertainties. Sensitivity tests show that this method is robust to the problem of missing data. We will illustrate this method by applying it to Tongariro and Taranaki volcanoes (NZ) and analogues obtained from the GVP catalogue.

508

Magmatic and Tectonic processes in Songliao Basin revealed by ICDP borehole SK2

Professor Pujun Wang[1]
[1]Jilin University, College of Earth Sciences,Changchun, China

The Songliao Basin (SLB) covers an area of approximately 260,000 km2 in northeastern Asia and preserves a continuous and complete Cretaceous terrestrial record. Although oil and gas exploration and development in the SLB has been carried out since the early 1950s, some fundamental geological problems are still unsolved; for example, how formation of the giant basin was initiated, the nature of the coupling process between the basin basement and the overlying sedimentary cover, and the details of the response relationship between seismic reflectors and geological properties. Understanding these issues will require characterization of the basin-filling sequence and stratigraphic boundaries. To obtain high-quality geological records to investigate the development of the SLB, an International Continental Scientific Drilling Project (ICDP) deep borehole, well SK2, was drilled in the center of the basin. This borehole represents the deepest continuously cored ICDP borehole to date, with a bottom depth of 7,108 m below the surface. The long continuous core sections provide a great opportunity for new discoveries relating to the geodynamics of an active continental-margin rift basin. Our results showed that the current stress in the SLB does not change at or above the basement–cover boundary but instead occurs within the Triassic sequence in a much deeper section below the basement–cover boundary. In situ stress measurements in borehole SK2 demonstrated that the stress state differs markedly between the upper and lower zones of the Triassic strata. In the upper section, the maximum principal stress, $\sigma 1$, is nearly vertical; in contrast, it is nearly horizontal in the deeper section. Given that there is synergy between the past and present tectonic evolution of the SLB and that basement central fault systems are still major tectonic features in northeastern China, it can be concluded that the increasing metamorphism and deformation with depth are stress-controlled.

1067

Fast or Slow: Evaluating the Ti-in-Quartz Diffusion Coefficients Against Plagioclase Diffusion Timescales

Miss SOPHIA WANG[1], Professor Guilherme Gualda[1], Dr. Jordan Lubbers[2], Professor Adam Kent[3]
[1]Department of Earth and Environmental Sciences, Vanderbilt University, Nashville, U.S.A., [2]U.S. Geological Survey Alaska Volcano Observatory, Anchorage, U.S.A., [3]College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, Corvallis, U.S.A.

Diffusion geochronometry in feldspars and quartz crystals has become a valuable method to understand the evolution of magma bodies prior to eruption. Given that feldspars and quartz co-crystallize for most of the magmatic history of silicic magmas, diffusion timescales of quartz and plagioclase should be very similar – except for that plagioclase crystallization may start prior to quartz saturation.

A new Ti-in-quartz diffusion coefficient was proposed by Jollands et al. (2020, Geology), which is three orders of magnitude lower than the previously determined diffusion coefficient (Cherniak et al., 2007, Chemical Geology), implying that magmatic residence times of quartz could be much longer than previously thought. This drastically affects our understanding of the timing of magmatic events.

We present quartz Ti-diffusion times for the Cerro Galán Ignimbrite, obtained by cathodoluminescence imaging of 96 quartz crystals from 8 samples, using both diffusion coefficients. Approximately 4-5 diffusion profiles were taken from each quartz crystal from a combination of core, interior and rim regions. For each studied region of a crystal, we selected 11 parallel profiles that form a band, from which we derive an average and standard deviation for each selected diffusion profile. We then use a Monte Carlo approach to provide a best estimate for the diffusion profile, from which diffusion times are calculated.

We compare quartz diffusion timescales with Mg-in-plagioclase and Sr-in-plagioclase diffusion timescales derived from the same samples. Our results demonstrate that timescales estimated using the Cherniak et al. (2007) coefficient are much more similar to plagioclase timescales than those derived using the Jollands et al. (2020) coefficient. We conclude that the Jollands et al. (2020) diffusion coefficient leads to magmatic timescales that are geologically unreasonable, and the Cherniak et al. (2007) diffusion coefficients should be used for studies of Ti diffusion in quartz under magmatic conditions.

629

Plumbing system anatomy of spatially and geochemically anomalous arc volcanoes: Insights from Muriah, Indonesia

Mr Jack Ward[1], Teresa Ubide[1], Gideon Rosenbaum[1], Felix Mulia Hasudungan Sihombing[2,3], Rio Priandri Nugroho[4], Gamma Abdul-Jabbar[3], Al-Tamini Tapu[1], Alice MacDonald[1]
[1]School Of Earth And Environmental Sciences, The University Of Queensland, Brisbane, Australia, [2]Department of Earth Sciences, University of Oxford, Oxford, United Kingdom, [3]Department of Geoscience, Faculty of Mathematics and Natural Sciences, Universitas Indonesia, , Indonesia, [4]Geological Engineering, Universitas Pertamina, Jakarta, Indonesia

Compositional zoning in magmatic crystals records intricate physiochemical processes occurring within volcanic plumbing systems. Recent studies leveraging in situ analysis of clinopyroxene have shed light on eruption timescales, hazard potential, magma mixing and fractionation, and broader plumbing system architecture in arc and intraplate systems. Little is known, however, about the plumbing system anatomy of spatially and geochemically 'anomalous' arc volcanoes. Here, we present a comprehensive petrological and geochemical analysis of clinopyroxene from Muriah (an alkaline Holocene volcano located in Central Java, Indonesia, ~270 km above the subducted Indo-Australian slab) to investigate plumbing system anatomy of an anomalous arc volcano. Eruptive products at Muriah contain >20 vol% subhedral–euhedral clinopyroxene phenocrysts that can be divided into two main groups: dominantly green ferro-augite crystals and dominantly white diopside crystals. Green clinopyroxenes display complex concentric and sector zoning, and they often contain white antecrystic cores that are patchy, sieved, resorbed, and/or show concentric zoning. White clinopyroxenes have patchy cores and thin, green, unzoned rims. White cores are Mg- and Cr-rich (Mg# 85–90; Cr >800 ppm) and display comparable major and trace element compositions (La <20 ppm), indicating a common origin. Green mantles and rims share similar geochemical characteristics and are more evolved (Mg# 70–80; Cr <100 ppm; La 20–80 ppm) than white cores. Thermobarometric modelling shows white cores formed at ~1150ºC and 2–5 kbar (10–20 km). Green mantles and rims formed at similar pressures, but at ~1000ºC. Our data suggest the plumbing system of Muriah is characterised by a main region of magma storage with dominantly cold, dynamic magmatic environments that preserve a memory of early mafic injections. Absences of mafic recharge rims on clinopyroxene phenocrysts suggest processes other than mafic replenishment triggered eruption. Future work will tap into the plagioclase cargo to assess shallow storage, ascent, and degassing.

651

Determining the Lifespan of Pumice Rafts from the 1883 Krakatau Eruption

Sarah Ward[1], Dr. Kristen Fauria[1], Dr. Amber Madden-Nadeau[2], Dr. Sebastian Watt[3], Dr. Michael Cassidy[2], Dr. Tushar Mittal[4], Dr. Samantha Engwell[5]

[1]Vanderbilt University, Nashville, United States, [2]University of Oxford , Oxford , United Kingdom , [3]University of Birmingham , Birmingham , United Kingdom , [4]Pennsylvania State University , State College, United States , [5]British Geological Survey , Edinburgh, United Kingdom

Pumice-producing eruptions near large bodies of water can create pumice rafts, which are large swaths of floating pumice tens to thousands of square kilometers in area. These rafts can transport eruptive products hundreds to thousands of kilometers from their source, influencing the grain-size and thickness of seafloor pumiceous deposits and the preservation of large eruptive events in the marine eruptive record. Although previous work has shown that pumice floats due to capillary gas trapping and isolated porosity, it is not clear if or how floatation characteristics or mechanisms evolve within a single eruption and therefore how the style and magnitude of an event may influence the formation and extent of pumice rafts. Here we quantify the textural and flotation characteristics of 25 clasts from two fall deposits, one pyroclastic flow deposit, and one deposit with both fall and flow characteristics from the 1883 eruption of Krakatau—an eruption which produced large-scale pumice rafts. We measure clasts' total and connected porosities and assess the time it takes individual clasts to sink in the lab. While all deposits exhibit similarly high pore connectivity (0.7-1) and total porosities (77-97%), pyroclastic density current (PDC) deposits sink faster than airfall deposits. Further analysis of clast microtextures using 3D images obtained via x-ray microtomography may illuminate the degree to which clasts that floated longer are microtexturally distinct from those that sank more quickly. Overall, our results help us to discern the mechanisms that impact the lifespan of pumice rafts.

603

Distinct Pumice Flotation Mechanisms of the Texturally Heterogeneous products of the 2019 Unnamed Volcano eruption, Tonga

Sarah Ward[1], Dr. Kristen Fauria[1], Dr. Martin Jutzeler[2]
[1]*Vanderbilt University, Nashville, United States,* [2]*University of Tasmania, Hobart, Australia*

Large swaths of floating pumice covering tens to thousands of square kilometers (pumice rafts) can be a striking product of submarine volcanic eruptions. Pumice rafts can damage near-shore infrastructure, obstruct ship routes, and dramatically impact the eruptive record by floating hundreds to thousands of kilometers away from their source. Although previous work determined that pumice float via capillary gas trapping and isolated porosity, it is unclear which floatation mechanism is most important within a particular pumice raft. Further, isolated porosity (i.e. closed pores surrounded by an impenetrable wall of glass) is not often measured in pumice, and it is unclear how common its abundance is. Here we quantify the flotation characteristics of 45 clasts from the 2019 eruption of unnamed Volcano, Tonga. We measure clast total and connected porosity and relate these measurements to the time and distance (70–4000 km) from the vent when the clasts were collected. Clasts exhibit high total porosity (69-93%) and a wide range of connectivities (0.2-1, where 1 means all the pores are connected). There is no significant difference between the connectivities of clasts collected close to the vent and those distally sampled. The wide range in connectivities suggests that some clasts float due to their isolated porosity alone while others float because of capillary gas trapping. We plan to analyze clast macrotexures and microtextures with 3D x-ray microtomography imagery. By combining the textural analysis with flotation experiments in the lab, we hope to better distinguish clasts with significant isolated porosity from those without. Overall, this work will further our understanding of the mechanisms that prolong the lifespan of pumice rafts and provide further assessment on their potential hazard.

892

Investigating the Evolution of the Magma Plumbing System of Pavlof Volcano, Alaska, USA with Melt Inclusion Analyses

Valerie Wasser[1], Taryn Lopez[1], Jessica Larsen[1], Matthew Loewen[2], Pavel Izbekov[1], Megan Newcombe[3], Christopher Waythomas[2], Kayla Iacovino[4]

[1]University Of Alaska Fairbanks, Geophysical Institute, Alaska Volcano Observatory, Fairbanks, United States, [2]USGS Alaska Volcano Observatory, Anchorage , United States , [3]University of Maryland, College Park, United States, [4]Jacobs-NASA Johnson Space Center, Houston , United States

Pavlof Volcano is one of the most frequently active volcanoes in Alaska, erupting several times per decade over the past century. Activity at Pavlof Volcano typically consists of minor tephra emissions associated with strombolian-type explosions and lava effusion. Occasionally larger ash eruptions with plumes reaching over 10,000 m above sea level have occurred. Frequent eruptions and characteristically minor precursory signals of unrest, even before significant eruptions, makes monitoring and forecasting Pavlof eruptions challenging.

We investigate Pavlof's magma plumbing system by analyzing the volatile concentration in melt inclusions and hope to identify the presence or absence of significant magma reservoirs at depth in order to help inform future monitoring efforts. In this study, we analyze melt inclusions from tephra deposits associated with two prehistoric Pavlof eruptions (< 2,000 yrs) and the recent 2016 eruption. We use reflectance and transmittance FTIR measurements to determine the concentration of CO_2 and H_2O in melt inclusions in olivine crystals separated from bulk tephra deposits. Where present, CO_2 shrinkage bubbles are homogenized with a heating stage at atmospheric pressure.

Preliminary results on eight inclusions in four different crystals from a late Holocene tephra show H_2O concentrations up to 4.6 ± 0.2 wt.% and CO_2 concentrations up to ~100 ± 50 ppm. Six out of eight measured inclusions, however, have H_2O <1.5 wt.% and CO_2 at or below detection limit of ~30 ppm. These results suggest entrapment pressures of up to 1.8 kbar (7 km) but typically <300 bar (1.2 km). These low pressures may be the result of shallow pre-eruptive magma storage or slow magma ascent allowing for degassing and H_2O re-equilibration, while most CO_2 had already exsolved at greater depths. Further melt inclusion work on other temporally constrained samples will help determine if shallow magma storage is a characteristic of other late Holocene eruptions.

443

Late Quaternary tephrochronology of Sweden - state of art and future perspectives

Professor Stefan Wastegård[1]
[1]*Stockholm University, Stockholm, Sweden*

The first tephra studies in Sweden were made by Christer Persson at Stockholm University during the 1960s. Christer Persson met the “Father of tephrochronology” Sigurdur Thorarinsson during an excursion in Iceland and a PhD project was set up aiming at exploring the possibilities of finding tephra in Scandinavian bogs. Persson found several tephras in Swedish bogs, among them Askja-1875, Hekla-3 and Hekla-4. Later studies have confirmed his findings and many additional tephras have been added to the Holocene tephra network of Sweden.

The Last Glacial-Interglacial transition (LGIT; c. 14-8 ka BP), was a complex time period, but suitable for tephra-based studies. Recent developments of tephra detection and extraction and improved analytical protocols for geochemical analyses has led to a rapid expansion of tephrochronology to distal sites. This led to the first confirmed record of the Vedde Ash (12.0 ka BP) in Sweden as well as two significant new additions to the LGIT frameworks of NW Europe, the Hässeldalen (11.4 ka BP) and Askja-S tephras (10.8 ka BP) that were first decribed from sites in SE Sweden.

Several sites in south Sweden have been investigated for the widespread Laacher See Tephra (LST; 13.0 ka BP), but it was not until recently that the LST was confirmed in a palaeo-lake sediment sequence in S Sweden.

Several recent investigations have confirmed the potential of tephrochronology in Sweden, but some areas and time periods are still underinvestigated, such as Holocene peat records in south Sweden and interstadial deposits in central and north Sweden. Many research questions have been solved with the use of tephras, but there are several others that tephrochronology has a potential to provide answers to, such as the timing and synchronicity of events during the LGIT, errors in the glacial varve chronology and the age of interstadial deposits.

526

Temporal development from crystal mush to melt-dominated reservoirs in Miyakejima volcano, Izu-Bonin arc, Japan

Shota Watanabe[1], Takeshi Hawagawa[1], Teruki Oikawa[2], Nobuo Geshi[2]
[1]Graduate School of Science and Engineering, Ibaraki University, Mito, Japan, [2]Geological Survey of Japan, AIST, Tsukuba, Japan

Defining the magmatic characteristics of a volcano after a long dormancy is critical for understanding reactivation processes. Combined analysis of stratigraphic and petrologic data of ~4.0–2.3 ka eruption products from Miyakejima volcano reveals the evolution of magmatic system after >3,000 years dormancy. The eruptive activity can be divided into Period 1 (~4.0–3.5 ka) which produced porphyritic lava flows (10–35 vol.% phenocrysts) containing troctolitic xenoliths, and Period 2 (3.5–2.3 ka) which produced aphyric scoria and lava (phenocrysts < 6 vol.%).

Lavas of Period 1 have two distinct phenocryst populations: macrocrysts (> ~1 mm) and small phenocrysts (0.3–1 mm). Troctolitic xenoliths have a porphyritic texture with macrocrysts surrounded by finer groundmass crystals, suggesting that they are the fragments of crystal mush. The variation of macrocryst abundance forms a linear whole-rock compositional trend of the lavas of Period 1. The small phenocryst compositions in the lavas suggests that the carrier of the macrocrysts is andesite magmas with SiO_2 ~60 wt.%. The whole-rock SiO_2 compositions of the Period 2 range from 54 to 60 wt.% forming a differentiation trend. Most products have euhedral phenocrysts with both normal and reverse zonation, indicating the maintenance of a melt-dominated reservoir by repeated recharge of basaltic andesite magmas.
The porphyritic lavas of Period 1 suggests that the injection of andesite magma disaggregated and removed troctolitic crystal mush that accumulated during the dormancy. Similarity of petrologic feature of porphyritic magma from Miyakejima, Iceland, and mid-ocean ridges suggests that mush disaggregation and entrainment processes globally exist in basaltic to andesitic system. Then, the replenishment of basaltic andesite magma formed a melt-dominated reservoir during Period 2. Our case study of Miyakejima provides an implication for understanding of the evolution and reactivation processes of reservoir architecture in basaltic to andesitic systems after a long dormancy.

1482

GEOMORPHIC TIME SERIES REVEALS THE CONSTRUCTIVE AND DESTRUCTIVE HISTORY OF HAVRE VOLCANO, KERMADEC ARC

Dr Erica Spain[1], Associate Professor Rebecca Carey[2], Associate Professor Jo Whittaker[2], Associate Professor Vanessa Lucieer[2], Dr Jodi Fox[2], Dr Sally Watson[1,3]
[1]NIWA, Wellington, New Zealand, [2]University of Tasmania, Hobart, Australia, [3]University of Auckland, Auckland, New Zealand

Change detection in the deep ocean is rare due to a paucity of data at appropriate scales. Monitoring of active seafloor processes requires repeat, comparable surveys. Here, we utilize an exceptional suite of bathymetric surveys across a spatio-temporal range at Havre volcano, Kermadec Arc, Southwest Pacific, over a period of 13 years. Surveyed in 2002 by the RV Tangaroa, the Havre caldera was resurveyed in 2012 (RV Tangaroa) and 2015 (RV Roger Revelle, AUV Sentry, and ROV Jason), following the largest observed deep-marine rhyolitic volcanic eruption.

These unprecedented datasets allow us to compare landforms across spatial and temporal scales and understand the constructive and destructive forces driving the evolution of Havre volcano. Multiple bathymetric datasets are used to parameterize geomorphological features and volcanic products over the caldera. We then interpret the volcanic, tectonic, erosional, and depositional processes driving the caldera's morphological evolution.

Four geomorphic groups at varying scales are interpreted: (i) large-scale tectonic features, e.g. faults, calderas; (ii) coherent volcanic products, e.g. lavas and domes; (iii) clastic volcanic products, e.g. ash, ash-lapilli-block, and giant pumice deposits; and (iv) mass-wasting features, e.g. debris flows and mega blocks. We use high-resolution AUV bathymetry to develop a fine-scale geomorphic map that reveals additional landforms and processes obscured in coarse resolution data. We integrate bathymetric data with sampling data and video footage from ROV Jason to refine geomorphic boundaries. We also integrate data from previous geological studies of Havre to inform the geomorphic interpretation.

Our work reveals additional growth on the primary dome emplacement (dome OP) between 2012 and 2015, which was not previously recognized. We also confirm voluminous shedding on the northern caldera wall and smaller scale shedding on the south-eastern wall. Our map reveals a variety of geomorphic forms reflecting a range of processes, highlighting the importance of repeat, high-resolution bathymetric surveys.

249

The fate of gases seeping from the Calypso Hydrothermal Vent, offshore Taupō Volcanic Zone

Dr Sally Watson[1,2], Dr Sarah Seabrook[1], Dr Yoann Ladroit[1], Dr Erica Spain[1], Ass. Prof. Geoffroy Lamarche[2], Ass. Prof. Vanessa Lucieer[3]
[1]NIWA, Wellington, New Zealand, [2]University of Auckland, , New Zealand, [3]Institute for Marine and Antarctic Studies, University of Tasmania, , Australia

In the past decade, thousands of sites of seafloor fluid expulsion have been identified around the world, including hydrothermal systems. The Calypso Vents in the Bay of Plenty are a suite of well-known hydrothermal vents located in ~200 m water depth. The Calypso Vents represent the offshore extension of the Taupō Volcanic Zone and are located ~40 km from the coast. The Calypso Vents lie within the active extensional back arc system, associated with active volcanism and faulting. Underwater seeps, such as the Calypso Vents, can have far-reaching and varied impacts on the surrounding environment, dependent on fluid composition and flux, water depth and ocean currents. In this presentation, we will: (1) quantify the bubble size and gas flux from the Calypso Vents using hydroacoustic data, (2) correlate acoustic and chemical signals in the water column to characterise the fluid composition and footprint of the Calypso Vent system, and (3) investigate the fate of hydrothermal fluids within the Bay of Plenty region, including contributions to ocean acidification, deoxygenation, and atmospheric carbon reservoirs.

Constraining the physical and chemical footprint of hydrothermal systems will improve our understanding of the downstream impacts of underwater seep systems on the broader environment. This work will enable more accurate monitoring of the extent of hydrothermal systems as well as associated gas exchange in the ocean for improved environmental management under future climate scenarios.

910

Infrasonic gliding reflects a rising magma column at Mt Etna (Italy)

Leighton Watson[1], Mariangela Sciotto[2], Andrea Cannata[3,2], Massimo Cantarero[2], Emanuela De Beni[2], Jeffrey Johnson[4]

[1]University Of Canterbury, Christchurch, New Zealand, [2]Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo, Catania, Italy, [3]Università degli Studi di Catania, Catania, Italy, [4]Boise State University, Boise, USA

Infrasound is increasing applied as a tool to investigate magma dynamics at active volcanoes, especially at open-vent volcanoes, such as Mt. Etna (Italy), which are prodigious sources of infrasound. Harmonic infrasound signals have been used to constrain crater dimensions and track the movement of magma within the shallow plumbing system. This study interprets the remarkable systematic change in monotonic infrasound signals preceding a lava fountaining episode at Mt. Etna on 20 February 2021. We model the changing tones (0.7 to 3 Hz fundamental frequency) as a rise in the magma column from 172+/-25 m below the crater rim to 78+/-8 m over the course of 24 hours. The infrasonic gliding disappears approximately 4 hours before the onset of lava fountaining as the magma column approaches the flare of the crater and acoustic resonance is no longer supported. The featured 20 February event was just one of 52 lava fountain episodes that occurred at Mt. Etna over the course of 9 months in 2021 and was the only lava fountain episode where dramatic gliding was observed as a subsequent partial collapse of the crater prevented future resonance. The results presented here demonstrate that analysis of infrasonic gliding can be used to track the position of the magma free surface and hence may provide information on the processes taking place within the plumbing system before eruptive activity.

911

Infrasound radiation from impulsive volcanic eruptions: 3D nonlinear computational aeroacoustic simulations

Leighton Watson[1], Eric Dunham[2]
[1]University Of Canterbury, Christchurch, New Zealand, [2]Stanford University, Stanford, USA

Infrasound observations are increasingly used to constrain properties of volcanic eruptions. In order to better interpret infrasound observations, however, there is a need to better understand the relationship between eruption properties and sound generation. As it is challenging to simulate fluid flow and the generated nonlinear acoustic waves, most simulations use linear acoustics approximations or consider nonlinear acoustics with waves excited by a region of high pressure or density.

Here we perform three-dimensional (3D) computational aeroacoustic simulations where we solve the compressible Navier-Stokes equations for pure-air with a large-eddy simulation (LES) approximation. This allows us to simulate the fluid flow with acoustic waves being generated naturally in our simulations. This builds upon our previous 2D simulation work.

We vary exit velocity, vent radius, and temperature of the erupted fluid. We examine anisotropy of the radiation pattern and compare our nonlinear simulations with the commonly used analytical linear acoustics model of a compact monopole source radiating acoustic waves isotropically in a half-space. This work will help refine infrasound-derived estimates of eruption properties.

688

A window into the inner workings of proto-oceanic rift volcanoes: An Afar case study

Miss Emma Watts[1], Dr Thomas Gernon[1], Dr Rex Taylor[1], Dr Derek Keir[1,2], Dr Melanie Siegburg[1], Miss Jasmin Jarman[1], Dr Carolina Pagli[3], Dr Anna Gioncada[3]
[1]University of Southampton, Southampton, United Kingdom, [2]University of Florence, Florence, Italy, [3]University of Pisa, Pisa, Italy

The Danakil depression in the Afar region of Ethiopia is a proto-oceanic rift, marking the change from subaerial continental rifting to seafloor spreading further north in the Red Sea. Extension and volcanism in this incipient spreading center is localised to the ~70-km-long, 20-km-wide active Erta Ale volcanic segment (EAVS), with multiple volcanic centers comprising fissures, shield volcanoes, and stratovolcanoes. This study uses three volcanoes within the EAVS (Alu, Dalafilla, and Borale) to better understand how the characteristics of volcanism change during progressive rifting.

We present our combined results from mapping (using remote sensing), major element, trace element, and isotopic analysis of the three volcanoes. We show the new high-resolution map and chronology illustrating how volcanism can be split up into 4 main stages of activity, each with its own compositional and morphological characteristics. Trace element ratios Ce/Pb and ΔNb are both elevated (33-44, 0.25-0.38 respectively) throughout all four stages indicating the consistent presence of a HIMU component, potentially supplied by the Afar plume, which is supported by Pb-Nd-Sr isotopic values.

Melting conditions (estimated through [Sm/Yb], [Dy/Yb], and [Ce/Sm]) were relatively stable over the duration of activity with a melt fraction of ~0.8% and primarily derived from spinel lherzolite (~90 %) with minor garnet lherzolite (~10 %). However, one stage within the EAVS evolution experienced a slightly higher degree of melting (~1 %) derived primarily from the spinel lherzolite facies. These variations in melting conditions show that the EAVS has experienced periods of both shallow and deeper melting during its evolution. Overall whilst the Afar plume appears to be the dominant mantle component in the volcanic rocks, the melt characteristics and storage beneath the EAVS shows variability controlled by both rifting and subvolcanic processes.

794

Characterising the wind-advected fountaining deposit from Fissure 8 during 2018 LERZ eruption, Hawaii

Miss Emma Watts[1], Professor Bruce Houghton[2]
[1]University of Southampton, Southampton, United Kingdom, [2]University of Hawaii at Manoa, Honolulu, United States of America

An eruption began on May 3rd 2018 in the Lower East Rift Zone (LERZ), Hawaii involving the opening of 24 fissures before focussing on a singular fissure, Fissure 8 (F8). The volume erupted is estimated to have been ~1 km^3, with 92-96% being from F8 alone (Gansecki et al., 2019) through a combination of fountain-fed lava flows and fall deposits. This study characterises the distal tephra deposit dominated by reticulate and golden pumice using isopleth & isopach maps alongside total grain size distribution (TGSD) analysis, shedding light on the tephra production and dispersal mechanisms occurring during the fountaining at F8.

The distal deposit (>10cm thickness) covers approximately 0.22 km^2, best modelled through a power-law thinning rate. TephraFits model (Biass, Bonadonna and Houghton., 2019) estimated the corresponding volume of the distal tephra blanket to be ~$2x10^4$ km^3; just 0.02% of the total volume erupted from F8.

TGSD analysis showed that the deposit has a modal grain-size of -3.5 to -4 Φ, and was in agreement with the Voronoi tessellation model. Maximum clast did not show a 'typical' fining-relationship with distance from the vent, instead it appeared semi-random. We attribute this to the extremely low density, of the reticulate and pumice which enabled them to be re-entrained, often repeatedly, by large eddies downwind of the vent. The low densities are a function of the secondary vesiculation event occurring at the very top of the fountain described by Namiki et al., (2019), and, as such, this complex aerodynamics did not affect the bulk of the ejecta, which was released from the top and the margins of the fountain.

This should be considered in future studies as the clasts involved are rarely well preserved in the geologic record due to their fragile nature but their presence adds complexity to the inferred eruption dynamics.

1330

Sintering of vesiculating and diffusively outgassing hydrous pyroclasts

Dr Joshua Weaver[1], Doctor Fabian B. Wadsworth[2], Doctor Anthony Lamur[1], Doctor Jackie E. Kendrick[1], Ms. Maliha Ashraf[3], Doctor Jeremie Vasseur[1], Professor Yan Lavallée[1]

[1]Department of Earth- and Environmental Sciences, Ludwig Maximillian University, Munich, Germany, [2]Department of Earth Sciences, Durham University, Durham, United Kingdom, [3]Department of Electrical and Electronic Engineering, University of Liverpool, Liverpool, United Kingdom

Hot, hydrous, pyroclastic deposits are common in volcanic conduits and in rheomorphic ignimbrites. In volcanic conduits, they can play a central role in determining the efficiency and longevity of shallow, gas-venting porous networks, which impact gas emissions and the explosive potential of volcanic systems. In such fragmental systems, pyroclasts can simultaneously sinter, vesiculate, and diffusively outgas (i.e., volatiles lost from fragment surfaces)– a combination which remains unconstrained. Here we experimentally and theoretically investigate the evolution of the permeable porous network during sintering of vesiculating and diffusively outgassing melt fragments of different grain sizes. We observe that during sintering in oversaturated and coarse-grained hydrous fragmental systems, the intergranular porous network can shut subsequently open due to concomitant vesiculation and diffusive outgassing. Both bubble growth during vesiculation and bubble resorption during diffusive outgassing impede sintering and compete to determine the intra-fragment isolated porosity. This development of intra-fragment vesicularity directly impacts the inter-fragment pore space and its connectivity, which first decreases during vesiculation and then increases during diffusive outgassing, prompting complex, non-linear permeability evolution. We show that the evolution of the porous network is strongly influenced by fragment size – coarse fragments attain greater vesicularities than finer ones – and therefore, the coarse fragmental pyroclasts experience a greater, yet transient, reduction in connected porosity and permeability. Our results suggest that an integrated sintering, vesiculation, and diffusion model is able to resolve the evolution of hydrous fragmental volcanic systems in shallow conduits and in pyroclastic deposits. We apply our integrated model to some natural examples (e.g., from Long Valley and Krafla Calderas) and evaluate possible physico-chemical conditions extant during their emplacement.

1324

Exploring the competition between bubble growth and diffusive outgassing in vesiculating pyroclasts

Dr Joshua Weaver[1], Professor Yan Lavallée[1], Ms. Maliha Ashraf[2], Doctor Jackie E. Kendrick[1], Doctor Anthony Lamur[1], Ms. Jenny Schauroth[3], Doctor Fabian B. Wadsworth[4]
[1]Department of Earth- and Environmental Sciences, Ludwig Maximillian University, Munich, Germany, [2]Department of Electrical and Electronic Engineering, University of Liverpool, Liverpool, United Kingdom, [3]Department of Earth and Environmental Sciences, University of Liverpool, Liverpool, United Kingdom, [4]Department of Earth Sciences, Durham University, Durham, United Kingdom

During volcanic eruptions, bubble growth and outgassing determine the porosity, buoyancy, and rheology of magmas. These attributes in turn dictate the potential for explosive eruption. Whilst the processes resulting in magmatic fragmentation have received substantial attention, the subsequent evolution of fragmented pyroclasts remains poorly constrained. Here, we perform isothermal experiments on obsidian cylinders in the ash to lapilli size range (1–12 mm diameter) to explore vesiculation and subsequent densification. We find that closed system bubble growth is progressively suppressed by fragment size-dependent, diffusive outgassing. We find that volatiles diffusively outgas when the volatile partial pressure external to the sample is lower than in the melt-hosted bubbles. This volatile loss produces a bubble-free dehydrated rind, which progressively thickens proportional to the diffusion lengthscale. Samples with higher surface area to volume ratios are able to outgas more. Therefore, pyroclasts with a smaller initial radius develop a higher proportion of dehydrated rind, densify faster, and attain more subdued vesicularities. Diffusive outgassing is able to produce fully dense, non-vesicular pyroclasts, effectively erasing the textural evidence of the vesiculation event altogether. Using an analytical approximate approach to the evolving clast geometry, we show that current closed system bubble growth models and diffusion models can be combined to estimate vesicularity in pyroclasts surrounded by a free gas of relatively low partial pressure of H2O. Our analyses highlight that a single explosive eruptive episode with disequilibrium volatile partial pressures may produce both dense and vesicular pyroclasts depending on their grain size, and that end products may not necessarily represent their vesiculation histories.

1198

A modular framework for the development of multi-hazard, multi-phase volcanic eruption scenario suites

Dr Alana Weir[1], Dr Stuart Mead[2], Prof Mark Bebbington[2,3], Prof Thomas Wilson[1], Dr Sarah Beaven[1], Ms Teresa Gordon[4], Mr Craig Campbell-Smart[5]

[1]School of Earth and Environment | Te Kura Aronukurangi, University Of Canterbury | Te Whare Wānanga o Waitaha, Ōtautahi Christchurch, Aotearoa New Zealand, [2]Volcanic Risk Solutions, School of Agriculture and Environment, Massey University, Palmerston North, Aotearoa New Zealand, [3]School of Mathematical and Computational Sciences, Massey University, Palmerston North, Aotearoa New Zealand, [4]Ministry for Primary Industries (MPI), New Plymouth, Aotearoa New Zealand, [5]Taranaki Civil Defence and Emergency Management, New Plymouth, Aotearoa New Zealand

Understanding future volcanic eruptions and their potential impact is a critical component of disaster risk reduction, and necessitates the production of salient, robust hazard information for decision-makers and end-users. Volcanic eruptions are inherently multi-phase, multi-hazard events, and the uncertainty and complexity surrounding potential future hazard behaviour can be highly challenging to communicate to decision-makers. Volcanic eruption scenarios are recognised to be an effective knowledge-sharing mechanism between scientists and practitioners, and recent hybrid scenario suites partially address the limitations surrounding the traditional deterministic scenario approach. Despite advances in scenario suite development, there is still a gap in the international knowledge base concerning the synthesis of multi-phase, multi-hazard volcano science and end-user needs.

In this study we present a new modular framework for the development of complex, long-duration, multi-phase, multi-hazard volcanic eruption scenario suites. The framework was developed in collaboration with volcanic risk management agencies and researchers in Aotearoa New Zealand, and is applied to Taranaki Mounga volcano, situated in a region of high volcanic risk. This collaborative process aimed to meet end-user requirements, as well as the need for scientific rigour. This new scenario framework development process could be applied at other volcanic settings to produce robust, credible and relevant scenario suites that are demonstrative of the complex, varying-duration and multi-hazard nature of volcanic eruptions. In addressing this gap, the value of volcanic scenario development is enhanced by advancing multi-hazard assessment capabilities and cross-sector collaboration between scientists and practitioners for disaster risk reduction planning. We also present examples of uptake of the scenarios in science, practice and policy, and evaluate the research co-production process.

1246

Long-duration multi-scale volcanic impact assessment

Dr Alana Weir[1], Prof Thomas Wilson[1], Dr Nicky McDonald[2], Mr Roger Fairclough[3], Ms Teresa Gordon[4], Mr Craig Campbell-Smart[5], Prof Mark Bebbington[6,7], Dr Sarah Beaven[1], Dr Stuart Mead[6], Prof Anita Wreford[8], Dr Stefania Mattea[2], Dr Nam Bui[2]

[1]School of Earth and Environment | Te Kura Aronukurangi, University Of Canterbury | Te Whare Wānanga o Waitaha, Ōtautahi Christchurch, Aotearoa New Zealand, [2]M.E Research, Auckland, Aotearoa New Zealand, [3]Neo Leaf Global Ltd, Wellington, Aotearoa New Zealand, [4]Ministry for Primary Industries (MPI), New Plymouth, Aotearoa New Zealand, [5]Taranaki Civil Defence and Emergency Management, New Plymouth, Aotearoa New Zealand, [6]Volcanic Risk Solutions, School of Agriculture and Environment, Massey University, Palmerston North, Aotearoa New Zealand, [7]School of Mathematical and Computational Sciences, Massey University, Palmerston North, Aotearoa New Zealand, [8]Agribusiness and Economics Research Unit (AERU), Lincoln University, Lincoln, Aotearoa New Zealand

Volcanic impact and risk assessment underpins effective volcanic risk management and risk reduction. Volcanic risk is driven by the interaction between the complex, multi-hazard, multi-phase volcanic system, and the equally complex societal systems exposed. These dynamic volcanic risk drivers are relatively well-understood and well-identified, but are challenging to quantify and incorporate into volcanic impact and risk assessment frameworks. Volcanic multi-hazards can cause a variety of impacts to critical infrastructure networks (and dependent sectors), which underpin the everyday operations and well-being of society. These impacts range from highly damaging to mildly disruptive, and have the potential to provoke widespread systemic impact far beyond the hazard extent. Current methods for volcanic impact assessment are limited by their generally single-phase, single-hazard perspective. They are further limited by their static, one-dimensional incorporation of exposure, vulnerability and impact, despite recognition of the dynamic properties of these risk drivers. Complex multi-scale challenges of this nature are increasingly being addressed by bringing scientists and practitioners together to collaborate in the production of disaster risk reduction (DRR) knowledge and disaster risk management (DRM) strategies.

Using long-duration, multi-hazard volcanic eruption scenarios for Taranaki Mounga volcano, we have developed an impact assessment approach that incorporates many facets of volcanic risk assessment and resilience planning, extending beyond traditional methods. Over multi-year time frames, we consider critical infrastructure recovery, the interplay between infrastructure loss of service and agricultural impact and recovery, disaster waste clean-up and how evacuation management influences the aforementioned facets of response, recovery and resilience-building. This work involved considerable engagement with research partners and their stakeholder networks. The methodological development process has led to the identification of several areas for further exploration, including dynamic evacuation management and the testing of mitigative actions, from small-scale infrastructure component improvement, to large-scale policy change.

1135

Rapid Volcanic Ashfall Impact Assessment for the 2022 Hunga Eruption: a bespoke approach and lessons learned

Dr James Williams[1], Thomas Wilson[1], Alana Weir[1], Josh Hayes[2], Carol Stewart[3], Graham Leonard[2], Christina Magill[2], Susanna Jenkins[4], Rebecca Fitzgerald[2], Shane Cronin[5], Taaniela Kula[6], Siale Faitotonu[7], Bruce Smallfield[8], Rosie Paterson-Lima[8], Stuart Fraser[9], Antonios Pomonis[10], Rashmin Gunasekera[10], James Daniell[10,11]

[1]School of Earth and Environment | Te Kura Aronukurangi, University of Canterbury | Te Whare Wānanga o Waitaha, Ōtautahi | Christchurch, Aotearoa New Zealand, [2]2 GNS Science | Te Pū Ao, Te Awakairangi | Lower Hutt, Aotearoa New Zealand, [3]School of Health Sciences, College of Health | Te Kura Hauora Tangata, Massey University | Te Kunenga Ki Pūrehuroa, Te Whanganui-a-Tara | Wellington, Aotearoa New Zealand, [4]Earth Observatory of Singapore, Nanyang Technological University, Singapore, Singapore, [5]School of Environment | Te Kura Mātai Taiao, University of Auckland | Waipapa Taumata Rau, Tāmaki Makaurau | Auckland, Aotearoa New Zealand, [6]Tonga Geological Services, , Kingdom of Tonga, [7]Civil and Natural Resources Engineering | Te Tari Pūhanga Metarahi, Rawa Taiao, University of Canterbury | Te Whare Wānanga o Waitaha, Ōtautahi | Christchurch, Aotearoa New Zealand, [8]International Development Unit, Plant & Food Research Rangahau Ahumara Kai, Lincoln, Aotearoa New Zealand, [9]Fraser Disaster Risk Consulting Ltd, Brighton, United Kingdom, [10]World Bank Group, Washington, United States of America, [11]Geophysical Institute and Center for Disaster Management and Risk Reduction Technology, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

When large, unprecedented disasters occur, rapid impact assessments can be used to release funds, mobilise aid and direct response priorities. The 15 January 2022 eruption of Hunga volcano, Tonga, and the resultant shockwave, ashfall and tsunami, caused substantive impacts across the Kingdom of Tonga, but the provision of international aid was made difficult by communications disruption. A need emerged for a rapid remote volcanic impact assessment and provision of specialist advice on volcanic impacts, to help inform the response of international partners.

This presentation outlines a bespoke rapid, remote volcanic impact assessment approach undertaken in the first 10 days after the eruption, using pre-existing vulnerability models, and progressively updating hazard (e.g. ashfall) and exposed asset (e.g. buildings, farms) data as it became available. There was considerable engagement with expatriate Tongan, and other technical experts, who provided important knowledge, insights and local context to inform the process. We focused on assessing ashfall impacts to buildings, critical infrastructure, and agriculture, and estimated clean-up requirements, on Tongatapu (the main island), as these are known to be important for community wellbeing in the aftermath of ashfall events and because geospatial datasets were available. Informed by the impact assessment, we also provided advice for managing the impacts of volcanic ashfall to critical infrastructure and agriculture sectors based on other recent eruptions in the Pacific. This paper will discuss lessons, successes, challenges, and opportunities learned for future rapid remote volcanic ashfall disaster impact assessment, which are particularly valuable for syn- and post-eruption contexts with limited communications.

567

The effect of bubble size distribution and textural characteristics on magma fragmentation: An experimental study on Mt. Taranaki (NZ)

Mr Daniel Weller[1], Ms Bettina Scheu[1], Mr Donald Bruce Dingwell[1], Mr Shane Cronin[2]
[1]Earth and Environmental Sciences, Ludwig-Maximilians-Universität München, Theresienstrasse 41, 80333 Munich, Germany, , , [2]School of Environment, University of Auckland, Science Centre, Building 302, 23 Symonds Street, Auckland Central, New Zealand , ,

Magmatic fragmentation is a key process of explosive eruptions and strongly influences the ejection behavior of pyroclasts and eruption plumes. Mechanisms of fragmentation vary considerably with magma viscosity, volatile content and mass eruption rate. Rather brittle fragmentation of vesicular magma by rapid decompression is a key mechanism for highly viscous andesitic magmas such as Mt. Taranaki (NZ). Key factors affecting this “vesicle-burst” fragmentation are magma strength, porosity, and permeability. Differences in bubble textures are hypothesized to also be important for magma fragmentation and pyroclast morphology. However, little is known so far about these relationships.

We performed rapid decompression experiments of andesitic eruptive products with a range of bubble and crystal textures from the AD1655 Burrell eruption of Mt. Taranaki to explore the effect on magma fragmentation and the size and shape of resulting pyroclasts. We focused specifically on bubble number density (BND) and bubble morphology. A transparent autoclave enables visual control via high-speed recording of the fragmentation process, in particular fracture location and evolution with respect to bubbles and crystals, well as particle ejection into the sampling tank. The generated pyroclasts are recovered and grain size as well as grain morphology is determined by sieving, laser diffraction analysis including high-speed cameras, SEM, and laser-microscopy. The latter is also used for surface roughness analysis of the particles. Preliminary results suggest that at given porosity and permeability the BND and the morphology of individual bubbles show only a minor effect on the onset of fragmentation (fragmentation threshold), but they modulate the fragmentation process itself, and in particular affect ash generation as well as the morphology of ash particles.

568

Alteration of basaltic glass - Ion exchange with recent and Archean seawater

Mr Daniel Weller[1], Ms Christina Springsklee[1], Mr Thomas Matreux[2], Mr Christof Bernhard Mast[2], Mr Daniel Weidendorfer[1], Mr Donald Bruce Dingwell[1], Ms Bettina Scheu[1]
[1]Earth and Environmental Sciences, Ludwig-Maximilians-Universität München, Theresienstrasse 41, 80333 Munich, Germany, , , [2]Systems Biophysics, Ludwig-Maximilians-Universität München, Amalienstrasse 54, 80799 Munich, Germany, ,

Fluid-rock interactions alter not only the solids, they also significantly influence the water chemistry of water reservoirs in proximity to volcanic active regions on Earth. A prominent example is palagonitization, where highly reactive basaltic glass, either as ash released by, e.g. Surtseyan eruptions, or as hyaloclastites at pillow lavas in contact to seawater will undergo devitrification resulting in the formation of clay minerals and iron oxides, etc. This process was likely present on earth since the emergence of the first oceans and was a key parameter controlling ocean chemistry, even before the emergence of life.

In this study, we experimentally explore basaltic glass/rock alteration in different water compositions relevant for early Earth as well as present day oceans. As starting material served 180-250 µm sized particles of a natural basalt rock from Krafla volcano and a synthesized crystal-free basaltic glass with the same composition. The particles underwent alteration in sealed chambers containing synthetic seawater, mirroring recent and Archean composition. At 85°C water temperature, the experiments lasted for 17, 30 and 45 days in non-stirred and stirred conditions. Water chemistry was analyzed with ion chromatography. The pH and conductivity of the solutions were monitored, however only minor changes were observed due to the high rock:water ratio (1:200). SEM and microprobe analyses of the altered particles show evidence of palagonitization. The first surface alteration was visible after 17 days, especially for glass in contact with recent seawater. Element mapping showed an alteration rim of 2-5 µm thickness, enriched in Mg, Cl, and Fe, while Si and Ca were depleted. The Archean seawater showed lower reactivity, and under reducing conditions, only calcite precipitation was visible. These preliminary results give first insights into fluid-rock interactions active on early Earth, relevant for the emergence of life and put them into perspective to present-day fluid-rock interactions.

614

Detecting Deep Volatiles at a Dormant Volcano, Taranaki, New Zealand

Cynthia Werner[1], C. Ian Schipper[2], Shane J. Cronin[3], Peter H. Barry[4], Michael K. Stewart[5], James Muirhead[3]
[1]Contractor (University of Auckland), New Plymouth, New Zealand, [2]Victoria University, Wellington, New Zealand, [3]University of Auckland, Auckland, New Zealand, [4]Woods Hole Oceanographic Institution, , USA, [5]Aquifer Dynamics and GNS Science, Wellington, New Zealand

Indicators of volatile emission from subsurface magmas are often subtle at dormant volcanoes. Magmatic carbon dioxide (CO_2) reacts with cold groundwaters, providing a long-term mechanism for deep CO_2 transfer to the surface that can easily go undetected. While rarely used for monitoring, understanding how dissolved volatiles vary in time could provide important insight into the reawakening of dormant volcanic systems.

Mineral springs occur at various distances around Taranaki volcano, New Zealand. Cold mineral springs that deposit ferrihydrite (kōkōwai) emerge on flanks 1.5 to 5 km from the summit, and warm springs emerge ~13 km from the summit on the ring plain. All cold have elevated DIC, degas CO_2, and sometimes hydrogen sulphide (H_2S) and methane (CH_4) are detected. Concentrations of CO_2 and H_2S are up to 6000 and ~1 ppmv, respectively, downwind of some kōkōwai springs. Warm springs (25-32 ^oC) are associated with travertine deposits at 250-300 m elevation, and appear to have a weak hydrothermal component. The $\delta^{13}C$ of the dissolved inorganic carbon (DIC) in the kōkōwai springs varies between -4.1 to -8.3, and air corrected He isotopes from 5.13 to 5.92 Rc/Ra, suggestive of a magmatic contribution. The observed $^3He/^4He$ and $C/^3He$ (~10^{11}) in the springs are consistent with volcanic gases from the TVZ (10^{10} - 10^{11}). The correlation of the $\delta^{13}C$ with DIC concentrations in the warm springs point to a Kōkōwai-type primary source water and suggest minimal mixing with fluids from sedimentary source rocks beneath the volcanics. Springs sampled in 2020 show little change in their chemistry since the last sampling ~40 years ago. Modelling of tritium data suggests a mean residence times of ~8-50 years at the various kōkōwai springs. These young ages combined with elevated magmatic DIC suggests present-day degassing of magmatic CO_2 into the upper edifice of Mount Taranaki, and possibly steady-state conditions.

375

Experience is a good teacher: Practical tools and tips for working with the news media.

Ms Liz Westby[1], Carolyn Driedger[1]
[1]*U.S. Geological Survey, Vancouver, United States*

In 2004, Mount St. Helens volcano reawakened with blasts of ash and steam before settling into 40 months of continuous lava dome growth. Eruption impacts were minimal, yet the news media's demands for information created a communications crisis, requiring as much or more attention than that needed for volcano monitoring and analysis.

What became necessary, essentially overnight, was a scalable framework for the news media response with clearly defined roles for observatory staff. A tentative news media management plan emerged for this immediate need, which has been sharpened by almost two decades of communications practices. This plan is formalized as the U.S. Geological Survey Cascades Volcano Observatory "News Media Management Guide: General Protocols and Templates."

This document is based upon best practices established during volcanic crises and relative calm, and extensive pre-crisis planning sessions. It offers checklists and strategies for news media engagement at four levels: normal day-to-day interactions, increasing interest, intense engagement, and multi-agency collaboration. Key elements, such as understanding the roles and needs of the news media, effective inter- and intra-agency plans for communication, and staff trainings, can be addressed calmly and deliberately prior to a crisis. Appendices provide guidance for creating messaging, preparing for and giving effective interviews, and developing communication plans.

Volcano observatories and partner agencies must maintain a state of readiness for conveying science and hazards information to the news media. This requires strong partnerships, preparation of communication plans, timely, consistent, and complementary messaging, and easily shareable visual and textual products.

In this presentation we describe lessons learned, key findings, and templates from the News Media Management Guide, including a Single Overriding Communication Objective worksheet, Communication Plan template, Rapid Response Reference Guide, and Inter-agency Communication Protocols.

539

Intermittent cessation and renewal of volcanism in the Oslo Rift revealed through detailed mapping and stratigraphy

Mr Jack Whattam[1,2], Dr Henrik Svensen[1,2], Dr Ivar Midtkandal[1], Dr Sara Callegaro[2], Dr Dougal Jerram[2,3]
[1]Department of Geosciences, University Of Oslo, Oslo, Norway, [2]Centre for Earth Evolution and Dynamics, University of Oslo, Oslo, Norway, [3]DougalEarth Ltd, Solihull, United Kingdom

The Permian Oslo Rift is a well-established example of a failed, highly-magmatic continental rift, nevertheless, there is much still to be investigated. The Oslo Rift is mainly known for its porphyritic lava flows, however, significant eruptive centres developed in the late stages that would have had a marked influence on Permian palaeo-environment. Previous workers highlighted the presence of 18 large caldera centres, formed in the middle to late stages of rift activity, yet despite the likely significance of such calderas to the Oslo Rifts volcanologic history, the caldera-related deposits have not yet been the focus of detailed study. Post-rift erosion has removed the youngest rift deposits, with caldera centre remnants now dominated by shallow plutonic rocks. Additionally, much of what remains is hidden by soil and undergrowth cover. Thus, the record of caldera volcanism is patchy, further complicated by ambiguous deposits, alteration through contact metamorphism, and faulting. However, one caldera remnant (the Alnsjø area of the Nittedal caldera) hosts a succession of caldera related rocks that highlights the complexity of volcanism and sedimentation in the early stages of caldera formation. Whilst limited in area, detailed geological mapping and logging has established a significant preserved stratigraphic thickness with large textural variations between volcanic units. We present a detailed account of the stratigraphy and mapping of deposits that show the evolution of volcanism from dominantly basaltic lavas and ignimbrites, transitioning through a period of quiescence marked by a lacustrine mudstone, into dominantly felsic ignimbrites. Our detailed mapping demonstrates far greater complexity in the remnant deposits than suggested by current geological mapping of the Oslo Rift. This work highlights the value of combining detailed geological mapping, stratigraphic logging, and cross-section construction, with thin section and geochemical analyses, to provide a meaningful understanding of the volcanic evolution in such a complex and challenging area.

583

Using Ultra-High-Resolution Topography and Three-Dimensional Data Processing to Evaluate Planetary Analog Maar Volcanoes

Dr Patrick Whelley[1,2], Mr. Jonathan Kissi-Ameyaw[3], Ms Frankie Enriquez[1,4], Dr. Jacob Richardson[1], Dr. José Miguel Hurtado, Jr[4], Dr. Lauren Edgar[5], Dr. Kelsey Young[1], Dr. Kenneth McIsaac[3], Dr. Gordon Osinski[3], Dr. Timothy Glotch[6], Mr. Luke Bateson[7], Mr. Lee Jones[7], Dr. Annie Winson[7]

[1]NASA Goddard Space Flight Center, Greenbelt, United States, [2]University of Maryland College Park, College Park, United States, [3]University of Western Ontario, Institute for Earth and Space Exploration, London, Canada, [4]The University of Texas at El Paso Earth, Environmental and Resource Sciences, El Paso, United States, [5]USGS Astrogeology Science Center, Flagstaff, United States, [6]State University of New York, Stony Brook, Department of Geosciences, Stony Brook, United States, [7]British Geological Survey, Kenworth, United Kingdom

Maar volcanoes result from magma and groundwater interactions. The frequency, location, and explosivity of these interactions determine the shapes and sizes of resulting craters through overlapping destructive and depositional events. The chaos in maar formation complicates evaluating the relationship between crater and tuff-ring dimensions with explosive energy, the latter of which is a function of magma-to-water ratio. Maars have been found on Mars and studying them on Earth provides a robust analog. Accurately relating maar eruptive products to explosion dynamics would illuminate both groundwater and volcanic histories on Mars.

To evaluate maars on Earth, we use (a) ultra-high-resolution topography, (b) three-dimensional (3D) data processing incorporating unsupervised machine learning, and (c) various numerical techniques to automatically characterize geomorphology. Kilbourne Hole and Hunts Hole (New Mexico, USA), along with Rattlesnake Crater and Vent 235 (Arizona, USA) are maars with irregular craters, asymmetrical tuff-rings, and varied formation histories. We present measurements of surge-bed cross-bedding foresets from within these maars' tuff-rings, obtained from terrestrial and aerial LiDAR. Data were collected over four field expeditions between 2017 and 2022, supported by the SSERVI-RIS4E (Solar System Exploration Research Virtual Institute – Remote, In Situ, and Synchrotron Studies for Science and Exploration) and Goddard Instrument Field Teams.

Geomorphological parameters (e.g., strike, dip, slope, curvature) are derived automatically from the data with custom software that processes LiDAR point clouds directly. Bedding attitudes measured in the field are compared to the software derived measurements to validate our methodology.

At Kilbourne we find that the explosion center moved from the eastern edge of the crater to the southwest. In contrast, at Rattlesnake, the explosion center remained somewhat steady. This indicates that the magma-water interactions that made these maar volcanoes were appreciably different, possibly as a consequence of intrusion geometry or the distribution of water in the subsurface.

200

Method selection in short-term eruption forecasting

Dr Melody Whitehead[1], Prof. Mark Bebbington[1]
[1]*Massey University, Palmerston North, New Zealand*

For accurate and timely information on the evolving state of our volcanoes we need reliable short-term forecasts. These forecasts directly impact crisis management from evacuations, exclusion zones, and when it is safe to return. Eruption forecasting should not be viewed as an academic exercise or a theoretical discussion in a back room, nor is now the time for dramatic data interpretations or a set of 'we-told-you-so' hindcasting demonstrations. To produce a short-term eruption forecast, a systematic evaluation of options is required with a critical assessment of outstanding issues and assumption validity. We run this lens over a set of existing short-term eruption forecasting methods and provide a straightforward data-driven methodology for forecast selection. Six eruption forecasting methods are presented here: (1) Expert interpretation, (2) Event trees, (3) Belief networks, (4) Failure forecasting, (5) Process / Source models, and (6) Machine-learning algorithms with a view to forecasting: (1) Eruption occurrence (onset time), (2) Eruptive vent location(s), (3) Eruption size, (4) Initial eruption style/phase, (5) Eruption phase duration, and (6) Eruption specific hazards.

This work constitutes a decision tool that can be directly applied to a volcanic system of interest to determine which eruption forecasting methods are possible, plausible, and with what implementation steps. Accompanying this is an extensive evaluation of assumption validity (and assumption avoidance options) to ensure the accurate and transparent application of any eruption forecasting method. Significant potential is identified in methods that are generally data-hungry (e.g., belief networks and machine-learning algorithms), and/or by the coupling of probabilistic methods to process/source models. However, as most volcanic systems are data-poor, expert interpretation and event trees remain the only currently available forecasting methods that can be readily and widely applied during volcanic crises.

1225

Better living through calorimetry: Testing methods to determine crystallinity in basaltic lavas with Differential Scanning Calorimetry (DSC)

Dr Alan Whittington[1], Ms Ashley Emerson[1], Ms Brenna Halverson[1], Dr Julia Hammer[2], Ms Justice Lira[1]
[1]The University of Texas at San Antonio, San Antonio, United States, [2]The University of Hawaii at Manoa, Honolulu, United States

Crystallinity can reveal important information on the rheology of lava and the rate at which it cooled. It is often determined by petrographic analysis, which can also give textural information on crystal shape and size distribution. The crystallinity of very fine-grained (and cryptocrystalline) samples can be hard to assess. An alternative strategy is to determine crystallinity by calorimetric analysis. We tested two different calorimetric approaches, using a Netzsch DSC404 Differential Scanning Calorimeter, and 30-40 mg aliquots of powdered basalt.

The first approach involves determining the magnitude of the increase in heat capacity (Cp) at the glass transition (Tg). Pure glass undergoes a significant Cp increase at Tg, which corresponds to the configurational heat capacity of the liquid. A mixture of glass and crystal undergoes a proportionally smaller increase, with a purely crystalline sample exhibiting no change at Tg. To use this method on an unknown sample requires testing a remelted glass, which can often be done using the same sample as long as it is cooled rapidly at the end of its first heating scan. Crystallinity can be estimated to ±10% using this method. The second approach is more complex and involves measuring the enthalpy of crystallization (on heating above Tg) and then the enthalpy of melting (on heating to the liquidus). Fully crystalline samples only undergo melting, and provide the value of ΔHfusion. Fully glassy samples can undergo extensive crystallization, but these crystals then get remelted, allowing the temperature-dependence of ΔHfusion to be estimated. Combining liquid and glass Cp, the actual enthalpy of fusion for an unknown sample can be determined, and hence its original crystallinity. We are currently assessing the agreement between these two methods and petrographic analysis for lavas erupted from the 2018 Kilauea Lower East Rift Zone eruption.

1136

Global Volcano Monitoring Infrastructure Database (GVMID)

Dr. Christina Widiwijayanti[1], Ms. Thin Zar Win Nang[1], Prof. Fidel Costa[1,2,3], Ms. Duong Quynh Chi Nguyen[4], Dr. Tania Espinosa-Ortega[1], Prof. Benoit Taisne[1,3]

[1]Earth Observatory Of Singapore, Nanyang Technological University, , Singapore, [2]Institut de Physique du Globe de Paris, Université de Paris Cité, CNRS, , France, [3]Asian School of the Environment, Nanyang Technological University, , Singapore, [4]School of Physical and Mathematical Sciences, Nanyang Technological University, , Singapore

Monitoring infrastructure is the fundamental asset in volcano hazard mitigation, ensuring timely warning and accurate assessment, preventing live and economic losses. Moreover, the recent advancement in monitoring technologies from the ground and space also offer major contribution to the progress in volcano science, provide a comprehensive knowledge on volcanic processes in space and time. Though there is no one-system-fits-all, optimizing infrastructure observation capability became the main goal in volcano surveillance. Understanding that the impacts of volcanic hazards can affect local to global scale, and range from short to long term period, improving volcano monitoring infrastructure is of global significance. The design of volcano observatory infrastructure needs to be optimised to capture the targeted parameters, along with commitment to share information and to cooperatively address the current challenges in volcanology. To this end, we started the open-access GVMID, which archives metadata information of the worldwide volcano monitoring infrastructure from the ground and space. The database contains information about monitoring networks, stations, and instrument types include those that record changes in seismicity, deformation, gas emission and other parameters that manifested volcanic activities. The interface (https://wovodat.org/gvmid/home.php) provides a snapshot and baseline view of the techniques and instrumentation that are in place at various volcanoes, which can be interactively queried, visualised and downloaded. The interface and dataset can be use by observatories as resource: (a) to setup new monitoring system or improving networks at a specific volcano, (b) to explore the existing instrumentations used at other analogous volcanoes, helps design and justify their current system, (c) to identify of what monitoring gaps exist, which can be then targeted by remote sensing infrastructure and future instrument deployments. Here we invite active contribution from volcano community to the development of GVMID with experiences and capabilities in their volcano monitoring operational and practice.

1133

Exploring global volcanic rock chemical compositions and their corresponding volcanic provenance by establishing interoperability between GEOROC and GVP databases

Prof. Frédérique Oggier[1], Dr Christina Widiwijayanti[2], Prof. Fidel Costa[2,3,4]
[1]School of Physical and Mathematical Sciences, Nanyang Technological University, , Singapore, [2]Earth Observatory of Singapore, Nanyang Technological University, , Singapore, [3]Asian School of the Environment, Nanyang Technological University, , Singapore, [4]Institut de Physique du Globe de Paris, Université de Paris Cité, CNRS, , France

The geochemical composition of rocks throughout the lifetime of a volcanic system is a key factor for understanding volcanic eruption processes and styles, which are in turn important for volcanic hazard mitigation. Hence, a comprehensive record of the eruptive history and its corresponding geochemical rock composition is critical for long-term hazard and risk evaluations of a volcano. Different pieces of information are available across several geochemical and volcanological databases, but no aggregated resource is currently available. In this work, we integrate data from two existing global databases, the Geochemistry of Rocks of the Oceans and Continents (GEOROC) of the Digital Geochemistry Infrastructure (DIGIS), and the Volcanoes of the World (VOTW) of the Smithsonian's Global Volcanism Program (GVP). The integration is done first at the volcano level, by linking GEOROC samples with GVP volcanoes, using the geographic location and name of both the samples and volcanoes, and then at the eruption level, by matching the eruption dates of the GEOROC samples with those reported by GVP. We create an interactive dashboard application called DashVolcano that allows exploratory analysis of the two linked databases. The application allows to: (1) Query datasets for a specific volcano, or for a pair of volcanoes for comparison, (2) visually explore datasets for spatial distribution in a map, for nomenclature volcanic rock type in TAS and Harker diagrams, and for temporal distribution in a chronogram summarizing the eruptive history, (3) download the selected datasets and print the plots for further analysis. DashVolcano produces a unified dataset that associates volcano's background information, eruptive history and the corresponding chemical rock compositions, giving access at once to data associated to most of the world's Holocene volcanoes.

581

Combining field observations and tephra dispersal modelling to evaluate eruption source parameters

Joshua Wiejaczka[1], Thomas Giachetti[1]
[1]University Of Oregon, Eugene, United States

During real-time forecasting, volcanic ash transport and deposition models rely on studies of analogous eruptions to constrain the input Eruption Source Parameters (ESPs). These include erupted volume, plume height, mass eruption rate (MER), and the Total Grain-Size Distribution (TGSD) of particles ejected into the atmosphere. In particular, the TGSD is crucial for accurate forecasts as it constrains the distribution of particles within the plume and, in turn, where/when particles of a given size, shape, and density will be deposited. In situ measurement of TGSD during an eruption is difficult and, for prehistoric eruptions, building a TGSD is often challenging due to poor deposit exposure and preservation. Here we calculate all ESPs for Phase 2 of the ~7.7 ka Cleetwood eruption of Mount Mazama (Crater Lake/giiwas, Oregon, USA) that preceded the caldera-forming, climatic eruption. The Cleetwood eruptive sequence consisted of three distinct and consecutive VEI 4 eruptions with the second being the most intense. This phase deposited a volume of 0.98 km^3 from a 19 km-high plume with a MER of 3.1×10^7 kg s^{-1}. The TGSD was determined using Voronoi tessellation and constructed from samples collected at 25 locations 6–72 km from the vent. All points used to build the TGSD are within the 5 cm isoline which represents 97% of the total erupted volume. Fitting all particles ≥ 0.5 mm yields a Fractal Dimension (D) of 3.1±0.1, like other historic VEI 4 eruptions. We then evaluate the influence of the TGSD on the modeling of tephra transport and deposition using the Eulerian ash dispersion model Ash3D. We compare different assumptions such as variable D values, bi-fractal distributions, or only considering particles above a certain size fraction. In this ongoing work, we compare not only the modeled mass load, but also local grain size distributions with those measured in the field.

338

Receiver Function Imaging of Kilauea Volcano using Nodal and Broadband Seismometers

Ms Jade Wight[1], Dr. Helen Janiszewski[1], Dr. Ninfa Bennington[2]
[1]University Of Hawai'i At Mānoa, Honolulu, United States, [2]Hawaiian Volcano Observatory, Hilo, United States

Constraining the locations of magma storage at volcanoes helps improve our understanding of eruption processes and interpretations of volcano seismicity. Using data recorded by nodal and broadband seismometers deployed on the Big Island of Hawaiʻi, we calculate teleseismic receiver functions, a traditional seismic imaging technique sensitive to abrupt velocity boundaries, to image the crustal structure of Kilauea. The use of nodal seismometers for passive seismic imaging targets has significantly expanded over the past decade, even though they are primarily sensitive to a higher frequency range than broadband seismometers. This is due to their smaller size, lower cost, and smaller footprint, which allows deployments in larger numbers and in culturally and environmentally sensitive or difficult to access environments. Previous studies have successfully leveraged the dense deployment design to image shallow crustal features that would otherwise be aliased by the typical spacing of broadband instruments, as well as image deeper structures in equal or greater detail than broadband deployments using receiver functions. We apply this technique to teleseismic earthquake data recorded during a 2018 rapid nodal deployment at the caldera and lower East Rift Zone of Kīlauea, and aim to expand our analysis to a 2022 nodal deployment on the Southwest Rift Zone. We ground-truth the nodal data against data from the nearby permanent broadband network maintained by the Hawaiian Volcano Observatory. Additionally, we use the broadband data from 2009-2021 to create a sparse array background model of Kilauea. The analysis of these data sets will combine to reveal higher resolution images of the crustal magma system at the caldera, lower East Rift Zone, and Southwest Rift Zone of Kilauea.

355

Evacuation decision-support for the Auckland Volcanic Field using a cost-benefit analysis and Bayesian Event Tree

Mr Alec Wild[1], Prof Mark Bebbington[2], Prof Jan Lindsay[1]
[1]*University Of Auckland, Auckland, New Zealand,* [2]*Massey University, Palmerston North, New Zealand*

Auckland's metropolitan area is situated upon the monogenetic Auckland Volcanic Field (AVF), posing a significant risk to the population. Evacuation is the preferable risk response during a volcanic crisis to preserve life within the exposed population. However, the decision to call an evacuation is complex and challenging, especially in distributed monogenetic volcanic settings and for volcanoes with long repose periods. One approach to support the evacuation decision-making process is to apply cost-benefit analysis (CBA), which compares the cost of evacuating versus the expected loss from not evacuating, expressed as a 'break-even' probability of fatality. We use a Bayesian Event Tree for Short-term Volcanic Hazard (BET_VHst) to assess the probability of fatality for a range of hypothetical unrest and eruption scenarios within the AVF. The BET_VHst for the AVF was developed by extending a recently revised Bayesian Event Tree for Eruption Forecasting (BET_EF) to also consider the eruptive style, phenomena produced, and the impact exceedance probability as a function of distance. We examine how three possible transitional parameters for the weight of the monitoring component affect the output spatial vent likelihood and subsequent BET_VHst outputs. This is compared to the current default weight, leading us to recommend that there is value in treating this component as a transitional parameter. For the CBA, we review four different thresholds, using two evacuation durations and two values of life used to determine the cost of not evacuating. The proposed combination of the CBA with BET_VHst is used to identify locations that are cost-beneficial to evacuate. The combinations of these two models are tested using a synthetic AVF unrest dataset to define an evacuation area for each day leading up to the eruption. While suitable evacuation areas were identified, they vary in extent due to the model parameters during the unrest sequence.

189

The Io GIS Database, v. 1.0: A new tool to support research of Jupiter's volcanic moon

Dr David Williams[1], Mr David Nelson[1], Dr Moses Milazzo[2]
[1]Arizona State University, Tempe, United States, [2]OtherOrb, LLC, Flagstaff, United States

Beyond Earth, Jupiter's moon Io is the most volcanically active object in our Solar System. It has been explored by Earth-based telescopes (most recently, using adaptive optics for higher spatial resolution) and by several NASA robotic planetary missions, most notably Voyager and Galileo. We have assembled many of the peer-reviewed and published data sets of Io from the last 20 years, building on the Io global geologic map by Williams et al. [1], into an ArcGIS™ environment we call the Io GIS Database, v. 1.0 [2]. The contents of this Database include image, topographic, geologic, and thermal emission data of Io in a geospatially-registered format. The goals of this database are: 1) to make higher-order data products of Io more accessible and usable to the broader planetary science and volcanology communities, particularly to new scientists that were not associated with the past projects that obtained the data; 2) to enable new scientific studies with the data; and 3) to create a tool to support observation planning for future Io-focused planetary missions. Currently NASA's Juno Jupiter polar orbiter is making distant flyby observations of Io as part of its Extended mission, and next decade the European Space Agency's Jupiter Icy Moons Explorer (JUICE) mission (launching Spring 2023) will also conduct distant Io observations. In this presentation we will describe the specific data sets in the Io Database, and how the Database can be used for future research.

References: [1] Williams, D.A., Keszthelyi, L.P., Crown, D.A., Yff, J.A., Jaeger, W.L., Schenk, P.M., Geissler, P.E., and Becker, T.L., 2011. Geologic map of Io, U.S. Geological Survey Scientific Investigations Map 3168, scale 1:15,000,000, http://pubs.usgs.gov/sim/3168/; [2] Williams, D.A., D.M. Nelson, M.P. Milazzo, 2021. The Io GIS Database 1.0: A proto-Io planetary spatial data infrastructure, Planetary Science Journal, 2:148, Open Access, https://doi.org/10.3847/PSJ/ac097f.

1087

Hybrid volcaniclastic deposits: recognising uncertainty in proximal volcanic stratigraphies

Dr Rebecca Williams[1], Dr Natasha Dowey[2]
[1]*University Of Hull, Hull, UK,* [2]*Sheffield Hallam University, Sheffield, UK*

Interpreting volcanic stratigraphies is the fundamental method that volcanologists use to understand and reconstruct a volcano's past behaviour. General understanding of the products and processes of Plinian and subplinian eruptions also inform numerical models that aim to mitigate against future hazards. However, the frameworks which we use to understand volcanic lithofacies can sometimes be overly simplified, with interpretations falling into distinct categories. For example, pyroclastic deposits are often considered from either a fallout or pyroclastic density current (PDC) perspective, with little attention given to facies exhibiting characteristics of both processes. Such hybrid units may be created where fallout and PDCs act simultaneously, where a transitional phase between the two occurs, and/or due to reworking.

Our study defined a novel hybrid pyroclastic lithofacies found on Tenerife (Canary Islands) and Pantelleria (Italy). The facies is proposed to record the simultaneous interaction of very proximal fallout and turbulent PDCs, and it reveals a fuller spectrum of hybrid deposition than previously reported. We propose that this work highlights uncertainty in interpreting volcanic lithofacies. However, how important is resolving this uncertainty in the proximal zone, when the hazard is high regardless of specific processes? We argue that recognising hybrid deposition in the rock record at any location is important in improving our understanding of volcanic processes and piecing together coherent eruption histories; particularly given that lack of preservation or erosion frequently create gaps in the rock record that could be misleading when interpreted in isolation. Furthermore, numerical models of lateral transport of pyroclastic material rely on proper assessment of eruption column conditions, thus interpreting these conditions from proximal units would improve hazard modelling.

1086

Spontaneous unsteadiness in pyroclastic density currents and the impact on volcanic stratigraphy

Dr Rebecca Williams[1], Dr Pete Rowley[2], Mr Thomas Johnston[1], Mr Matthew Johnson[1], Dr Gregory Smith, Dr Natasha Dowey[3]

[1]*University Of Hull, Hull, UK,* [2]*University of Bristol, Bristol, UK,* [3]*Sheffield Hallam University, Sheffield, UK*

Pyroclastic density currents (PDCs) are often inferred to be unsteady, experiencing variations in current dynamics such as velocity at a given point through time. This has been inferred from interpreting deposits that appear to show evidence of transient current conditions and through observations of PDCs which appear to show pulsatory behaviour in sustained currents. This unsteadiness is often inferred to be related to fluctuations at source as the generation mechanisms of PDCs are inherently unsteady. For example, they may be formed by progressively collapsing lava domes, or through variably collapsing eruption columns that wax and wane as the eruption progresses. Unsteadiness in a sustained pyroclastic density current is thought to affect the distance a pyroclastic density current can travel, and the nature of the deposit it leaves behind.

Analogue experiments on aerated granular currents have revealed that current unsteadiness may be spontaneously generated within the current. This study explores how current unsteadiness is generated in sustained, aerated granular currents and the impact this has on current behaviour and deposit formation. Unsteadiness manifests as pulses generated at different stages of current propagation. We investigate unsteadiness in both mono- and polydisperse mixtures, and the role of particle segregation and stratification in their generation and propagation. Resulting deposits record this through grading, variations in bedforms, and fines-rich packages, revealing a closer link between current unsteadiness and lithofacies architecture than previously realised. Further work needs to explore the impact of analogue current unsteadiness on the flow-boundary zone. Quantifying the link to deposit architecture will improve the interpretation of the sedimentation of ignimbrites, and thus our understanding of PDC dynamics.

564

Using field observations and microstructural data to understand magma flow in mafic sills: A case study of the Whin Sill

Miss Kate Williams[1], Dr Janine Kavanagh[1], Dr Elisabetta Mariani[1], Dr John Wheeler[1], Dr Stefano Urbani[1]
[1]*University Of Liverpool, Warrington, United Kingdom*

Understanding how magma is transported within sills is key to improving quantification of magma transport timescales, of potentially eruptible magma volumes and to determine the locations of mineral deposits associated with intrusions. 3D geophysical studies have suggested sill complexes are responsible for the transport of magma for hundreds of kilometres. Such transport likely requires focusing of magma flow, resulting in flow rate variations in space and time. However, how this is recorded within the rock record is poorly constrained.

Two field campaigns were undertaken to the Whin Sill to explore the dynamic processes recorded within a mafic intrusion. The Whin Sill is a quartz-microgabbro sill that intruded 295±6 Ma into Carboniferous sedimentary strata, underlying 4500 km2 of northern England. Field-based observations of macroscopic structures (individual flow units, magma fingers, ropy flow structures, elongated vesicles) preserve variations in magma flow over a range of scales. However, such observations are not common, relying on outcrop quality and exposure extent. Therefore, microscale observations are required to quantify magma flow. Anisotropy of magnetic susceptibility (AMS) fabrics have been documented for the Whin Sill, however other datasets are needed to support inferred flow trajectories. New scanning electron microscopy (SEM) and electron backscatter diffraction (EBSD) analysis of orientated microgabbro show evidence of weak crystallographic preferred orientations (CPO). The samples used in this analysis were not orientated, but the presence of CPO suggests orientated samples may contain such fabrics, which can be compared with magnetic fabrics from AMS analysis. A new method for analysing magma flow is proposed, using the quantification of elastic strain and stresses using Cross-Court 4 software and intracrystalline deformation. This information can be used to quantify small-scale variations in flow within a single outcrop. These results provide new insights into how local small-scale variations in magma flow can be measured within mafic intrusions.

563

Integrating magma flow and heat transfer numerical models with application to contact metamorphism around sills

Miss Kate Williams[1], Dr Adelina Geyer[2], Dr Catherine Annen[3], Dr Janine Kavanagh[1]
[1]University Of Liverpool, Warrington, United Kingdom, [2]CSIC, , Spain, [3]Czech Academy of Sciences, , Czechia

Analogue experiments and field studies have suggested that magma flow within mafic sills is rarely uniform; instead, flow becomes focused with adjacent areas of stagnated flow. These areas of focused flow would maintain higher temperatures for greater durations, which could alter the temperatures recorded in the country rock. Studies into the effect of igneous intrusions on the surrounding host rock are key to understanding contact metamorphism processes, mineralisation and the maturation of organic matter for petroleum prospects close to intrusions.

To investigate the effects of magma flow on the temperatures recorded in the country rock around mafic sills, a thermal and fluid dynamic finite element model was created in COMSOL multiphysics v.6.0, which includes the thermal properties of the country rock and magma as well as the flow properties of the magma. Our model differs from existing numerical models of intrusions which consider the heat transfer and the magma flow separately, while this model considers how the interaction of the different dynamic thermal and fluid processes may alter the resulting temperatures. We apply our numerical model to natural examples by inputting values specific to the Whin Sill, which is a quartz-microgabbro intrusion underlying 4500 km2 of northern England with a thickness ranging from 1.8 to 80 m. The sill intruded at a depth of 1500 m into Carboniferous aged sedimentary rocks, and has a contact aureole with a thickness range of 4 m to 25 m with little correlation with the thickness of the sill. The results of our model provides further evidence for the complexity of heat transfer processes, mineralisation and the timescales of emplacement for mafic sills. Such a model is versatile and applicable to intrusions of different dimensions and starting conditions, making it capable of providing insights into magma emplacement timescales and cooling under specific conditions.

1143

Probabilistic hazard and impact assessment of the Auckland Volcanic Field, Aotearoa New Zealand

Dr James Williams[1], Thomas Wilson[1], Josh Hayes[2], Graham Leonard[2], Christina Magill[2], Mark Bebbington[3,4], Stuart Mead[3], Alana Weir[1], Rebbecca Fitzgerald[2], Nicole Allen[5]

[1]University of Canterbury | Te Whare Wānanga o Waitaha, Ōtautahi |Christchurch, Aotearoa New Zealand, [2]GNS Science | Te Pū Ao, Te Awakairangi | Lower Hutt, Aotearoa New Zealand, [3]Volcanic Risk Solutions, School of Agriculture and Environment | Te Kura Mātauranga mō Ahuwhenua me Te Taiao, Massey University | Te Kunenga Ki Pūrehuroa, Te Papa-i-Oea | Palmerston North, Aotearoa New Zealand, [4]School of Mathematical and Computational Sciences, Massey University | Te Kunenga Ki Pūrehuroa, Te Papa-i-Oea | Palmerston North, Aotearoa New Zealand, [5]Geoscience Australia, Canberra, Australia

Volcanic eruptions can be particularly complex events capable of producing multiple hazards simultaneously and/or consecutively, causing eruptions to have compounding impacts on society. Comprehensive volcanic risk assessments are, therefore, required to inform appropriate disaster risk and resilience strategies. We present a conceptual framework for probabilistic volcanic multi-hazard impact assessments for societal elements. We apply this framework to recent, and in-development, probabilistic volcanic hazard assessment methodologies and models, and existing eruption scenarios for the Auckland Volcanic Field (AVF), Aotearoa New Zealand. This probabilistic approach allows robust quantification of uncertainty, reduces the potential for bias that scenarios inevitably suffer from, and allows easier comparison with other similarly assessed risks (e.g. seismic).

We use existing dynamic eruption scenarios for the AVF, which include multiple volcanic hazards and transitions in eruptive style, for which we have relative likelihoods at every location in the field based on the matching of environmental factors and eruption styles. We will combine these with detailed location-specific modelling of hazard phenomena to produce pseudo-probabilistic hazard and impact estimates. We anticipate producing results that can be interpreted as the site-specific probability of various hazard impacts, including combinations of hazard impacts arising from the entire suite of scenarios, weighted by likelihood of occurrence. The results of this framework application will inform short- to long-term planning and mitigative strategies locally in the AVF, and for nationally significant sectors. The framework will be incorporated as a module for broader national volcanic risk assessment and management frameworks.

1463

Volcanic Hazard and Risk Assessment for Transpower NZ's National Transmission Network: co-producing knowledge to inform resilience investment

Professor Thomas Wilson[1], Alana Weir[1], Christina Magill[2], Roger Fairclough[3], Leo Liu[4], Charlie Noakes[4], Steve Peake[4], Mark Bebbington[5,6], Noel Kortright[7], Stuart Mead[5], Hugh Mace[1], Sophia Tsang[8], Laura Tilley[1], Julian Morton[4], Matthew Hansen[4], Shaun McCarthy[4], Matthew Bate[4], Matthew Haddington[4], Tom Middleton[4], Wayne Billot[4], Simon Carter[4], Sarah Sutherland[4], Richard Joyce[4], Keith McCallum[4], Nathan Lynn-Watts[4], Cijina Kunnath[4]

[1]School of Earth and Environment, University Of Canterbury, Christchurch, New Zealand, [2]GNS Science, Lower Hutt, New Zealand, [3]Neo Leaf Global Ltd, Wellington, New Zealand, [4]Transpower New Zealand Ltd, Wellington, New Zealand, [5]Volcanic Risk Solutions, School of Agriculture and Environment, Massey University, Palmerston North, New Zealand, [6]School of Mathematical and Computational Sciences, Massey University, Palmerston North, New Zealand, [7]Nkor Consulting Ltd, Lower Hutt, New Zealand, [8]School of Environment, University of Auckland, Auckland, New Zealand

The national electricity transmission network of Aotearoa New Zealand, operated by Transpower New Zealand Ltd, is exposed to a range of volcanic hazard risks from Aotearoa's many volcanoes. While it has been well-established the national grid is exposed to volcanic hazards, including the experience of ashfall induced flashover disruption to circuits during the 1995 eruptions of Ruapehu volcano, there has been limited, if any, systematic studies on the assessment of volcanic hazard and risk to the national electricity transmission network. This study was commissioned by Transpower to investigate the hazard and potential impact of volcanic eruptions on its assets and services in a semi-quantitative manner, as part of a wider programme of resilience work. This study was developed as a partnership between relevant volcanic hazard and risk researchers, lifelines experts and Transpower to: a) co-produce knowledge which will be used to assess and reduce volcanic risk to Transpower's operations and stakeholders, and b) specifically co-produce impact and mitigation scenarios which can be used as inputs for sophisticated electrical and economic system models for Transpower and national benefits.

Using the best available research knowledge and models, coupled with a collaborative co-production methodology, the volcanic risk team engaged and worked with relevant Transpower teams and specialists to develop, improve and customise the required outputs of the study. Broadly following the conceptual natural hazard and risk assessment framework, we developed a bespoke approach to identify assets that are particularly exposed and/or vulnerable to impact from volcanic eruptions, estimate return periods of volcanic events, and estimate the extent of potential damage and service interruption. We also make recommendations for preventative and mitigative measures, to help inform resilience investment cases. The co-development of the aforementioned outputs has highlighted several major findings of relevance to national transmission volcanic risk and resilience.

1284

Microseismicity reveals the fault geometry and internal structure of the re-inflating Bárðarbunga caldera

Dr Tom Winder[1], Nick Rawlinson[1], Bryndís Brandsdóttir[2], Kristín Jónsdóttir[3], Robert White[1], Omry Volk[4]
[1]*University Of Cambridge, Cambridge, United Kingdom,* [2]*University of Iceland, Reykjavík, Iceland,* [3]*Icelandic Meteorological Office, Reykjavík, Iceland,* [4]*SeismicAI, Tel Aviv, Israel*

Between 2014-2015 Bárðarbunga caldera collapsed, subsiding by 65 metres as magma flowed out from beneath it to feed a fissure eruption at Holuhraun. Subsequent inflation, accompanied by sustained seismicity along the caldera ring faults with reversed polarity compared to the eruption period, indicate resurgence of the caldera and recharge of the crustal magma storage reservoir. In summer 2021 an array of 6 seismometers was installed on the ice cap above Bárðarbunga, to improve constraints on earthquake locations and focal mechanisms, as well as ray coverage for tomographic imaging.

QuakeMigrate was used to produce a catalogue of 8,000 earthquakes over the 8 week deployment, with magnitude of completeness ML -0.8. Refined locations from waveform cross-correlation and relative-relocation reveal a sharply defined ring fault, consistent with geodetic constraints obtained during the caldera collapse. Tightly constrained focal mechanisms reveal further details of the caldera-bounding fault system. In addition to these high-frequency volcano-tectonic earthquakes around the caldera margins, we resolve shallow events within the ice-cover, and long-period (LP) earthquakes beneath the centre of the caldera at both 6-8 km, and between 15 – 25 km depth b.s.l. These anomalous events are likely caused by fluid movements, with the shallowest cluster possibly marking the location of the shallow crustal magma storage reservoir, and those in the ductile lower crust indicating magma/fluid ascent pathways.

Precise manually picked phase arrival times will be inverted to produce a local body-wave tomography model of the internal structure of the volcano, providing constraints on the relative geometry of the caldera ring faults and the magma reservoir that drained during the 2014-15 caldera collapse. These may be compared to laboratory and numerical models of caldera formation and faulting mechanisms to provide an improved general understanding of this important volcanic phenomenon.

1282

Lower crustal earthquakes reveal the trans-crustal magma plumbing systems of Icelandic volcanoes (I): spatial distribution & frequency content

Dr Tom Winder[1], Tim Greenfield[1]
[1]*University Of Cambridge, Cambridge, United Kingdom*

We present a combined analysis of deep long-period (DLP) microseismicity at volcanoes across Iceland, founded on newly revised earthquake catalogues produced using the QuakeMigrate software package. We achieve an order of magnitude increase in detections for previously known DLP clusters, and identify new clusters now covering every active central volcano in central Iceland, and spanning the entire thickness of the lower crust, from 6 to ~ 40 km depth. We investigate DLP seismicity accompanying eruptions and lower-crustal intrusions, as well as persistently active clusters which exhibit episodic but intense hours- to days-long swarms.

These micro-earthquakes stand apart from typical, shallow microseismicity due to their occurrence in the normally ductile lower crust (here > 6-8 km depth) and their lack of energy at high frequencies (dominantly ~ 2 Hz). The DLP events' location, spectral properties and focal mechanisms, combined with independent geochemical and/or petrological evidence, have led to their interpretation as indicating fluid ascent pathways, similarly to DLPs beneath volcanoes in Japan, Hawai'i, Klyuchevskoy, and elsewhere. However, in all cases, conclusive evidence constraining the physical mechanism (or mechanisms) responsible for generating these distinctive earthquakes remains elusive.

The newly recognised ubiquity of DLP events at active volcanoes in central Iceland shows they represent a reliable fingerprint of the magma plumbing systems through which melt ascends from the mantle to the shallow crust, and provides a rare opportunity to compare their characteristics between adjacent clusters and volcanoes. Here we investigate the sometimes markedly different spatial distributions and frequency content of DLP clusters, and in the companion presentation (Greenfield & Winder – same session) we provide detailed analysis of their varied temporal occurrence and magnitude distributions. Collectively, we aim to illuminate both the architecture of these volcanoes' deep roots, and the nature of the seismic events that trace their path from mantle to surface.

600

Crystal mush evolution and storage conditions at Cordón Caulle, Chile

Heather Winslow[1], Philipp Ruprecht[1], Martin Oeser[2], Stefan Weyer[2], Helge Gonnermann[3], Patrick Phelps[3], Matthew Pritchard[4], Francisco Delgado[5], Carolina Munoz-Saez[1]

[1]University Of Nevada, Reno, Reno, United States, [2]Leibniz University Hannover, Hannover, Germany, [3]Rice University, Houston, United States, [4]Cornell University, Ithaca, United States, [5]Universidad de Chile, Santiago, Chile

Puyehue-Cordón Caulle (PCC) is an active volcanic complex located in the SVZ of the Andes that has had three major historic rhyolitic eruptions with the most recent event in 2011-12. Petrologic and geochemical evidence suggest PCC is underlain by a crystal-rich magma mush using recently identified basaltic mafic enclaves that highlight the involvement of distinct mafic magma components during the 2011-12 eruption. The dominant population of mafic enclaves are equigranular, crystal-rich (45-55%), vesiculated, and display interlocking grains between phases. Trace element data from the enclave interstitial glass is nearly identical to the whole-rock rhyolite lava the enclaves are hosted in supporting a genetic relationship between the mafic enclaves and host rhyolite. Textural and geochemical data suggest the mafic enclaves represent remnants of the crystal-rich mush that get entrained during eruption of the crystal-poor rhyolite melt lens cap.

Here, we present quantitative estimates of the mafic enclaves to further constrain the crystal mush architecture using Mg partitioning in plagioclase as a thermometer, clinopyroxene-liquid barometry, and Mg-Fe isotopes in olivine to unravel crystal mush evolution and storage. Published geothermobarometry from the 2011-12 rhyolite suggests shallow magma storage (100-140 MPa, 895°C), which we compare against newly determined thermometry that indicates the enclaves were stored at ~900-1000°C at the time of eruption suggesting both a compositionally and thermally zoned magma system. Clinopyroxene-liquid barometry points toward shallow storage and differentiation (~100-400 MPa) with some clinopyroxene core crystallization occurring deeper. Thermobarometry estimates support a relatively shallow crystal mush that can be spatially connected to the rhyolite melt lens cap. Preliminary results of Mg-Fe isotopes in olivine present dominantly growth controlled chemical zonation and overall, isotopically light Fe isotopes which introduces new questions about ongoing differentiation and storage processes in an active mush. Investigation into these results will provide insight into crystal mush dynamics at PCC.

909

Contrasting eruption styles from the intermediate composition, Devil's Ink Pot fissure eruption, Ascension Island.

Miss Rebecca Winstanley[1], Dr Richard Brown[1], Dr Charlotte Vye-Brown[3], Dr Katie Preece[4], Dr Katy Chamberlain[2], Dr Fabian Wadsworth[1]

[1]Durham University, Durham, United Kingdom, [2]Teesside University, Teesside, United Kingdom, [3]British Geological Survey, Edinburgh, United Kingdom, [4]Swansea University , Swansea, United Kingdom

Ascension Island is a Holocene, intraplate volcanic island in the South Atlantic Ocean and exhibits a wide compositional range of magma from basalt to rhyolite. The 1.3 km long Devil's Ink Pot fissure (DIP), in the south-east of the island represents one of the youngest and best-preserved intermediate-composition eruptions on the island. We present detailed field work, petrographic and geochemical data to reconstruct the evolution of the DIP trachyandesite eruption and provide insights to future eruption scenarios on Ascension. The fissure is composed of 18 craters, 3 lava flow fields and tephra fall deposits up to 2 m thick. Two contrasting eruption styles are evidenced in crater deposits along the fissure. Some craters are characterised by moderately- to densely-welded spatter and fed lava flows. Other craters are characterised by weakly agglutinated spatter, loose lapilli and bomb clasts and an abundance of lithic and ballistics clasts (>1 m in diameter). Tephra fall deposits are composed of scoria, pumice, dense clasts, and lithic clast components. Despite the morphological and lithological differences along the fissure, whole rock major and trace element analyses show that the erupted magma is chemically uniform. Initial analysis of feldspar microlite textures and anorthite contents indicate variations in the time spent in the upper conduit for the tephra and lava/spatter samples. This suggests that the magma feeding the lava/spatter-forming eruption style was characterised by a greater overall residence time in the shallowest portions of the upper conduit zone, consistent with recent conceptual models of fissure eruption localisation, and so-called hybrid explosive-effusive eruption styles. Small volume eruptions may be missing from the geological record, leading to a potential underestimation of their frequency. However, even small-volume eruptions are significant on small islands with limited options for self-evacuation of local inhabitants.

908

Generation, storage, and eruption of an intermediate composition magma on Ascension Island.

Miss Rebecca Winstanley[1], Dr Richard Brown[1], Dr Katy Chamberlain[2], Dr Katie Preece[4], Dr Charlotte Vye-Brown[3], Dr Fabian Wadsworth[1]

[1]Durham University, Durham, United Kingdom, [2]Teesside University , Teesside, United Kingdom, [3]British Geological Survey, Edinburgh, United Kingdom, [4]Swansea University, Swansea, United Kingdom

Ascension Island is a Holocene, intraplate volcanic island in the South Atlantic Ocean. The island exhibits a wide compositional range of basalt-trachybasalt-basaltic trachyandesite-trachyandesite-trachyte-rhyolite(1) magma, but intermediate products make up <5% of the surface deposits. Here, we focus on the 1.3 km long, trachyandesite Devil's Ink Pot fissure (DIP), located in the south east corner of the island, and one of the youngest and best-preserved intermediate composition eruption on the island. We use a combination of petrological and geochemical data collected from juvenile components and present whole rock major and trace element data, crystal textures, and compositions, melt inclusion data and associated modelling of intensive variables to understand the genesis and triggers of intermediate melts, and relate this to the processes of magmatic evolution at low-flux ocean island volcanoes. Whole rock and trace element analyses show that the erupted magma is chemically uniform. However, petrological, and geochemical analysis of plagioclase and olivine crystals identified textural and chemical variations. MELT's modelling from the least evolved Ascension Island deposits is not able to reproduce the same intermediate composition of the Devil's Ink Pot fissure. Previous island wide studies have shown that intermediate melts formed by fractional crystallisation, but MELTs modelling and eruption specific studies suggest that additional processes are involved in the generation of intermediate melts.

(1) Weaver, B., Kar, A., Davidson, J. and Colucci, M., 1996. Geochemical characteristics of volcanic rocks from Ascension Island, south Atlantic Ocean. Geothermics, 25(4-5), pp.449-470.

418

Syn-emplacement volatile pathways in the Sandfell laccolith, eastern Iceland

Taylor Witcher[1], Steffi Burchardt[1], Tobias Mattsson[2,3], Orlando Quintela[1]
[1]Uppsala University, Uppsala, Sweden, [2]Stockholm University, Stockholm, Sweden, [3]University of St. Andrews , St. Andrews, United Kingdom

Organized bands of cm-scale tensile fractures have been observed in several different igneous settings and are likely a volumetrically significant degassing mechanism for shallow silicic intrusions. The fracture system exists to some degree at every outcrop of the rhyolitic Sandfell laccolith (>50 vol%). They host significant concentrations of REEs, Fe oxide and Mn carbonate, suggesting the fractures acted as traps for metal-bearing volatile phases. Lack of water in the Sandfell system kept magma viscosity high and hydrothermal fluids low, uniquely preserving this syn-magmatic fracture system while trapping metals and REEs that would otherwise have been transported away (Witcher et al, IAVCEI poster 2023). Here we present results from a field campaign mapping the extensive brittle deformation within the Sandfell laccolith, including orientations of the bands and associated fractures, a 3D model created in the MOVE software, paleomagnetic measurements (Twomey et al, in prep), field photos and thin section analyses.
The deformation can be categorized into four stages, in order of increasing size: 1) porous flow bands (mm); 2) single-orientation tensile fracture bands (cm); 3) multiple fracture sets overlapping in the same fracture band (10s cm), and 4) indistinguishable orientations and indistinguishable bands (breccia zone). These degrees of deformation are mapped on the 3D model. In addition, we plotted orientations of the fractures and the bands throughout the whole laccolith, and reversed laccolith inflation-related deformation to identify areas of highest stress. Paleomagnetic vectors from the laccolith and its surroundings will offer a time-stamp of emplacement behavior, and complement the deformation model.
We compare the types of deformation with the identified areas of stress concentration during laccolith inflation, and conclude on the connection between deformation and volatile degassing.
The results shed light on the magmato-tectonic forcing of brittle deformation as a metal-transport mechanism that is usually overprinted by the time of exhumation.

416

Textures and compositions of syn-magmatic fracture fillings in the Sandfell laccolith, eastern Iceland

Taylor Witcher[1], Steffi Burchardt[1], Tobias Mattsson[2,9], Anne Pluymakers[3], Michael J. Heap[4], Alexandra R. L. Kushnir[5], Iain Pitcairn[2], Pim Kaskes[6], Johann Lissenberg[7], Tobias Schmiedel[3], Shaun L. L. Barker[8]
[1]Uppsala University, Uppsala, Sweden, [2]Stockholm University, Stockholm, Sweden, [3]Delft University of Technology, Delft, The Netherlands, [4]Université de Strasbourg, Strasbourg, France, [5]Écoloe Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland, [6]Vrije University, Brussels, Belgium, [7]Cardiff University, , UK, [8]University of British Columbia, Vancouver, Canada, [9]University of St Andrews, , UK

The processes removing ore metals from silicic magma in the early stages of emplacement are poorly constrained. Current ore formation models account for evolved systems forming metal-rich fluid channels between the crystal network, but evidence for melt-rich processes is typically erased by crystallization and/or hydrothermal fluid alteration. Here we present a preserved magmatic fracture system in the Sandfell laccolith (eastern Iceland). The cm-scale fractures are tensile, and organized in a rhyolitic microlite groundmass with uniform height and width in concentrically parallel bands.

We collected samples and found mineralization of Fe-oxides, Mn carbonates and REE encrustations within the fractures. The surrounding groundmass is unaltered except for a small decrease in Fe, which is visible on fresh surfaces as a light-colored halo around each fracture. 3D imaging of the fracture bands reveals individual fracture lengths greatly exceed their height. Smaller fractures sometimes join two main fractures together, otherwise each individual fracture is quite isolated.

We hypothesize the uniaxial compression against the host rock created mode I fractures to open in the magma during inflation. The resulting void space drew in volatiles which carried with them associated metals (Fe, REEs). Incremental growth of the fractures changed the fluid composition as more volatiles entered the system. Smaller fractures joining two large ones together disturbed the minerals, reworked them and pushed them into traps.

Based on this evidence, we propose that these fracture bands act as a degassing mechanism for silica-rich, shallow crustal intrusions. Additionally, the degassing removes incompatible elements (metals and REEs) from the melt. The presence of similar fracture bands in other igneous settings proves that their formation is not unique to the Sandfell laccolith, but shows how easily these features can be overprinted or erased after formation. This process is likely an important addition to the orthomagmatic/hydrothermal ore deposit formation model.

439

Future requirements for volcanic gas hazard forecasting for aviation

Dr Claire Witham[1], Dr Nina Kristiansen[1], Dr Frances Beckett[1]
[1]*Met Office, Exeter, United Kingdom*

Over the last 10 years, the aviation industry has become increasingly interested in the impacts of volcanic sulphur dioxide (SO_2) on passengers and aircraft. Elevated concentrations of SO_2 pose a potential health hazard to people whether they are on the ground or within an aircraft and may also impact aircraft components and hence increase maintenance cycles. Recent aviation interests have focused on the health hazard, with the International Civil Aviation Organization actioning work to explore how a future forecasting service could provide relevant real-time information.

The exposure and level of potential risk to air crew and passengers is determined by the extent and concentration of volcanic SO_2 plumes that the aircraft encounters. Determining these levels in real-time and forecasting them into the future requires a combination of monitoring, satellite observations and modelling. In addition, evidence-based thresholds need to be agreed that relate to health-related outcomes so that appropriate decisions can be made by the airline operators. The choice of these thresholds will significantly influence the area and duration for which a “hazard area” may exist. Based on case studies of recent eruptions, these areas can be substantially larger and longer lasting than the equivalent ash advisory areas.

This presentation will summarise the current drivers in this area and the state of the science. One of the recent sticking points is around appropriate health thresholds, both what these would be and how/if they would be applied. Expectations of future functionality currently exceed what is operationally feasible and point to a need for increased multidisciplinary work across health, observations, and modelling areas. The requirements are also likely to place an extra burden on volcano observatories.

245

Melt migration rates and styles in two-phase magmatic systems using a unified numerical model for porous, mush and suspension flows

Dr Ying Qi Wong[1], Dr Tobias Keller[1]
[1]ETH Zürich, Zürich, Switzerland

Magma ascent and processing in the Earth's mantle and crust involves multiple phases of different chemical compositions including solid crystals, liquid melt, and, in shallow regions, even volatile fluids. These processes involve magma mixtures that span a range of phase proportions and concomitant flow regimes, from partially molten rock in the asthenosphere (low melt fraction, porous flow) to magma mushes within the crust (intermediate melt fraction, mush flow) to melt-rich layers with suspended crystals in magma reservoirs (high melt fraction, suspension flow). However, most numerical models of multi-phase magmatic systems rely on theory for the porous and suspension flow endmembers – the McKenzie compaction model and the hindered Stokes settling model respectively. This limitation hinders self-consistent investigations into all flow regimes, particularly the mush flow regime. Building on a recent theory (Keller and Suckale 2019), we develop a numerical model to investigate the mechanics of two-phase, solid-liquid magma mixtures across all phase proportions. We calibrate effective transport coefficients (e.g., viscosity, permeability) to experiments and endmember models using CATMIP, a Bayesian parameter estimation procedure (Minson et al. 2013). The resulting model recovers well-known solutions in endmember solid-dominated porous and liquid-dominated suspension flow regimes. The model self-consistently extends into the mush regime and reveals that channelised flow plays an important role in extracting eruptible melt from a mush. Due to the inherent length scale of melt segregation and solid compaction, melt-rich channels or lenses develop a characteristic spacing and grow to a critical size at which they may ascend further by diapirism. We further apply the model to test how melt channelisation evolves under shear. Results of the model may explain the formation of stacked sill structures and yield melt accumulation rates that may explain how large volumes of eruptible melt are rapidly assembled from mush reservoirs.

1381

GasWEB: An Autonomous UAS-deployed Sensor Array for Measuring Spatiotemporal Volcanic Gas Chemistry

Dr Kieran Wood[1], Dr Emma Liu, Dr Thomas Richardson
[1]University Of Manchester, Manchester, United Kingdom, [2]University College London, London, United Kingdom, [3]University of Bristol, Bristol, United Kingdom

The chemistry of gases emitted from volcanoes provides unparalleled insight into the state of the magma and the structure of the shallow subsurface; however, known spatial heterogeneity in intra-crater emissions is not captured by current methods. Multi-species gas sensing instruments are typically installed at a single ground location or flown aboard single Uncrewed Aerial Systems (UAS). A measure CO2 is routinely estimated by combining such spot proximal gas ratio (CO2/SO2) measurements with an independent measure of SO2 flux. An assumption of uniform gas chemistry, in both time and space, is implicit in this approach; if this assumption breaks down, then the resulting CO2 fluxes can be highly uncertain.

GasWEB is an integrated array of low cost, autonomous, and drone-deployable sensor nodes capable of relaying spatially-resolved gas data in real time to a distant base-station using radio, and where necessary, satellite, communications. This simultaneous distributed sensor approach aims to overcome limitations of single-point, or single-time measurements. Individual nodes measure prominent volcanic gas species and meteorological variables using a miniaturised intermittent pumped system. With an emphasis on low-mass, -power, and -cost, the sensors are flexible for deployment using moderate sized UAS in complex volcanic environments, therefore allowing significantly longer time series data collection at the most inaccessible volcanoes. Previous tests have demonstrated the feasibility of individual components of the concept and now a full distributed gas measurement system has been created.

New results from a multi-node deployment will be presented based upon lab tests and a field trial on Etna volcano using an array of 10 sensors. Preliminary analysis indicates the system can reliably and autonomously collect gas ratio data and transmit via satellite. In contrast to a single sensor approach, an array of simultaneous measurements will have a potentially transformative impact on volcanic gas monitoring though harnessing novel spatiotemporal information.

608

Juvenile ash textures from first eruptions – a new petrologic forecasting tool?

Dr Heather Wright[1], Dr Katharine Cashman[2], Dr Raffaello Cioni[3], Dr Matthew Loewen[4]
[1]USGS - Volcano Disaster Assistance Program, Vancouver, United States, [2]University of Oregon, Eugene, United States, [3]Università degli Studi di Firenze, Florence, Italy, [4]USGS - Alaska Volcano Observatory, Anchorage, United States

Volcanic eruption style is dictated by the history of gas saturation, degassing, gas transfer, and outgassing from/into erupted magma, where rapid decompression and limited outgassing lead to the most intense eruptions and vice-versa. Microlite number densities in intermediate to silicic volcanic rocks provide one proxy for volatile exsolution rate and, in some cases, decompression rate (Toramaru 2008) that precedes eruption. Indeed, many effusive dome-forming and Vulcanian eruption products have lower microlite number densities than those from subPlinian/Plinian eruptions (e.g., Cassidy et al. 2018). However, the relationship between eruption style and microlite number density does not always hold. At Mount St. Helens, pre-climactic and cryptodome samples have maximum plagioclase number densities of 105 mm-2, orders of magnitude higher than subPlinian to Vulcanian eruptive products of summer 1980 (Cashman and Hoblitt 2004; Cashman and McConnell 2005). Pre-climactic subPlinian and Vulcanian eruptive products from Pinatubo reach similar number densities (105 mm-2) despite wide ranging individual column heights and volumes (Hammer et al. 1999). The earliest samples erupted from Mt. Pelee on May 18, 1902 precede the climactic blast phase of that eruption but also have remarkably high plagioclase microlite number densities reaching 105 mm-2 (Martel and Poussineau 2007).

We posit that microlite number densities in vanguard magmas within closed systems may correlate not with the rate of pre-eruptive ascent but instead with the eruptive intensity of the forthcoming eruption, as illustrated by a plot of maximum column height vs. plagioclase number density of the first juvenile ash. In this model, the maximum microlite number density of the first ash reflects the characteristics of the crustal container, particularly the ability for pressure to build and cycle (decompress/recompress; Lindoo and Cashman, 2021).

591

Mitigation of human cognitive bias to improve volcanic eruption forecasting

Dr Heather Wright[1], Dr Jeremy Pesicek[1], Dr Stephen Spiller[2]
[1]USGS - Volcano Disaster Assistance Program, Vancouver, USA, [2]UCLA - Anderson School of Management, Los Angeles, USA

Volcanic eruption forecasts incorporate a wide variety of methods, paralleled by variation in the practical process by which these methods are applied. These variations include how eruption forecasters gather data, discuss possible volcanic outcomes, incorporate model results, and assign relative or absolute probabilities to each forecast scenario. Here, we discuss the cognitive biases that commonly enter forecasts and ways to mitigate their effects.

We address 1. Information biases, relating to how we collect and interpret information from sources; 2. Group effects/social biases, relating to how we build upon and modify our interpretations based on discussions with our peers; and 3. Process/decision biases, relating to how we rank information and make decisions using data.

We build upon research in behavioral decision-making and economics that shows practical ways for eruption forecasters to improve forecast success include: 1. Choose the right forecast questions, 2. Involve the right people, 3. Minimize error and reduce bias, 4. Forecast as a team, 5. Aggregate forecasts, 6. Revise forecasts and evaluate success.

We apply strategies shown to mitigate the effects of above-mentioned biases and to maximize forecast success to volcanic eruption forecasting in the form of a checklist:

1. Brainstorm all possible unrest scenarios (including low likelihood and non-eruptive scenarios)
2. Present/share base rate and current unrest information (avoid starting with inside view/emotional or intuitive reaction)
3. Collect anonymous forecast likelihoods (and rationale) before group discussion
4. Discuss and encourage diverse opinions, record outstanding questions, list desired additional data streams or measurements, and brainstorm models that would be useful. Assign someone to play devil's advocate. Discuss potential bias sources
5. Re-elicit anonymous forecasts after discussion
6. Aggregate opinion
7. Create an update schedule
8. Conduct after-action review (e.g., through Brier Scores or Counterfactual analysis)

1323

Magmatic volatiles in the 15th January 2022 Hunga volcano, Tonga

Dr Jie Wu[1], Dr Ingrid Ukstins[1], Prof Shane Cronin[1], Dr David Adams[1], Dr Annaleise Klein[2], Dr Jitraporn Vongsvivut[2], Dr Joali Paredes-Mariño[1]
[1]The University of Auckland, Auckland, New Zealand, [2]Australian Synchrotron, Melbourne/Clayton, Australia

The 15th January 2022 eruption from the Hunga Volcano was the largest eruption in 140 years, with an eruption column reaching a height of at least 55 km. This is unusual for magmas with an andesitic composition. To better understand the eruption mechanism and magma processes, we analyzed volatile concentrations in volcanic products including ash and lapilli samples from the Tongatapu and Ha'apai islands as well as fine particles collected from the sea floor 40–105 km west of the volcano. Pumice and glass shards were prepared as double-polished wafers <100 µm in thickness for analysis of OH concentration using Fourier-transform infrared spectroscopy (FTIR) at Australian Synchrotron, and sulfur and chlorine concentrations by electron microprobe analysis (EMPA). Total measured water concentrations are 0.24–2.71 wt%, sulfur concentrations are 29–777 ppm (average 123 ppm), and chlorine concentrations are 261–3597 ppm (average 1267 ppm). Variations in volatile concentrations may reflect different degrees of degassing in the shallow conduit before eruption. The highest measured water content (2.71 wt%) is lower than the global average value for arc magmas. This suggests that volatiles in the magma may not be the main driving force producing such an explosive eruption, or the Hunga glasses are significantly degassed. In addition, mixing/mingling between two texturally contrasting magmas is observed: preservation of a diffusive boundary (~200 µm) in adjacent magmas within the same ash shard with vesicle-poor and vesicle-rich textures shows a contact between 2.26 wt% H2O magma and 1.55 wt% H2O magma, respectively, and suggests that eruption occurred during or shortly after the mixing event.

1334

Pre-Taranaki magma evolution in the Taranaki volcanic lineament, New Zealand

Dr Jie Wu[1], Prof Shane Cronin[1], Dr Ingrid Ukstins[1]
[1]*The University of Auckland, Auckland, New Zealand*

The Taranaki volcanic lineament (TVL) in New Zealand consists of four volcanoes including, from NW to SE, Paritutu (1.7 Ma), Kaitake (575 ka), Pouakai (210-250 Ka), and Mt Taranaki (<200 ka). Here we present new whole-rock and mineral chemistry data for the old volcanoes to investigate pre-Taranaki magma evolution. Lavas from the TVL are sub-alkaline ranging from basaltic to andesitic compositions (47–61 wt% SiO2) and become more K2O-rich over time (0.40–2.45 wt% K2O). Compared to Paritutu and Kaitake, Pouakai lavas have higher concentrations of Rb, Sr, Zr, Nb and Y+REEs and larger variations in Sr-Nd-Pb isotopic compositions (0.7044–0.7051 vs 0.7043–0.7046 86Sr/87Sr; 0.51277–0.51289 vs 0.51285–0.51295 143Nd/144Nd excluding one Kaitake outlier; 15.601–15.622 vs 15.605–15.620 207Pb/204Pb). Disequilibrium textures such as patchy cores and sieved rims are common in plagioclase from all lavas, indicating complex crystal growth and magma mixing. Plagioclase compositions became more enriched in CaO, MgO and FeO over time with An# mode at 46, 50, 59. Calcic plagioclase cores with An>80 and Mg-rich (Mg# >84) pyroxene cores, which are more abundant in younger lavas, likely represent early crystallization in a deep crustal hot zone. Clinopyroxene Mg# ranges from 73–82. Two-pyroxene thermobarometry indicate that both the Kaitake and Pouakai magma bodies were stored at a depth of 5–10 km and 890–960 ^{o}C. Amphibole thermometry from Paritutu and Kaitake show unimodal temperature distributions with peaks at 940 and 870 ^{o}C respectively, while Pouakai has peaks at 910 and 990 ^{o}C, representing low-Al and high-Al compositional groups. This suggests an increasing proportion of mafic magma and crystal cargo supplied from deep crust in the pre-Taranaki magmatic systems with time, which is likely a result of thermal and chemical maturation of the local crust which allowed more efficient magma transport through the transcrustal magmatic system.

1131

The influence of the 2022 Tonga tsunami in the near field

Dr Zhonghou Xu[1], Dr Emily Lane[1], Dr Cyprien Bosserelle[1]
[1]*Niwa, Hamilton, New Zealand*

The Hunga Tonga-Hunga Ha'apai volcanic eruption on 15 January 2022 triggered a global tsunami reinforced by atmospheric waves. Other factors played a significant role in the near-field tsunami, e.g., underwater eruption, pyroclastic density currents, and potentially caldera collapse. To reconstruct the tsunami in the near field, we use explosion-induced cavities as the initial disturbance to the water surface coinciding with large explosions recorded during the eruption. The pressure anomaly also played a significant role in the near-field tsunami. We use a local atmospheric pressure forcing developed from gauge measurements throughout Tonga including 1-minute data from the Tongatapu pressure gauge. The open-source model BG_Flood (Block-adaptive on Graphics processing unit Flood model) was employed to simulate the tsunami, which can accelerate computation using GPU and refine results with an adaptive quadtree mesh. It solves the shallow water equations, with the ability to simulate tsunami propagation and inundation. The water levels from simulation agree well with measurements at three gauges (Nukualofa, Neiafu and DART NZG). The simulated runup heights are also comparable with those surveyed in Tongatapu. In some locations on Tongatapu, witness accounts and other evidence show that the most damaging waves occurred significantly after the initial eruption. This highlights the need to consider other tsunamigenic factor that may have occurred during the eruption to explain these later large arrivals.

495

Erupted tephra mass estimate by infrasound observations and link to the maximum eruption cloud height

Dr Taishi Yamada[1], Professor Masato Iguchi[1], Dr Takeshi Tameguri[1]
[1]*Sakurajima Volcano Research Center, DPRI, Kyoto University, Kagoshima, Japan*

Erupted tephra mass from volcanic eruptions is an essential index for eruption and hazard size evaluations. Since infrasound is associated with the emissions into the atmosphere, the observed infrasound signals can represent emitted tephra mass. Here we focus on infrasound coda to examine signals from ash emission, not from the gas-dominant impulsive signal at the onset of eruptions. Combining ground-based sampling data of tephra mass m (kg) and infrasound coda energy Einf (J), we obtain a representative relation between m and Einf (J) as m/Einf=0.02–0.1 at Sakurajima (Minamidake), Kuchinoerabujima, and Kirishima volcanoes. Since most of the examined event in the above relation is short-lived eruptions, the m can be converted to the eruption cloud buoyancy of the thermal, F (N), which also converts the m/Einf relation into F/Einf as 0.3–3.5 with possible tephra temperature ranges. We validate the expected F/Einf relation with the eruption cloud buoyancy inferred from the maximum eruption cloud height. Although the result of F/Einf scatters in a range of $1–10^2$, we obtain a correlation coefficient of 0.82 between F and Einf. Therefore, the intensity of F can also be evaluated by Einf. We then apply the F/Einf relation to eruptions at Merapi and Suwanosejima volcanoes to estimate m. Two phreatic eruptions at Merapi in 2018 follow the trend of F/Einf examined above, and m is evaluated as in the order of 10^8 kg. On the other hand, eruptions at Suwanosejima in July 2021 have F/Einf values of $10^2–10^3$ and are considerably away from the trend. A particular feature of eruptions at Suwanosejima is that a series of degassing accompanying small infrasound pulses follows the eruption cloud rises. This sequence implies that considerably large F is not only fed by the heat from tephra itself, but also by magma at the lower portion of the conduit.

1159

40Ar/36Ar dating for lavas from the Younger Ontake Volcano, central Japan

Dr Seiko Yamasaki[1], Dr Teruki Oikawa[1], Dr Daniel Miggins[2], Professor Anthony Koppers[2]
[1]Geological Survey of Japan, AIST, Tsukuba, Japan, [2]College of Earth, Ocean and Atmospheric Sciences, Oregon State University, Corvallis, USA

Ontake Volcano (3069 m a.s.l) is a composite volcano with a volume of 80 km3 and the second highest active volcano in Japan. The recent eruptions in 1979, 1990, 2007 and 2014 were phreatic (non-juvenile) eruptions, but some magmatic eruptions also occurred during the Holocene. Volcanism associated with Ontake Volcano is divided into two periods: the Older (ca. 780-420 ka) and the Younger Ontake (ca. 110 ka - Present). We conducted 40Ar/39Ar dating for six andesite lava samples from the Younger Ontake Volcano, especially for long lava flows (over 10 km). Incremental heating 40Ar/39Ar dating was applied for groundmass separates that were measured using multicollector ARGUS-VI mass spectrometry at the Oregon State University Argon Geochronology Laboratory.

The 40Ar/39Ar ages for two lava samples from Mamakodake Volcano in the northern part of Ontake Volcano, yielded overlapping plateau ages of 37 ± 4 ka (errors: 1σ) and 34 ± 2 ka. Also, we obtained similar 40Ar/39Ar plateau ages of 36 ± 5 ka and 30 ± 2 ka for samples from the Yonnoike lava flow in the north-eastern part. However, the sample from the Gandate lava flow (12 km in length) on the northwest side, yielded an older age of 65 ± 7 ka. This age is reproduced by one drill core sample from thick lava of Kongodo Volcano at the east flank showed an overlapping age of 61 ± 3 ka.

These age results are consistent with the reported K-Ar ages for the volcanic materials dated from a wide distribution on the northern-eastern flank (30-40 ka) and the southern-eastern flank (50-70 ka) of the volcano. The clustered age data suggest that there were at least two peaks of activity in Yonger Ontake period, and that the tens of kilometer long lava flows erupted at higher effusion rates in these active periods.

445

Methane-rich fluid inclusions and the indicative significance in volcanic rocks of the Songliao Basin, NE China

Dr Zhuolong Yang[1], Prof. Dr. Pujun Wang[1]
[1]College of Earth Sciences, Jilin University, Changchun, China

Methane-rich fluids in the oceanic crust were detected in basaltic glasses and submarine hydrothermal vents. CO2 and H2O are the most abundant volatile species in the fluids outgassing from mid-ocean ridge magma chambers. Similar cases show that CO2, CH4 and H2 are significant components of fluids venting on seafloor. H2O-CO2-CH4-bearing fluids were found in quartz from ferberite (Fe95Mn05WO4) vein within the low-grade metamorphic aureole of the Borne granite (French Massif Central). In fracture zone environment, carbon-bearing fluids may be of particular importance in chemical and thermal exchanges between the upper mantle and the lithosphere. The reduced nature of carbonic fluids in silica-undersaturated alkalic igneous systems has long been recognized and reduced fluids were also found in peralkaline granite. These fluids are dominated by methane, almost invariably contain significant proportions of heavier alkanes (C2 to C5 and higher), and less frequently, contain unsaturated aliphatic hydrocarbons. They are also characterized by an unusually high hydrogen content and commonly contain significant nitrogen. Samples were collected from core-drillings of volcanic gas reservoirs with reversed δ13C of alkane in the Xujiaweizi depression of the Songliao Basin. The volcanic rocks are rhyolite dominant being enriched in the more incompatible elements like Cs, Rb, Ba, Th, U and Th and with relative high LREE, depleted HREE and negative anomalies of Ti and Nb, suggesting a melt involving both in mantle source and crustal assimilation. Primary fluids hosted in the volcanic rocks should have the same provenance with the magma. The authors concluded that the enclosed CH4 in the volcanics are mantle/magma-derived alkane and the reversed δ13C of alkane in the corresponding gas reservoirs is partly resulted from mixture between biogenic and abiogenic gases. We provide here in this paper direct evidence for abiogenic gases, the primary fluid inclusions hosted in the volcanic reservoir rocks.

746

A critical review of the sedimentary record of the `Millennium Eruption' of Changbaishan/ Paektu-san volcano

Dr Qingyuan Yang[1,2], Dr. Susanna F. Jenkins[1,2], Dr. Geoffrey A. Lerner[3], Dr. Clive Oppenheimer[4], Dr. Amy Donovan[4], Dr. James O. S. Hammond[5], Dr. Jiandong Xu[6], Dr. Bo Pan[6], Dr. Haiquan Wei[6], Dr. Ryo Nakanishi[7,8]
[1]Earth Observatory Of Singapore, Nanyang Technological University, Singapore, Singapore, [2]The Asian School of the Environment, Nanyang Technological University, Singapore, Singapore, [3]Instituto de Geofísica, National Autonomous University of Mexico, Mexico City, Mexico, [4]Department of Geography, University of Cambridge, Cambridge, U.K., [5]Department of Earth and Planetary Sciences, Birkbeck College, University of London, London, U.K., [6]National Observation and Research Station of Jilin Changbaishan Volcano, Institute of Geology, China Earthquake Administration, Beijing, China, [7]Atmosphere and Ocean Research Institute, The University of Tokyo, Kashiwa, Japan, [8]Graduate School of Frontier Sciences, The University of Tokyo, Kashiwa, Japan

The Millennium Eruption of Changbaishan/Paektu-san Volcano, situated today on the People's Republic of China and Democratic People's Republic of Korea border, ranks as one of the largest eruptions of the Common Era. Its products have been widely studied in different contexts and from different perspectives, resulting in some conflicting interpretations. Here, we review previous works on the pyroclastic deposits of the Millennium Eruption with a focus on their stratigraphic and sedimentological features, identify points of contention and propose new interpretations, questions, and hypotheses as a guide to future work. Its total volume is re-estimated as 40-98 km3 with evidence given. To develop further understanding of the Millennium Eruption we call for new research along the following lines (i) a coherent stratigraphic and sedimentological field research programme focused on the proximal tephra record, and spanning the international frontier; (ii) further studies of the distal tephra, the B-Tm ash, to identify compositional, stratigraphic and spatial variations that can reveal tephra dispersal from different eruptive phases and improve constraints on the total volume of the eruption.

747

Two paradoxical problems in estimating tephra volumes with the isopach-based method

Dr Qingyuan Yang[1,2], Dr. Susanna F. Jenkins[1,2]
[1]*Earth Observatory of Singapore, Nanyang Technological University, Singapore, Singapore,* [2]*The Asian School of the Environment, Nanyang Technological University, Singapore, Singapore*

We study two paradoxical problems in estimating tephra volumes when the isopach-based method is used. The first problem occurs due to the inevitable misfit between the isopach data and the fitted model, i.e., fitted curves that describe how tephra deposit thins with the square root of isopach area. The second problem occurs as tephra volume is estimated based on both interpolated and extrapolated thickness, but the latter cannot be validated. The volumes estimated from the two are thus subject to different levels of uncertainty. The second problem has been raised previously, but left unanswered. We demonstrate the importance of the two problems on a theoretical level, and use six isopach datasets to demonstrate their presence. The proposed measures to address the problems are proposed and tested. For the first problem, a stricter criterion to evaluate the goodness-of-fit should be adopted, and tephra volume variability can be estimated based on the envelope (or union thickness) defined by different fitted curves that do not deviate greatly from the isopach data, rather than volumes estimated from individual curves. For the second problem, the volumes from interpolation and extrapolation should be reported separately, and as the extrapolated thickness cannot be validated, we can only test whether the potential variability of the extrapolation volume is sensitive to the total volume, rather than attempting to quantify its uncertainty. The universality of the problems is discussed.

882

Understanding caldera degassing from a detailed investigation at Lake Rotoiti, Okataina Volcanic Centre, New Zealand

Mr Jimmy Yang[1,2], Isabelle Chambefort[1], Agnes Mazot[1], Michael Rowe[2], Brad Scott[1], Nick Macdonald[1], Cynthia Werner[3], Tobias Fischer[4], Cornel de Ronde[5]
[1]GNS Science, Wairakei research Centre, Taupo, New Zealand, [2]School of Environment, University of Auckland, Auckland, New Zealand, [3]Research Geologist (under GNS Science contract), New Plymouth, New Zealand, [4]Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, U.S.A., [5]GNS Science, Lower Hutt, New Zealand

Volcanic lakes in large silicic caldera volcanoes are an important source of CO2 emissions. However, quantifying CO2 output is challenging due to the lack of observed historical CO2 flux records and the large size of the volcanic and hydrothermal systems. Twenty percent of the surface area of Okataina Caldera (caldera size 450 km2) is covered with lakes. Geothermal expressions, predominantly on the Okataina caldera margin, occur in at least six different locations, with surface expressions both on land and under water. Lake Rotoiti is located at the northwest edge of the Okataina Caldera, spans across the Tikitere and Taheke geothermal fields, and has inputs from on-land thermal springs, lake floor hydrothermal vents, and from Lake Rotorua. CO2 flux from Lake Rotoiti was assessed using the accumulation chamber method and three techniques are used to process the data for total CO2 emission of the lakes: (1) sequential Gaussian simulation (sGs) method allow quantification of CO2 emission with spatial control, (2) graphical statistical approach (GSA) allows the quantification of CO2 emission from different degassing regimes, and (3) a method based on water chemistry of the lake. We find CO2 is mostly emitting at Tumoana Bay and Central Basin, and the emission rate is 271± 38 t d-1 of CO2 (based on sGs) We then added this estimated emission data to the existing CO2 data for individual geothermal systems distributed around the active Okataina volcanic centre and calculate that the entire caldera is emitting at least 1856 t d-1 of CO2. The total emission is dominated by the lakes, where the topography is lower. We discuss the implications of this study in terms of preferential degassing locations and the amount of degassing, in particular for CO2, in an active caldera setting.

238

Paleomagnetic evidence for episodic construction of the Mamiyadake tephra ring, Ohachidaira maar-caldera complex, Hokkaido, Japan

Dr Yuki Yasuda[1]
[1]The University Of Tokyo, Tokyo, Japan

Tephra rings that surround maar craters are typically inferred from field observations to be emplaced rapidly over a time period of days to years and thus monogenetic, which is, however, rarely assessed quantitatively. This presentation describes the discovery of polygenetic origin of the Mamiyadake tephra ring (Japan), comparing the paleomagnetic directions obtained from 39 sites from north, northwest, west, southwest, south, and east sections of the tephra ring. The paleomagnetic directions are vertically consistent in the north and east sections, suggesting that these sections were emplaced rapidly enough that no significant secular variation was recorded. In contrast, the paleomagnetic directions change systematically with height through the sequence of the other sections, which is interpreted to record paleosecular variation (PSV) of the geomagnetic field during the eruptions. The data indicate that the Mamiyadake tephra ring records 5 distinct eruptive episodes, each corresponding to discrete clusters of the paleomagnetic directions. The paleomagnetic results, together with using an average rate of PSV during the Holocene in Japan, suggest that the tephra ring formed over at least ~1000 yr with four major breaks of a few hundred years or longer. The findings demonstrate that detailed paleomagnetic characterization uncover temporal evolution of tephra-ring deposits, providing a useful criterion for identifying time breaks, even where field evidence is lacking, and a minimum estimate of the time interval for their emplacement.

1077

Monitoring explosive activity at three volcanoes using seismic noise interferometry

Mr Alexander Yates[1], Dr Corentin Caudron[2], Dr Philippe Lesage[1], Dr Aurélien Mordret[1], Dr Virginie Pinel[1], Dr Jean Soubestre[1,6], Dr Thomas Lecocq[3], Dr Andrea Cannata[4], Dr Flavio Cannavo[5], Dr Yeşim Çubuk-Sabuncu[6], Dr Kristin Jónsdóttir[6]

[1]Univ. Grenoble Alpes, Univ. Savoie Mont Blanc, CNRS, IRD, IFSTTAR, ISTerre, Grenoble, France, [2]Université Libre de Bruxelles, Brussels, Belgium, [3]Royal Observatory of Belgium, Brussels, Belgium, [4]University of Catania, Catania, Italy, [5]National Institute of Geophysics and Volcanology (INGV), , Italy, [6]Icelandic Meteorological Office, , Iceland

Seismic noise interferometry is becoming an increasingly popular technique for monitoring volcanoes. By cross-correlating continuously recorded ambient noise, we can recover changes in seismic velocity that reflect the evolving behavior of volcanic systems. Despite this, wider usage beyond academic circles remains limited. This, in part, owes to the large influence that different processing choices can have on the final results and difficulties in their interpretation. Explosive activity, in particular, remains challenging to monitor, where the associated volcanic processes are often complex.

This work aims to better understand the potential to use seismic interferometry to monitor explosive activity. We target multiple volcanoes, including Mount Ruapehu (New Zealand), Stromboli (Italy), and Grímsvötn (Iceland). We apply various techniques to develop a suitable processing scheme at each volcano, including network covariance matrix analysis to identify key features of the seismic wavefield and hierarchical clustering of cross-correlation functions based on waveform similarity. The latter approach can identify structure in seismic interferometry datasets that aids both decision making in processing and the interpretation of results.

Seismic velocity changes from all studied volcanoes highlight the importance of accounting for environmental processes. At Mount Ruapehu, we observe velocity changes on the order of 1% associated with snow-loading. Similarly, while monitoring in real-time during recent unrest (starting March 2022), stations closer to the volcano were found to be more sensitive to environmental processes. At Stromboli, we model seasonal changes as due to fluid pressure changes following rainfall. After subtracting the seasonal component, we identify anomalous velocity changes in the months prior to major paroxysms in 2019, with opposite trends at different frequencies. This likely reflects a different response of seismic velocities at different depths. These results are encouraging towards the use of seismic interferometry to monitor explosive activity, though also highlight the need to account for non-volcanic processes.

IAVCEI 2023
SCIENTIFIC ASSEMBLY
Ko Rūaumoko e Ngunguru Nei
30 Jan - 3 Feb | Rotorua, New Zealand

293

USING ROVER-ANALOGOUS INSTRUMENTATION TO DISCRIMINATE BETWEEN VOLCANIC AND SEDIMENTARY PROCESS IN SUCCESSIONS DOMINATED BY IGNEOUS CHEMISTRY

Dr R Aileen Yingst[1], Dr Julie Bartley[2], Dr Barbara Cohen[3], Dr Brian Hynek[4], Dr Linda Kah[5], Richard Archer[4], Michael Lotto[4], Jennifer Tuggle Mooney[5], Justin Wang[4], Brittan Wogsland[5]
[1]Planetary Science Institute, Brunswick, United States, [2]Gustavus Adolphus College, St. Peter, USA, [3]Goddard Spaceflight Center, Greenbelt, USA, [4]University of Colorado - Boulder, Boulder, USA, [5]University of Tennessee - Knoxville, Knoxville, USA

Many outcrops observed on Mars contain abundant layered material which lack extensive chemical alteration and may have undergone aeolian modification. Such outcrops have proven challenging to discriminate among emplacement mechanisms using only remote rover-driven field methods. We tested rover science operations strategies to determine best practices for interrogating geologic sections where the bulk composition is igneous but depositional/emplacement processes range from sedimentary to volcanic. This scenario may mirror the situation in Jezero crater, Mars. Two field teams studied a 60 m vertical outcrop on Iceland's Tjörnes peninsula as an analog for a martian site containing interleaved layers of sedimentary and volcanic units. A Rover team commanded a human rover to execute observations based on common Mars rover sequences; the resulting data were used to characterize the geologic history of the location. Results were compared to that of a Tiger team using traditional terrestrial field methods to interrogate the same site. Results suggest that current rover-driven decision-making protocols are sufficient to identify the general nature of most facies (either sedimentary or volcanic) and make a preliminary assessment of the likely energy required for deposition, yielding reasonably accurate interpretations of depositional environment. Two datasets were crucial in facilitating interpretation: (1) handlens-scale images revealing grain morphology and relationships; and (2) datasets that allow comparison between surface and bulk geochemistry. Images at the sub-mm scale provided crucial data regarding grain size (sand-sized versus smaller), the presence and nature of sedimentary structures (e.g., laminae, sorting within layers), and the nature of grain fabric (e.g., matrix- versus clast-supported). Differences in VNIR data compared to bulk composition were indicative of surface versus surface-plus-interior compositions. However, sedimentary features were difficult to confidently identify; confident interpretations require lateral scanning of beds at meter-scales. This work illuminates the need for strategic planning, particularly of resource-intensive observations.

635

Monitoring evolution of magma properties during an eruption using geodetic measurements

Mr Stanley Yip[1,2], Prof. Juliet Biggs[1,2], Prof. Marie Edmonds[1,3]
[1]Centre for the Observation and Modelling of Earthquakes, Volcanoes and Tectonics (COMET), , United Kingdom, [2]University Of Bristol, Bristol, United Kingdom, [3]University of Cambridge, Cambridge, United Kingdom

The presence of gas bubbles in a magma reservoir increases magma compressibility, which decreases magma volume change and ground deformation. Therefore, time-series of co-eruptive ground deformation contain important information on how gas volume fraction evolves during an eruption. Here we normalise time-series of ground displacement by erupted volume, and compare our results to timeseries of SO_2 flux. Increasing normalised displacement may indicate decreasing magma compressibility and decreasing gas volume, i.e. a change from relatively gas-rich to relatively gas-poor magma. Conversely, decreasing normalised displacement may be the result of a change from relatively gas-poor to relatively gas-rich magma. We find that the 2004 eruption of Mount St Helens showed decreasing normalised displacement, consistent with the removal of a degassed plug. In contrast, the 2011 eruption of Cordón Caulle showed increasing normalised displacement, consistent with a compressible gas-rich cap. While these case study examples are end members, additional factors such as magma recharge would complicate the interpretation, and the framework presented here provides qualitative insights into changes in gas volume fraction during eruptions. Our future work will explore the evolution of magma properties at different timescale.

633

The influence of volatile content and segregation on co-eruptive deformation and SO_2 emissions

Mr Stanley Yip[1,2], Prof. Juliet Biggs[1,2], Prof. Marie Edmonds[1,3], Ms. Philippa Liggins[3], Dr. Oliver Shorttle[3]
[1]Centre for the Observation and Modelling of Earthquakes, Volcanoes and Tectonics (COMET), , United Kingdom, [2]University of Bristol, Bristol, United Kingdom, [3]University of Cambridge, Cambridge, United Kingdom

Integrating multi-parameter observations of volcanic eruptions has improved our understanding of magma storage conditions, but we still lack quantitative models. Here we use petrological data and thermodynamics to model magmatic gas content, deformation and SO_2 emissions. We calculate the weight fraction of the exsolved volatile species using solubility laws and partitioning models and use this to estimate the total gas mass fraction and the mass fraction of SO_2 in the reservoir. The exsolved volatile phase increases magma compressibility, which decreases the reservoir volume change during eruption. We then perform sensitivity analyses to explore the effects of changing magmatic volatile content (H_2O, CO_2, S), oxygen fugacity and pre-eruptive exsolved volatile segregation (e.g., exsolved volatile accumulation at the reservoir roof, or the formation of a 'degassed plug') on deformation and degassing of basaltic and rhyolitic magmas. Our model shows that 1) magmatic H_2O content is the dominant control on compressibility and therefore on ground deformation, 2) magmatic S content is the dominant control on SO_2 flux, and 3) rhyolitic eruptions are likely to show less co-eruptive deformation than basaltic eruptions. Comparison to compilation of 25 eruptions shows that while shallow reservoir depths promote gas exsolution and thus suppress the volume change of the reservoir, additional factors modulate this, namely magmatic H_2O content and pre-eruptive gas segregation. We find that all magmatic systems undergo some outgassing prior to an eruption, yet some intermediate-silicic magmas remain compressible because volatiles exsolved at depth may accumulate in shallow parts of the system. We also note that SO_2 emissions from mafic reservoirs are dominated by the exsolution of sulfur during magma ascent from the reservoir to the surface. While these thermodynamic models are not yet sufficiently accurate for modelling individual systems, they provide useful insights into the general behaviour of a wide range of eruptive styles.

556

Characterization of the volcaniclastic materials from the 2021 eruption of Fukutoku-Oka-no-Ba in the Ogasawara arc, Japan

Dr Kenta Yoshida[1], Dr. Yoshihiko Tamura[1], Mr. Tomoki Sato[1], Dr. Takeshi Hanyu[1], Dr. Yoichi Usui[2], Dr. Qing Chang[1], Dr. Noriko Tada[1], Dr. Morihisa Hamada[1], Dr. Erika Tanaka[1], Dr. Shigeaki Ono[1]
[1]*Japan Agency For Marine-earth Science And Technology, Yokosuka, Japan,* [2]*Kanazawa University, Kanazawa, Japan*

The Fukutoku-Oka-no-Ba (FOB) eruption of August 13, 2021 produced large amount of ejecta, including a vast spreading of pumice which drifted to the coastal area of Japan and neighboring eastern Asian countries (Yoshida et al. [1-2]). Despite drifting over >2 months and ~1300 km, the drift pumice raft arrived Japan had a large volume and contained a variety of pumice clasts. Most of the drift pumice clasts are gray in color and vesicular, and contain black enclaves and black pumice clasts are rarely found. Minor black pumice and the main gray pumice components have similar trachytic compositions, with $SiO2$ = 61–62 mass% and total alkalis = 8.6–10 mass%, with phenocrysts of clinopyroxene, plagioclase, and minor olivine. Thin-section observations show that the gray pumice has more elongated vesicles as compared with the black pumice that has spherical vesicles, even where the two types of pumice are in the same clast. Raman spectroscopy and TEM observation revealed that the brown-colored glass in the black pumice contains plenty of magnetite nanolites while nanolite does not exist in the gray pumice. High-Mg olivine in the black pumice has an equilibrium temperature of ~1200 °C and indicates the remnant of high-T mafic magma that triggered the eruption.

The textural relationships between the gray and black pumice in a single clast suggest that the black pumice had become black and viscous before the two types of pumice mixed. Therefore, precipitation of magnetite nanolites and a corresponding increase in melt viscosity played an important role in the eruption preparation process, which then resulted in a large-scale eruption.

We also report the proximal ejecta, including obsidian and woody pumice, from FOB that has been collected by R/V Yokosuka recently, to get a more detailed view of the eruption of FOB.
[1] 10.2343/geochemj.GJ22011 [2] 10.1111/iar.12441

948

Discovery of Late Jurassic-Early Cretaceous lamprophyres in western Songliao Basin of northeast China and their constraint on regional lithospheric evolution

先生 taiji yu[1], Dr Pujun Wang[1]
[1]*College of Earth Sciences, Jilin University, Changchun, China*

Contrary to the commonly accepted notion that the lithosphere in NE China thinned from the Late Jurassic through to the Early Cretaceous period, we report the discovery of a thickening episode in the backdrop of this long-term thinning. A series of lamprophyre dikes have been recently discovered in the Tuquan Basin of the western Songliao Basin that have been dated to 156.0 ± 2.3 Ma, 132.9 ± 1.2 Ma, and 126.2 ± 2.5 Ma by using the zircon U–Pb technique. These lamprophyres are subdivided into biotite orthoclase lamprophyre (BOL) from the Late Jurassic and quartz magnetite lamprophyre (QML) from the Early Cretaceous. The BOL and QMLs are shoshonite and calc-alkaline in series, are characterized by large amounts of FeOT, TiO2, MgO, and Mg#, and are rich in LREEs and LILEs but poor in HREEs and HFSEs. They have high ratios of (La/Yb)N, La/Ta, La/Nb, Th/Y, Ba/Nb, Ba/Ta, and Ba/Th, and low ratios of Zr/Ba, La/Sm, and Nb/Zr. These features collectively point to the derivation of dike magmas from the partial melting of the enriched lithospheric mantle that had been previously metasomatized by subduction-related fluids. The BOL of magma from a high degree of partial melting of the phlogopite-bearing lherzolite mantle in the spinel–garnet transition zone at a depth of about 60 km. The QMLs of the magmas were derived from a low degree of partial melting of the lherzolite mantle in the garnet zone at a depth of ca. 85 km. The younger QML magma was formed at a shallower depth of the mantle (< 85 km) than the older one. These observations indicate that in 156–132 Ma, the lithosphere thickened by approximately 25 km at a rate of approximately 1.0 km/Myr. This is used to propose a model of geodynamic evolution in three stages.

828

Study to Predict the Damage Range of Pyroclastic Flow, Lahar, and Volcanic Flood that may occur to Mt. Baekdu Eruption

Professor Sung-Hyo Yun[1], Doctor Cheolwoo Chang[2]
[1]Pusan National Univ, Busan, South Korea, [2]Volcano Specialized Research Center(VSRC), Pusan National University, Busan, South Korea

Products of the eruption of Mt. Baekdu are identified as volcanic materials at the estuaries of the Songhuagang river to north, the Dumangang river to east and the Amnokgang river to west. More speficially, pyroclastic flows, lahars and volcanic floods can affect an area of 400 km in radius, centering around Lake Cheonji caldera. However, unlike the Millenium eruption(AD 946), the flow situation has been changed. Because multi-purpose dams and reserviors with a combined pondage of mora than 2 billion tons of water have been built in the rivers of which sources are originated from Lake Cheonji caldera. In addition, the flow of fluids expected to take place when the volcano has erupted is thought to be affected by artificial constructions in both direct and indirect ways. This study calculates the direction of fluids flow by using numerical analyses of pyroclastic flows, lahars and volcanic floods that can occur when the volcano of Mt. Baekdu has erupted. We also estimate the scope of damages by pyroclastic flows, lahars, volcanic flooding caused by the pondage of the dams and water storages in and around Mt. Baekdu. Pyroclastic flows transported over the steep slopes at the early times of eruptions move over the mountain slopes, affecting airplanes, and lahars due to leaks of Lake Cheonji could reach as far as major rivers and streams near Mt. Baekdu. Unlike historical accounts, volcanic flood is expected to be limited in its scope of influence to reservoirs bigger than Lake Cheonji in pondage. This work was supported by Meteorological/Earthquake See-At Technology Development Research Grant KMI2018-02710, Korea Meteorological Administration.

287

Comparative study of three geosites of different volcanic heritage with geotouristic and geoeducational values in the Coromandel Peninsula, New Zealand

Mr Vladyslav Zakharovskyi[1], Prof Karoly Nemeth[1,2,3]
[1]Massey University, Palmerston North, New Zealand, [2]Saudi Geological Survey, Jeddah , Kingdom of Saudi Arabia, [3]Institute of Earth Physics and Space Science, Sopron , Hungary

Geoeducation is one of the main aims of estimating geodiversity in conjunction with exploring the framework of geotourism, which require selecting and documenting geosites. Meanwhile, understanding of the volcanological process is one the key elements of geological education in New Zealand due to their hazard potential. Coromandel Peninsula have been chosen for this research as it is one of best-known places in New Zealand for its biological conservation and diverse volcanological and cultural history. An inventory of three geological location with different volcanic history have been selected based on systematic scientific literature reviews, application of GIS-aided geodiversity estimates and direct field observation. The Fletcher Bay is in the far north of the peninsula preserving superbly exposed dissected Miocene volcanic successions (Coromandel Group) with different types of andesite formations such as the geosites of Pinnacles and Sugar Loaf. Geosites in the SE part of Hahei Beach in the central eastern part of peninsula, exhibit coastal exposures of rhyolitic volcanic successions, part of the Whitianga Group offering iconic tourism places like Cathedral Cove and Gemstone Bay. The third place we investigated is located between Whitiroa Beach on the south and Papakura Bay on the north in the east part of the peninsula. This place presented by late Miocene ignimbrites and rhyolitic lava domes (Whitianga group). The three geosites are good representative of different types of volcanism of the peninsula to emphasize their significances for geoeducational and geotouristic perspectives. Application of geodiversity estimates for geosite identification using GIS technology, landscape analysis and evaluation of geological values were used to recognize the global and local significance of these sites in various scales providing evidence-based information to establish geotrails, geoeducation outlets and sustainable tourism. This inventory provides a conceptual framework to build volcanic geoheritage into the general conservation strategy of the Coromandel Peninsula.

648

Mapping topographic changes and deformation at Mount Sinabung using multi-sensor Synthetic Aperture Radar observations

Ms Eva Zand[1], Dr Susanna Ebmeier[1], Assoc. Prof. Yosuke AOKI[2], Prof. Andy Hooper[1]
[1]University Of Leeds, Leeds, United Kingdom, [2]University of Tokyo, Tokyo , Japan

Mount Sinabung, Indonesia, has erupted twice within the 21st century. The first period, phreatic and short-lived, occurred in 2010 and was accompanied by pre and post-eruptive deformation whose source depth and origin vary in interpretation [1,2]. The second (2013–2021) showed multiple eruptive styles from explosive to effusive, including ash plumes, lava flows, dome growth and collapse, and PDCs [3]. These topographic alterations can affect emplacement mechanisms and reshape hazard-prone areas, making them key targets for volcano monitoring.

We produce an overview of different SAR applications suitable for studying volcanic activity at Mt Sinabung and compare the results from four different sensors. We use X-band (COSMO-SkyMed, TerraSAR-X), C-Band (Sentinel-1) and L-Band (ALOS-1, ALOS-2) acquisitions, with different resolutions and wavelengths, to evaluate the extent of topographic changes and deformation occurring during the second eruptive period. We investigate both the effect of different wavelengths on the observations of volcanic deposits, and the coherence between frames to propose which sensors provide the most valuable observations. We also re-evaluate previously reported deformation linked to the 2010 eruption.

Our preliminary results show estimates for lava thicknesses emplaced in 2014 and their subsequent subsidence rate using interferometry. Additionally, we identify changes to the crater during eruptive events, dome growth and collapse, the extent of pyroclastic deposits and flow behaviour using the amplitude component of the SAR imagery. This combination of techniques provides unprecedented details of Mt Sinabung's eruptive activity over the last decade.

[1] Chaussard et al. 2013. Characterization of open and closed volcanic systems in Indonesia and Mexico using InSAR time series. JGR.

[2] González et al. 2015. Shallow hydrothermal pressurization before the 2010 eruption of Mount Sinabung Volcano, Indonesia, observed by use of ALOS satellite radar interferometry. PAGEOPH.

[3] Gunawang et al. 2019. The eruptions of Sinabung and Kelud volcanoes, Indonesia. JVGR.

478

Spatio-temporal evolution of scoria cones emplacements in the Paricutin-Tancitaro region inferred from a morpho-chronological analysis with the Average Erosion Index.

Dr Maria Cristina Zarazua Carbajal[1], Dr Ana Teresa Mendoza Rosas[3], Dr Servando De la Cruz Reyna[2]
[1]SNI-CONACYT, P.A.I.- Instituto de Geofísica, UNAM, Mexico City, Mexico, [2]Instituto de Geofísica, UNAM, Mexico City, Mexico, [3]CONACYT- Universidad Michoacana San Nicolás de Hidalgo, Instituto de Investigaciones en Ciencias de la Tierra, Morelia, Mexico

The Paricutín- Tancitaro volcanic region (PTVR), in central Mexico, is located within the Michoacán-Guanajuato monogenetic field, one of the world's largest. It has a high spatial density of scoria cones; the last one, Paricutin, formed during a nine-year eruption in 1943. The PTVR is centered at the Tancitaro, a large Quaternary stratovolcano located in the SW sector of the monogenetic field. Here, we use the Average Erosion Index (AEI) to estimate the relative ages of 170 scoria cones located within a radius of about 100 km around Tancitaro Volcano.

The AEI quantifies the erosional state of scoria cones from a morphological analysis of their level contours extracted from a high-resolution DEM (the 12-m TanDEM-X in this case). The analysis provides a metric for the undulations reflecting the shape and amplitude of rills and gullies on the cone's surface along the level contours.

We compute the functional relationship between AEI and age by correlating 10 published radiometric ages with the measured AEIs of those cones. We assume that all the considered monogenetic volcanoes have been exposed to similar erosive conditions, making the AEI a trustworthy measure of relative ages in clusters of scoria cones.

Our results suggest that the dispersed volcanic activity in the PTVR started to increase after the last eruption of Tancitaro (~237 ka), with a further activity increase during the Holocene, mainly concentrated on the NE sector of Tancitaro, where Paricutin is located. Furthermore, the detection of repeated seismic swarms in the PTVR, the last two in 2020-2021, implies an increase in volcanic and seismic hazards in that area. Locating and quantifying such hazards is the subject of our future research.

1450

Textural Evolution of Crystals and Bubbles in Tephra Erupted from a Dacite–Andesite Zoned Magma Reservoir

John Zayac[1,2,3], Dr. Marc-Antoine Longpré[2,1]
[1]*The Graduate Center, City University of New York, New York, United States,* [2]*Queens College, Queens, United States,* [3]*Vassar College, Poughkeepsie, United States*

Explosive volcanic eruptions are dynamic events, driven by the complex interplay between crystallization and volatile exsolution. Here, we investigate the textural evolution of two densely sampled (10 cm horizons) dacite to andesite compositionally zoned tephra falls from Cosigüina Volcano, Nicaragua, to document crystallinity and exsolved volatile gradients in the source stratified reservoir and constrain syn-eruptive processes. Early-erupted dacites are crystal-poor and highly vesicular (>80 vol.%). Vesicles exhibit two morphological populations, both sub-spherical and elongate. Late-erupted andesites host more phenocrysts and are significantly less vesiculated (<60 vol.%). The groundmass of these clasts is comprised of abundant microlites and large glass patches are rare. Vesicles show complex, irregular morphologies. Plagioclase phenocryst chemistry from both eruptions is also bimodal, with rim chemistries of An_{50} - An_{70} in the dacite and An_{80} - An_{95} for those found in andesite. Based on fluid dynamic considerations, we propose the following model to account for the above observations: (1) Exchange of crystals between the andesite body and the dacite cap was largely precluded; (2) Progressive pre-eruptive crystallization of the andesite body supplied heat and volatiles to the dacite, keeping the latter close to its liquidus and building overpressure; (3) Upon opening of a conduit and eruption onset, rapid evacuation of the dacite proceeded and depressurization of the andesite initiated a first phase of microlite crystallization, supplying latent heat to the system; and (4) Ascent of the andesite magma eventually ensued, triggering a second phase of microlite crystallization. We infer that this sequence of processes, involving complex feedbacks between crystallization and degassing, profoundly impacts the withdrawal dynamics of compositionally stratified magma reservoirs at Cosigüina Volcano.

1446

Fine Geochemical Stratigraphy Reveals Pre-Eruptive Crystallization-Driven Volatile Exsolution and Syn-Eruptive Mixing in a Zoned Magma Reservoir

John Zayac[1,2,3], Dr. Brian Monteleone[4], Dr. Marc-Antoine Longpré[1,2]
[1]The Graduate Center, City University of New York, New York, United States, [2]Queens College, City University of New York, Queens, United States, [3]Vassar College, Poughkeepsie, United States, [4]Northeast National Ion MIcroprobe Facility, Woods Hole, United States

Compositionally zoned eruptions, common across the volcano-tectonic spectrum, provide an opportunity to probe the commonly cited processes behind differentiation: crystallization, devolatilization, and recharge. Here, we investigate a major prehistoric zoned dacite (65–70 wt% SiO_2) to andesite (57–61 wt% SiO_2) tephra fall from Cosigüina Volcano, Nicaragua. Tephra clasts sampled at high stratigraphic resolution within the deposit were analyzed for matrix glass, mineral, and plagioclase-hosted melt inclusion compositions. Temperature and volatile saturation pressure estimates indicate the two melts were in close proximity, with andesite residing in a warmer and higher-pressure (~990 °C, ~130 MPa) space than dacite (~920 °C, ~115 MPa). The melt inclusions fall into two populations, while a zone of hybrid chemistry exists in two transitional matrix horizons, representing ~12% of the stratigraphy. Inclusions from these horizons are sourced from intermediate depth and temperature (~960 °C, ~120 MPa). Trace element systematics (Co, Sr, and Eu/Eu* and Dy/Dy* anomalies) indicate that the dacite is derived from the andesite through the crystallization of pyroxene and plagioclase, in agreement with observations. Volatile/K_2O ratios decrease with increasing SiO_2 content, revealing some partitioning of all volatiles (H_2O, CO_2, S, F, and Cl) to a pre-eruptive fluid phase during evolution from andesite to dacite. While melt inclusions show a distinct bimodality, matrix glass compositions are characterized by a more progressive transition from dacite to andesite. In addition, certain elements display reverse matrix glass–melt inclusion relationships in dacite and andesite. We interpret these observations to record limited pre-eruptive mixing during phenocryst growth and inclusion entrapment in the stratified reservoir followed by limited syn-eruptive mixing during magma withdrawal. Our results help constrain the role of crystallization-driven volatile exsolution — a commonly invoked eruption trigger — and withdrawal dynamics of zoned magma reservoirs.

199

Plutonic nature of transcrustal magmatic systems revealed by sub-micron Sr-disequilibria in plagioclase

Dr Daniel Coulthard Jr.[1], Dr Raimundo Brahm[2], Dr Charline Lormand[3], Professor Georg Zellmer[4], Dr Naoya Sakamoto[5], Dr Yoshiyuki Iizuka[6], Prof Hisayoshi Yurimoto[5]

[1]USGS, Menlo Park, USA, [2]Victoria University of Wellington, Wellington, New Zealand, [3]Durham University, Durham, United Kingdom, [4]Massey University, Palmerston North, New Zealand, [5]Hokkaido University, Sapporo, Japan, [6]Academia Sinica, Taipei, Taiwan

The new paradigm of transcrustal magmatic systems envisages remobilization of voluminous mush zones close to their solidus temperature with small amounts of interstitial melt. To test this paradigm, diffusion of major or trace elements across sharp compositional boundaries may be employed to obtain crystal residence times at magmatic temperatures. Plagioclase crystals are common crustal minerals yet reading the chronology of their zonation is hampered by complex high-frequency major element zonation, which determines trace element partitioning and diffusion behaviour. Here we present stacked CMOS-type active pixel sensor (SCAPS) isotopographic images yielding submicron-resolution Sr and major element zonation in volcanic plagioclase microantecrysts from the Southern Taupo Volcanic Zone (STVZ). Fourier-transform spatial frequency analysis of intracrystalline Sr disequilibrium during forward diffusion enabled parameterization of the decay of individual spatial frequencies and approximation of pre-eruptive zoning profiles. Pre-eruptive crystal residence times at magmatic temperatures are of the order of days to weeks for STVZ microantecrysts, timescales inconsistent with long residence at elevated temperatures. Our approach is applicable to volcanic systems globally. STVZ magmatism is characterized by ephemeral temperature spikes from small magma batches and remobilisation of small volumes of rapidly cooled antecrysts, characterizing the cool plutonic nature of this transcrustal magmatic system.

1453

Landscape processes around andesite stratovolcanoes – A case study of the volcaniclastic ring-plain succession at Mt. Taranaki, New Zealand

Dr Anke Zernack[1], Prof. Jonathan Procter[1]
[1]*Volcanic Risk Solutions, Massey University, Palmerston North, New Zealand*

Volcaniclastic successions represent valuable archives that hold a detailed record of volcanic and other landscape-shaping events and often provide the only way to reconstruct the long-term volcanic history of a region. The ability to accurately interpret the origin, transport and emplacement processes of such deposits is thus crucial to better understand the nature, magnitude and frequency of future volcanic and secondary hazards, including the potential for catastrophic edifice failure.

Continuous coastal erosion and tectonic uplift have exposed an almost complete stratigraphic record of medial-distal ring-plain successions at Mt. Taranaki, making it an ideal case study to assess typical lithofacies associations and sedimentary processes occurring around a long-lived andesite stratovolcano. Despite extreme climate fluctuations during the past 200 kyrs, the unconfined ring-plain depositional system shows a consistent pattern of volcaniclastic and reworked sedimentary facies. This suggests that volcanic processes, including the unusually high recurrence of edifice failures, were the primary control on accumulation style and frequency of mass flows.

Episodes of eruptive activity and repeated debris-avalanche emplacement not only induced instant landscape changes but also a long-term sedimentary and geomorphic response due to rapid, high input of loose volcanic material into the ring-plain system. These phases of mass wasting and redeposition led to incremental infilling, widening and/or shifting of active stream and river channels. In contrast, inter-eruptive periods were marked by landscape re-adjustment and dissection along with soil formation, peat accumulation and aeolian redeposition. Sedimentation during these intervals was also affected by non-volcanic processes like sea-level variations, regional climate and vegetational changes.

The main driver for the distribution of volcanic mass-flow deposits was edifice and ring-plain morphology at the time as deposition loci changed regularly in response to source area, trigger mechanism and landscape changes, which also influenced their sedimentary characteristics and deposit volumes, while climate conditions only had overprinting effects.

1454

A multidisciplinary investigation of ocean-rafted pumice found in Northern Norway

Dr Anke Zernack[1], Dr. Erlend Kirkeng Jørgensen[2], Dr. Anders Romundset[3], Dr. Anthony Newton[4], Prof. Felix Riede[5]

[1]Volcanic Risk Solutions, Massey University, Palmerston North, New Zealand, [2]Norwegian Institute of Cultural Heritage Research, Tromsø, Norway, [3]Norwegian Geological Survey, Trondheim, Norway, [4]School of Geosciences, University of Edinburgh, Edinburgh, United Kingdom, [5]Department of Archaeology and Heritage Studies, Aarhus University, Aarhus, Denmark

Ocean-rafted pumice is found on modern and paleo-beaches in volcanic and non-volcanic areas, from the North Atlantic and Mediterranean to the South Pacific. While not as accurate as tephrochronology, ocean-rafting events can be correlated to their source and used to date sedimentary records and landforms, including raised shorelines. Geochemical fingerprinting of artefacts made from ocean-rafted pumice can furthermore provide additional age constraints for pumice-bearing archaeological sites.

Our study explores links between spatiotemporal patterns of pumice redeposition along the North Norwegian coastline and prehistoric human use of this versatile resource. Use-wear analysis of frequently found, yet largely neglected pumice from spatially diverse Mesolithic to Norse-medieval sites showed that most pieces were being used as abrasive tools. Based on their geochemical composition, the samples were correlated to Holocene groups of tephras or individual eruptions from the Katla Volcanic System in Iceland. The data showed that estimated eruption ages typically predate the contexts by several hundred and up to 2-3,000 years, probably reflecting abundance and availability of certain pumice types at the time.

To investigate how distal resource availability is influenced by geological processes, such as eruption frequency, ocean-currents, and deposition/preservation of rafted pumice, we focused on the Varanger Peninsula. Here, strong Holocene uplift rates and sea-level changes have built a unique record of raised shorelines that provide windows into fossil beach ridges up to the marine limit, covered in little vegetation. We found that pumice was abundant on specific paleo-shorelines and in defined geomorphic settings but absent from older beach ridges, with the distinct mid-Holocene transgression high-stand accumulating the largest variety of pumice types and clast sizes. Correlation of the pumice sample suite to eruptive origin will contribute to a better understanding of the nature and frequency of Holocene silicic eruptions from Katla and improve age control for existing relative sea-level curves.

1144

Volcanic unrest driven by dike propagation: Implication from a new multiphysics model

Dr. Yan Zhan[1], Dr. Diana C Roman[2], Dr. Hélène Le Mével[2], Dr Patricia M Gregg[3]
[1]Earth System Science Programme, The Chinese University of Hong Kong, Shatin, Hong Kong, [2]Earth and Planets Laboratory, Carnegie Institution for Science, Washington, USA, [3]Department of Geology, University of Illinois at Urbana-Champaign, Urbana, USA

Before most volcanic eruptions, restless behaviors, such as surface deformation, temperature changes, earthquakes, and gas emissions, may be observed. As such, it is essential to quantify the subsurface processes and their resulting stress evolution leading to volcanic eruptions. To examine controls on the local stress field at Augustine Volcano, Alaska, before its 2006 eruption, Zhan et al. (GRL, 2022) calculated fault plane solutions for volcano-tectonic earthquakes from 2002 to 2006. The P-axis orientation was first aligned to the regional maximum compression (NW) and then rotated by about 90° after the onset of surface deformation in mid-August 2005. As Augustine Volcano is a volatile-rich system, volcanic gases may transfer the heat towards the surface when the system is open or pressurize the volcano leading up to eruptions when the system is closed. In Zhan et al. (EPSL, 2022), we found the 2005-2006 volcanic unrest of Augustine was likely driven by accumulating gases inside the volcanic edifice. One critical question is whether pressurized gas can trigger the rotation of the local stress field near a dike, as has been observed when a dike is filled with viscous magma (Roman et al., Nature, 2021). To answer this question, we have developed a new dike propagation model which couples damage mechanics with porous flow to explore the relationship between the local stress field and fluid mobility within the dike. The results show that whether the stress due to dike expansion can overprint the ambient stress is mainly controlled by fluid viscosity and the hydraulic conductivity of the dike. The new model sheds light on additional phenomena observed during the dike propagation, including the velocity of the magma ascent, geometry of the intrusions, and the earthquake migrations, which is applicable to many other systems, such as Bahadurgarh, Mount St Helens, and Piton de la Fournaise.

218

Sensitivity assessment of morphometric parameters of monogenetic volcanic landforms with global free DEMs

Rong Zhang[1], Gábor Kereszturi[2], Marco Brenna[1], Ung San Ahn[3]
[1]University Of Otago, Dunedin, New Zealand, [2]Massey University, Palmerston North, New Zealand, [3]Research Department for Hallasan, World Heritage Office, Jeju, Korea

Improvements in the resolution of Digital Elevation Model (DEM) have greatly facilitated the research of small to moderate landforms such as dunes, landslides/rockfalls, moraines/drumlins and monogenetic volcanoes. Global free 30 m DEMs including data derived from Shuttle Radar Topography Mission (SRTM), Advanced Land Observing Satellite (ALOS) World 3D 30 m (AW3D30), and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER GDEM) are widely used. However, little is known of whether they can be used effectively in monogenetic volcanology. The focus of this study is to explore the accuracy and potential application of global free SRTM 30 m and AW3D30, as well as ASTER GDEM (previously studied) in monogenetic volcanic fields. We compared SRTM and AW3D30 with four reference higher-resolution DEM dataset, including National Elevation Dataset (NED) 10 m in Uinkaret Volcanic Field (UVF) (United States), WorldDEM 12 m in Longgang Volcanic Field (LVF) (China), Contour Line Based DEM (CLBD) 1 m in Jeju Island Volcanic Field (JIVF) (South Korea), and Light Detection And Ranging (LiDAR) 1 m in Lunar Crater Volcanic Field (LCVF) (United States). The results indicate that AW3D30 has higher accuracy than SRTM in all comparisons including elevation, slope angle and morphological parameters of scoria cones and associated lava flows. However, the accuracy of AW3D30 is almost the same as that of SRTM in that it is affected by slope angle, volume of volcanic edifices, and morphological features of scoria cones. Overall, AW3D30 has the best potential in monogenetic volcano studies, followed by SRTM and ASTER GDEM.

205

Eruptive flare-ups at Mount Waesche during interglacial periods with implications for the past behavior of the West Antarctic Ice Sheet

Christine Burrill, Matthew Zimmerer[1], Laura Waters, Nelia Dunbar, William McIntosh
[1]*New Mexico Bureau Of Geology, Socorro, United States*

Comprehensive $^{40}Ar/^{39}Ar$ dating of lava flows from Mount Waesche, the youngest volcano in the Executive Committee Range of West Antarctica, documents pulses of increased activity during interglacial periods indicating that volcanism is, in part, controlled by changes in ice sheet geometry. Dating, mapping, and petrology establishes a total of 54 subaerial eruptions between 425.9 ± 4.8 and 94.6 ± 12.1 ka that span a continuous compositional range from basalt to tephriphonolite. Forty-one eruptions (76%) occurred during interglacial periods with most occurring during MIS 5. The temporal link between increased volcanism during interglacial periods suggests that decreases in ice sheet thickness promotes magma genesis, transport, and eruption. This phenomenon is envisioned to happen through enhanced decompression melting and via flexure of the crust during isostatic rebound, which in turns promote fractures that act as pathways for magma transport to the surface. Ongoing petrology studies will determine if magmas erupted during interglacial periods are generated at different depths and by different mechanism than eruptions during glacial periods. Many of the lava flows erupted during MIS 5 are located on the lowest exposures of southwestern flank near the current ice sheet. These flows are targets for drilling to obtain sub-glacial samples. The presence of cosmogenic isotopes in these flows will indicate prior exposure and thus will provide direct evidence for ice drawdown during the last interglacial period in West Antarctica. The average recurrence interval for the exposed eruptions is ~6 ka. The current repose period of 95 ka coupled with the absence of volcanism during the present interglacial — characteristics in direct contrast to prior activity — likely indicates Mount Waesche is now extinct.

256

Identification and ranking of subaerial volcanic tsunami hazard sources in Southeast Asia

Dr Edgar Zorn[1], Aiym Orynbaikyzy[2], Simon Plank[2], Andrey Babeyko[1], Herlan Darmawan[3], Ismail Fata Robbany[2], Thomas Walter[1]

[1]*German Research Centre for Geosciences GFZ, Potsdam, Germany,* [2]*German Aerospace Center DLR, Wessling, Germany,* [3]*Universitas Gadjah Mada, Yogyakarta, Indonesia*

Tsunamis caused by large volcanic eruptions and flanks collapsing into the sea are major hazards for nearby coastal regions. They often occur with little precursory activity, and are thus challenging to detect in a timely manner. This makes the pre-emptive identification of volcanoes prone to causing tsunamis particularly important, as it allows for better hazard assessment and denser monitoring in these areas. Here, we present a catalogue of potentially tsunamigenic volcanoes in Southeast Asia and rank these volcanoes by their tsunami hazard. The ranking is based on a Multicriteria Decision Analysis (MCDA) composed of five individually weighted factors impacting flank stability and tsunami hazard. The data is sourced from geological databases, remote sensing data, historical volcano induced tsunami records and our topographic analyses, mainly considering the eruptive and tsunami history, elevation relative to the distance from the sea, flank steepness, hydrothermal alteration as well as vegetation coverage. Out of 131 analysed volcanoes, we found 19 with particularly high tsunamigenic hazard potential in Indonesia (Anak Krakatau, Batu Tara, Iliwerung, Gamalama, Sangeang Api, Karangetang, Sirung, Wetar, Nila, Ruang, Serua) and Papua New Guinea (Kadovar, Ritter Island, Rabaul, Manam, Langila, Ulawun, Bam), but also in the Philippines (Didicas). While some of these volcanoes, such as Anak Krakatau, are well-known for their deadly tsunamis, many others on this list are lesser known and monitored. We further performed tsunami travel time modelling on these high-hazard volcanoes, which indicates that future events could affect large coastal areas in a short time. This highlights the importance of individual tsunami hazard assessment for these volcanoes, dedicated volcanological monitoring, and the need for increased preparedness on the potentially affected coasts.

255

Interactions of magmatic intrusions with the multi-year gradual flank destabilisation of Anak Krakatau volcano, Indonesia

Dr Edgar Zorn[1], Magdalena Vassileva[1], Thomas Walter[1], Herlan Darmawan[2], Leonie Röhler[1], Falk Amelung[3]
[1]*German Research Centre for Geosciences GFZ, Potsdam, Germany,* [2]*Universitas Gadjah Mada, Yogyakarta, Indonesia,* [3]*University of Miami, Miami, USA*

Volcano flank collapses have been documented at ocean islands worldwide and are capable of triggering devastating tsunamis, but little is known about the lead-up processes and deformation changes prior to flank failure. This makes the Dec 22nd 2018 flank collapse at Anak Krakatau in Indonesia a key event in geosciences. Here, we provide direct insight into the precursory processes of the final collapse. We analyse the satellite radar data (InSAR) during the 4 years prior to the collapse, and study the link between the deformation trend and intrusion occurrence through analogue modelling. We find that the flank was already moving for years prior to collapse, consistent with a slow décollement slip. Movement rates averaged approx. 27 cm/yr, but underwent two accelerations coinciding with distinct intrusion events in Jan/Feb 2017 and in Jun 2018. Analogue models suggest that these accelerations occurred by (re)activation of the décollement fault linked to a short episode of magma intrusion. During intrusion, we observe a change in the internal faults, where the outward directed décollement is accelerated whilst inward faults become partially blocked and the intruding magma is redirected towards the unstable side. These observations suggest that unstable oceanic flanks do not disintegrate abruptly but their collapse is preceded by observable deformations and accelerations. At Anak Krakatau, flank instability and collapse hazards were additionally advanced by new intrusions.

1117

Linking bed force fluctuations to macroscopic descriptions of granular flows using DEM-CFD

Mr P.J. Zrelak[1], Dr. Eric Breard[2], Dr. Josef Dufek[1]
[1]*University Of Oregon, Eugene , United States,* [2]*The University of Edinburgh, Edinburgh, United Kingdom*

Seismic deployments near active volcanos not only improve our understanding of magma reservoir location and activity, but also provide potentially valuable data on surface flows. Dense seismic deployments improves the chances of observing signals concurrent with lahars, pyroclastic density currents, rock falls, and landslides. However, we lack quantitative correlations between seismic signals to bulk flow properties to interpret signals in terms of flow dynamics. These events are governed by the complex interaction between granular materials, bed conditions, and viscous/fluid interactions. To interpret signals associated with such events, we must understand how the fluctuating component of basal forces, the seismogenic aspect of flow-bed interactions, are related to macroscopic flow properties. Here, we take a grain scale approach, utilizing discrete element methods (DEM-CFD) to resolve particle motions within dry and fluid immersed granular flows. We perform two sets of numerical experiments: constant pressure plane shear configurations, and inclined plane gravitational flows. These experiments span the visco-inertial regime μ(I,Iv) rheology that describes the phenomenological changes from quasi-static solid-like behavior, the transition into dense viscoplastic-like flow, and ultimately to the chaotic gas-like inertial regime. We find that the high frequency force fluctuations correlate with macroscopically derived non-dimensional shear (I), with the frequency content being controlled by microscopic properties of the particles. We explore the role of bed roughness on non-locality and the implications on basal forcing. Finally, we report that high frequency forcings scaled by the mean force and the granular temperature, collapses the spread across particle size and fluid viscosity. This result shows promise in the ability to model fluctuating basal forces utilizing mean flow properties and deriving a sub-grid model that can be used in continuum modeling of events on the scale of geophysical flows.

826

Magma storage conditions and eruptive processes in the 16 ka large-scale Plinian eruptions of Asama volcano, Japan

Mr Kazunori Zushida[1], Mr Fukashi Maeno[1]
[1]*Earthquake Research Institute, University of Tokyo, Bunkyo, Japan*

Magma storage conditions and eruptive processes interact closely and play a large role in driving Plinian eruptions. For understanding their relation, comparing similar-sized eruptions is the most effective way. The 16 ka large-scale pyroclastic eruption at Mt. Asama in Central Japan is a good case study for comparison. This eruption is divided into several stages, in which two VEI-5 Plinian eruptions occurred separately and produced two large fallout units: YP and YPk fallout deposits. We investigate the physical and chemical properties of the pumice and discuss the magma storage conditions and eruptive processes. The physical properties of the pumice in the two units differ: the average apparent density of pumice in YP is 0.47-0.49 g/cm3, which is clearly lower than the 0.69-0.83 g/cm3 of YPk. The vesicularity of YP is 85 %, which is higher than that of YPk at 75%. On the other hand, YP and YPk have almost the same chemical properties such as mineral compositions, and their magma storage conditions are similar; Pl, Opx, and Cpx phenocrysts have peaks at An50, Mg#67, and Mg#75, respectively. The magma reservoir temperatures obtained from Opx-Cpx and Mgt-Ilm thermometers are in the ranges of 840-900 °C and 800-880 °C, respectively. Both units show nearly identical magma reservoir pressure. However, YP is ~0.4 wt% higher in H2O than YPk. The similarity in chemical composition, temperature, and pressure obtained for the two units suggests that the series of eruptions occurred under almost consistent magma storage conditions, excepting a slight difference in H2O. Contrarily, differences in apparent density and vesicularity in the two units suggest that the magma eruptive processes were mainly affected by factors other than temperature and pressure conditions, although further investigation is necessary to reveal the effect of H2O on the eruptive processes.

Author Index

A

Á

B

C

c

Ç

D

d

E

F

G

H

I

J

K

L

M

N

O

Ó

P

p

Q

R

S

T

t

Þ

U

V

v

W

X

Y

y

Z