

May 5.—A Memoir “On the Distribution of the Erratic Boulders, and on the contemporaneous unstratified Deposits of South America,” by Charles Darwin, Esq., F.R.S., F.G.S., was read.

The extensive regions more particularly noticed in this paper are the plains traversed by the Rio Santa Cruz (lat.  $50^{\circ}$  S.); Tierra del Fuego, including the coasts of the Strait of Magellan, and the Island of Chiloe (lat.  $43^{\circ}$  S., long.  $73^{\circ}$  W.).

*Patagonia.*—Between the Rio Plata and the Rio Santa Cruz, Mr. Darwin did not observe any boulders, and the only one he noticed in ascending the first 100 miles of the latter river was a mass 7 feet in circumference, about 57 miles from its mouth, or 100 from the Cordillera. At 100 miles from the coast, or 67 from the nearest slope of the Cordillera, transported blocks first occur, and 12 miles nearer the chain they are extraordinarily numerous, consisting of clay-slate, felspathic rocks, chlorite schist and basaltic lava. They are generally angular, and some of them are of immense size, one being 60 feet in circumference, and projecting from 5 to 6 feet above the surface of the ground. The vast open plain on which they lie scattered, is here 1400 feet above the level of the sea, and its surface is somewhat irregular, owing partly to denudation and partly to the protrusion of hummocks and fields of lava. The plain slopes gently and regularly towards the Atlantic, where the sea-cliffs are about 800 feet high; but towards the Cordillera it rises more abruptly, attaining near the chain an elevation of 3000 feet. The highest peaks of the Cordillera in this part of its range do not exceed 6400 feet above the level of the sea. The following section, exhibited in the banks of the Santa Cruz in longitude  $70^{\circ} 50'$  W., is given by Mr. Darwin to illustrate the nature of the plain on which the boulders rest.

	feet.
1. Gravel, or well-rounded shingle, coarsely stratified, bearing chiefly on its surface great angular erratic blocks . . .	} 212
2. Basaltic lava . . . . .	} 322
3. Variously coloured thin strata, the lower ones containing minute pebbles of the same nature as the boulders, with the exception of the lava . . . . .	} 588
	1122
Bed of the Santa Cruz, above the level of the sea . . . . .	} 280
	1402

The shingle bed (1.) extends uninterruptedly to the coast, where it is certainly of submarine origin; and from the general similarity of its nature, Mr. Darwin is of opinion, that it was all accumulated under the same circumstances. The contrast in the means of transport between the deposits (3.) and (1.), the former consisting of fine particles and the latter of large pebbles and immense blocks of the same rocks with the former, is noticed by Mr. Darwin as an interesting circumstance.

The valley of the Santa Cruz widens, on approaching the Cordillera, into an estuary-like plain, which has an elevation of only 440 feet; and it is believed by Mr. Darwin to have been submerged within the post-pleiocene period, because existing sea-shells were found near the mouth of the plain, and because terraces, which, near the coast, certainly are of recent submarine origin, extend far up the valley. Around this estuary-like plain, and between it and the great high plain, is a second plain, 800 feet in height, the surface of which, as well as the bed of the river in this part, consists of shingle with great boulders. Some of these are of granite, sienite and conglomerate, rocks, which were not observed by Mr. Darwin on the high plain; and on the contrary, the boulders of basaltic lava which were so numerous there, were entirely absent from this lower plain and the river-course. From these circumstances, and likewise from the immense quantity of solid matter which must have been removed in excavating the valley of the Santa Cruz, the author infers that the boulders on the intermediate plain and in the bed of the river, between 30 and 40 miles from the Cordillera, are not derived from the wreck of the high plain, but were transported from the Cordillera subsequently to the modelling of the country, and within, or not long before, the period of existing shells.

Mr. Darwin did not observe erratic blocks in any other part of Patagonia, but he states, on the authority of Capt. King, that large fragments of primary rocks occur on the surface of the great plain which terminates at Cape Gregory, in the Strait of Magellan.

*Tierra del Fuego, and Strait of Magellan.*—The eastern portion of Tierra del Fuego is formed of large outliers of the Patagonian formation, fringed by deposits of more recent origin. These lower plains, varying in height from 100 to 250 feet, have been elevated within the post-pleiocene period; and they consist of finely grained

argillaceous sandstone arranged in thin horizontal or inclined laminae, and often associated with curved layers of gravel. On the eastern borders of the Straits of Magellan, and at Elizabeth Island, Cape Negro, Nuestra Señora de Gracia, all within the Straits, as well as along the line of coast extending to Port Famine, the sandstone passes into, or alternates with, great unstratified deposits, either of an earthy nature and whitish colour, or of a hardened coarse-grained mud of a dark colour, both containing angular and rounded fragments as well as great boulders of sienite, greenstone, felspathic rocks, clay-slate, hornblende-slate, and quartz. These are arranged without the slightest indication of order, and are derived from mountains at least 60 miles distant to the west or south-west. Sometimes the mass is divided by beds of stratified shingle. North of Cape Virgins, near the entrance of the Strait, it alternates with beds of argillaceous, horizontally laminated sandstone, often thinning out and becoming curvilinear at each end. The inclosed fragments must, in this case, have been transported at least 120 miles. Though Mr. Darwin observed only two boulders imbedded in this deposit, yet as he did not notice any scattered on the surface of the country, he concludes that the boulders which occur in vast numbers on all the beaches have generally been washed out of the cliffs: in St. Sebastian's Bay, however, on the east coast of Tierra del Fuego, he found many blocks in a protected position at the base of a naked cliff 200 feet high, entirely composed of thin strata of finely grained sandstone; he therefore infers that, in this instance, they must have been derived from a thin superficial deposit. From the form of the land where these boulders occur, it is clear, Mr. Darwin states, that long anterior to the present total amount of elevation, a wide channel must have connected the middle of the Strait of Magellan with the Atlantic; and from the occurrence of boulders on the low neck of land near Elizabeth Island, that at the same period a straight channel must have existed between Otway Water and the eastern arm of the Strait. As the present currents off Cape Horn set from the west, Mr. Darwin says, it is probable that the ancient currents had a similar direction, and this inference, he adds, is in accordance with the fact, that the boulders and smaller fragments have been transported from mountains to the west. Navarin Island, and several adjacent islets off the extreme southern parts of Tierra del Fuego, are fringed at about an equal height by an unstratified boulder deposit, very similar to that of the Strait of Magellan; and in Beagle Channel, which separates Navarin Island from Tierra del Fuego, it occasionally alternates regularly with layers of shingle. This extensive deposit resembles, Mr. Darwin states, the "Till" of Scotland, and the boulder formation of Northern Europe and the East of England. The interstratification of regular beds, the occasional appearance of stratification in the mass itself, the juxtaposition of rounded and angular fragments of various sizes and kinds of rock derived from distant mountains, and the frequent capping of gravel, indicate some peculiar but similar origin in this deposit of the above widely separated regions. Mr. Darwin follows Mr. Lyell in belie-

ving that floating ice, charged with foreign matter, has been the chief agent in its formation; but he adds that it is difficult to understand how the finest sediment was arranged in horizontal laminae, and coarse shingle in beds, while stratification is totally, and often suddenly, wanting in the closely neighbouring till, if it be supposed that the materials were merely dropped from melting drift ice; and he is disposed to think that the absence of stratification, as well as the curious contortions described in some of the stratified masses, are mainly due to the disturbing action of icebergs when grounded. He believes also that the total absence of organic remains in these deposits may be accounted for by the ploughing up of the bottom by stranded icebergs, and the impossibility of any animal existing on a soft bed of mud or stones under such circumstances. In confirmation of the disturbing action of icebergs, Mr. Darwin refers to Wrangell's remarks on their effects off the coast of Siberia.

*Chiloe.*—North of latitude  $47^{\circ}$  and between it and the southern extremity of Chiloe, the author landed at several points, but saw no boulders; and he explains their absence by the coast being at a distance from the Cordillera, and separated from it by intervening high land. At Chiloe erratic boulders, often of great size and consisting of granite and sienite, occur in vast numbers along the whole line of the eastern and northern beaches, as well as on the islets parallel to the eastern coast, and on the land at the height of upwards of 200 feet; but the author did not observe any on the western coast at the two points which he examined, nor during an excursion of 30 miles across the high central portion of the island. Chiloe consists, as far as Mr. Darwin ascertained, of mica-slate and volcanic formations, extensively bordered, but chiefly on the eastern and northern sides, by a horizontally-bedded tertiary sandstone and volcanic grit. On the eastern coast, the land is indistinctly modelled into successively rising plains, the surfaces of the upper and the whole thickness of some of the lower being in general composed of stratified shingle. A few boulders occur in this gravel; and as the shores have been extensively denudated, Mr. Darwin infers that most of the very numerous blocks on the beaches were originally included in it. At the northern end of the island, the granitic and sienitic boulders are intermingled, but 30 miles to the southward, the author noticed only granite blocks. The parent rock he believes lies in the Cordillera; and several of the varieties of granite and sienite at the northern end of the island are stated, on the authority of an intelligent resident, to form whole mountains in Reloncavi Sound, on the opposite part of the main land. The larger masses were quite angular, and resembled fragments at the foot of a mountain. One block measured 15 feet in length, 11 in breadth, and 9 in height; another, of a pentagonal form, 11 feet on each side, and at one part projected 16 feet above the sand, in which it was partly buried.

At the extreme northern point of Chiloe, a headland 250 feet high is joined to Lacuy peninsula by a low neck of land; and from its composition, height and stratification, Mr. Darwin ascertained that it was once continuous with the opposite coast. The boulders

were much more numerous on the isthmus and its sides at the height of 150 feet, than on any other part of the surrounding country; and as the sea must have flowed over this isthmus in a channel, previous to the amount of elevation, ascertained to have taken place here within the post-pleiocene period, the position of these boulders proves, according to Mr. Darwin, even more clearly than the cases occurring in Tierra del Fuego, the evident relationship between their distribution and the lines of anciently existing sea-channels. In the southern half of Chiloe, and on one of the Chonos islands, the author discovered a deposit of hardened mud, including far transported, angular and rounded fragments, and resembling the till of the Straits of Magellan. In a layer of loose sand at the base of the cliff in the latter locality, he noticed a quantity of comminuted marine shells with a fresh aspect; and at Chiloe he also observed, at a point where a mass of till passed into finely grained laminæ, small fragments of a *Cytheræa*.

With respect to the age of the boulder formation of Chiloe, Mr. Darwin offers no precise remark, but he says that it probably occurs within the post-pleiocene period, because at a height of 350 feet on the peninsula of Lacuy, and therefore considerably above the level of this formation, a great bed of existing sea-shells was observed, and neither the boulder nor accompanying beds appear to have been of deep-water origin. Similar evidence was adduced respecting the age of the till of Tierra del Fuego. North of  $41^{\circ} 47'$  S. lat., Mr. Darwin did not observe on the Pacific side of South America either boulders or till; nor any north of the Straits of Magellan, on the shores of the Atlantic side; and he accounts for the absence of erratic blocks in the latter region by its great distance from the Cordillera. He is also strongly of opinion that till will be found to be limited to the latitudes in which true boulders occur.

*Glaciers, &c.*—In the concluding part of his memoir, the author offers a few remarks on the glaciers of Tierra del Fuego, and on the transport of the boulders. He did not disembark on any glacier, but in the Beagle and Magdalen channels he passed within 2 miles of several. The mountains were covered with snow, and the glaciers formed many short arms, terminating at the beach in low perpendicular cliffs of ice. Their surface, to a considerable height on the mountains, was perfectly clean and of a bright azure colour; and the former condition he ascribes to their shortness, to their not being flanked by overhanging precipices, and to their not being formed by the junction of two or more smaller streams. The descent of the glaciers, Mr. Darwin states, cannot be very slow, as vast masses continually break off with a great noise, and produce a tumultuous surf on the adjacent beaches. The glaciers in the Beagle Channel were generally bordered by a tongue of land composed of huge fragments of rock, and many boulders were strewed on the neighbouring shores. The glacier which he approached most closely descended to the head of a creek formed on one side by a wall of mica-slate, and on the other by a broad promontory from 50 to 60 feet high, on which he landed: it appeared to consist en-

tirely of enormous masses of granite. This promontory, he conceives, was once a lateral moraine, and as it projects nearly half a mile beyond the extremity of the glacier, and is covered with old trees, he infers that the glacier has diminished in length to that extent.

Mr. Darwin says it is impossible to explain the distribution of boulders without the agency of ice, but he adds, that neither the till of the Strait of Magellan which passes into, and is irregularly interstratified with, a laminated sandstone containing marine remains, nor the stratified gravel of Chiloe, can have been produced like ordinary moraines. The boulders, likewise, on the lower levels at the head of the Santa Cruz river, he considers, could not have been distributed in their present position by glaciers, the surface having been modelled by the action of the sea; and the little inclination of the high plain from the ridge of the Cordillera to where the boulders occur, as well as the absence of mounds or ridges on it, and the form of the fragments, render it very improbable that they were propelled from the mountains by ancient glaciers. Hence, he concludes, that the blocks of Tierra del Fuego and Chiloe were certainly transported by floating ice, and most probably those of the low and high plains of Santa Cruz. Finally, he is of opinion, from the general angularity of the blocks, and from the present nature of the climate of the southern parts of America, which favours the descent of glaciers to the sea in latitudes extraordinary low, that it is more probable that the boulders were transported on the surface of icebergs, detached from glaciers on the coast, than imbedded in masses of ice, produced by the freezing of the sea.