

## DARWIN ON CORAL REEFS.\*

**S**ELDOM has a single stride of greater importance been taken in terrestrial physics than that which was marked by the publication of Mr. Darwin's work on coral reefs thirty years ago. A whole generation of geologists has since grown up with the advantage of entering upon their studies with clear and settled ideas upon a group or range of phenomena largely underlying any comprehensive view of the formation of the existing earth-crust. It was not enough to have learnt over how wide an area of the globe the present aspect of the surface is due to the action of minute submarine organisms, or to how vast a depth or thickness the growths of these patient workers had accumulated during untold ages, if science was still unprepared with any adequate or well-grounded theory to explain the mode in which these mighty structures were gradually piled up, and the causes which determined their distribution over various parts of the earth's surface. The bold and original generalizations of Mr. Darwin left little room for doubt in any reflecting mind that the theory of coral formation was thenceforth to take its place among the established certainties of science. Controversies might still arise over matters of detail, and much might be added by way of development, and even of correction, to the views laid down by this eminent naturalist. But for the main hypothesis, if that were to be called an hypothesis which with most men of science was accepted as an attested fact, nothing remained beyond wider expansion or more explicit enunciation. Several points of much interest have indeed been mooted in the intervening period by naturalists of note, which have given occasion to Mr. Darwin to go once more over the ground he explored with such good results a generation ago, criticizing with his usual candour and close logic the reasonings of later writers, and fortifying with new arguments and a fresh array of facts the main positions taken up by him in his original treatise.

The most important work upon corals and coral reefs is that of Professor Dana, published in 1852. Professor Dana, whilst concurring to the full in the fundamental proposition of Mr. Darwin that lagoon islands or atolls and barrier reefs have been found during periods of local subsidence, demurs to more than one point in his general scheme. One of these objections refers to the limitation of the area over which the growth of coral is at present known to extend. The limits laid down by Mr. Darwin, which he still sees no reason to alter, range no further north than the latitude of Bermuda ( $32^{\circ} 15' N.$ ), their extension so far northwards being no doubt due to the warmth of the Gulf Stream. In the Pacific the Loo Choo Islands ( $27^{\circ} N.$ ) have reefs on their shores, and there is an atoll in  $28^{\circ} 30'$  situated N.W. of the Sandwich Archipelago. In the Red Sea there are coral reefs in lat.  $30^{\circ}$ . In the Southern hemisphere they do not extend so far from the equatorial sea, Houtmans Abrolhos, on the western shore of Australia, in lat.  $29^{\circ} S.$ , being the most southerly reef. A glance at Mr. Darwin's chart will show how evenly the coral reefs of every kind are spread along the belt of the equator, leading to his original inference that the law of their distribution depends upon the range of ocean temperature. We could wish that the author had taken into his consideration the far wider extension of coral growths in earlier geological ages—their extensive distribution, for instance, over the limestone area of our own islands; and had indicated the inference which he would have us draw from facts like these as to the higher temperature of the Northern waters at remote periods. What has now to be accounted for is the remarkable fact of the absence of coral growths over a large area within the tropical seas. None were observed during the surveying voyages of the *Beagle* on the west coast of South America, south of the equator, or round the Galapagos Islands, nor have any been seen there north of the line; and though living corals have been found in the Bay of Panama, no reefs seem to have been formed by them. Mr. Darwin at first attributed this absence of reefs on the coast of Peru and elsewhere to the coldness of the currents from the south; but, on the contrary, the Gulf of Panama is one of the hottest pelagic areas in the world. The deficiency of carbonate of lime in certain waters cannot be taken into account, for at Ascension the waves, charged to excess, precipitate a thick calcareous layer upon the tidal rocks; but there are no corals there, nor at St. Jago, in the Cape Verdes, where carbonate of lime is not only abundant on the shores, but forms the chief part of some upraised post-tertiary strata. At the same time it is found that the bottom of the sea round certain islands is thickly coated with living corals, which nevertheless do not form reefs, either from insufficient growth owing to one cause or another, or from the species not being adapted to contend with the breaking waves. Another reason assigned was the accumulation of sediment brought down by rivers into the sea, and forming banks of mud whereby the polypifers were choked and their growth suspended. But this explanation, however plausible as regards the seaboard of South America, the West Coast of Africa, or the Gulf of Guinea, cannot be held good in the case of St. Helena, Ascension, the Cape Verdes, St. Paul's, or Noronha, which are free from reefs, though far out to sea, and composed of the same volcanic rocks, and having the same general form with those of the islands in the Pacific, the shores of which are surrounded by gigantic walls of coral rock.

Exception has been taken by Mr. Dana, and justly as Mr. Darwin allows, to that part of the argument which concerns the mean

\* *The Structure and Distribution of Coral Reefs.* By Charles Darwin, M.A., F.R.S., F.G.S. With 3 Plates. Second Edition, revised. London: Smith, Elder, & Co. 1874.

temperature of the sea, upon which sufficient weight, he considers, had not been laid. Yet even if Mr. Darwin had to some extent undervalued the effect of temperature during the coldest season of the year, it does not appear that we are any nearer an explanation of the remarkable absence of reefs in the cases enumerated, and our author has in consequence allowed those paragraphs of his work to stand as they were in the first edition. In the central and apparently hottest parts of the Pacific there are islands entirely free from reefs. Not that latitude has much to do with marine any more than with aerial temperature. The Galapagos are on the equator itself; and there the mean surface temperature was made out by Fitzroy to be 68° F. between September 16 and October 1835, the minimum at Albemarle Island being 58.5° at the S.W., and 62° or 63° on the western shore, whilst near Tahiti, over 17° S., the mean observed was 77.5°, the lowest any day being 76.5°. There is thus a difference of 9.5° in mean temperature, and of 18° in extremes; quite enough, as Mr. Darwin allows, to affect the distribution of organic beings in the two areas. Yet, even if we knew more of the variations of ocean temperature, we might remain almost as far from any satisfactory reason for the absence of coral reefs in such areas as we have mentioned. This is one of the points in regard to which we must look hopefully to the results which the cruise of the *Challenger* in equatorial waters may bring forth.

The proximity of volcanic land, owing to the lime generally evolved from it, has been thought by some to be favourable to the increase of coral reefs. Mr. Darwin, on the contrary, shows that nowhere are coral reefs more extensive than on the shores of New Caledonia and of North-Western Australia, which consist of primary formations, whilst the Maldiva, Chagos, Marshall, Gilbert, and Low Archipelagos, the largest groups of atolls in the world, are formed exclusively of coral, without any nearness to active volcanos. He had indeed urged the opposite view, that volcanic action impedes the growth of coral reefs. And it is made a point of objection by Professor Dana that he had not pushed this argument far enough. Mr. Darwin has in turn to question how far the heat or poisonous exhalations of a volcano could affect an area so wide as Professor Dana's theory implies. In the central parts of the Pacific there are islands wholly free from reefs, and in some of these cases this may be due, he considers, to volcanic action. But the existence of reefs, though scantily developed, and, according to Dana, confined to one part of Hawaii (one of the Sandwich group, and a volcanic centre of tremendous power), shows that recent volcanic action does not absolutely prevent their growth. Upon the question of the seemingly capricious distribution of coral reefs Mr. Darwin ultimately brings to bear the doctrine of the struggle for life. In those parts of the sea in which there are no such structures, there are, we may conclude, other beings supplying the place of the reef-building polypifers. It is shown in the chapter on Keeling Atoll that there are some species of large fish, besides the whole tribe of *Holothuræ*, which prey upon the tenderer parts of the corals. On the other hand, the polypifers may suffer from the diminution through whatever cause of the organic beings on which they prey. The relations which determine the formation of reefs on any shore must be very complex, and, with our present means of knowledge, inexplicable. Changes in the condition of the sea, not obvious to our senses, might restrain or destroy all the coral growths in one area and cause them to appear in another. The Pacific or Indian Ocean might become as barren of coral reefs as the Atlantic is now.

It has been a question whether a position of calm is more favourable to coral growths than the being exposed to the free and violent dash of the sea. Certain polypifers in the saxigenous lithophytes cited by MM. Quoy and Gaimard may be able to flourish only where the water is quiet and the heat intense. Yet, on the other hand, the most careful researches confirm the remark of Ehrenberg, that the strongest corals love the surf, and are most rich and massive where most exposed to the waves. The great mounds of living *Porites* and of *Millepora* round Keeling Atoll, occur exclusively on the extreme verge of the reef, which is washed by the breakers. It is indeed to the solid rampart formed by these massive outworks that the more delicate and more richly-branched corals of the inner water owe their existence. In proportion to the protection thus afforded do they gain in variety and delicacy while decreasing in bulk. If the question were put under what conditions the greater number of species of coral, not regarding their bulk and strength, were developed, Mr. Darwin would answer, with MM. Quoy and Gaimard, that this would happen where the water is tranquil and the heat intense. The total number of species in the circumtropical seas must be very great, 120 kinds, according to Ehrenberg, having been yielded by the Red Sea.

Whilst agreeing in general with Mr. Darwin's view that atolls or lagoon islands, as well as barrier reefs, have been formed during a period of subsidence, Professor Dana has instanced certain of the lagoon islands of the Low Archipelago and elsewhere as showing signs of recent elevation to the extent of a few feet; a view which had obtained support from the observations of Mr. Outhouy on the atolls of Paumotu and Fiji. Our author, while admitting the difficulty of judging the evidences of local elevation or subsidence, adduces notwithstanding many considerations tending to show that here too his fundamental proposition holds good. In no part of his present work do we see more of his characteristic grasp of facts and insight into natural causes. These evidences of elevation are, he shows, often but illusory. If they have not

undergone subsidence, these atolls or reefs may at least have remained stationary. Such circumstances as corals standing on the shores or in the midst of the lagoons from twelve to thirty inches above the sea-level, with the tops of their branches dead; the great shells of the *Tridacna* vertically embedded in coral rock at a height at which they cannot now exist; and the discovery of masses of coral rock which could never have been carried to their present places and have become water-worn while they stood at their present level, may be explained by the action of water breaking upon the shore and carrying up the living polypifers, aided by the agglutination of fragments of dead rock shells, and sand. Bathed by the troubled waters, their building action would long continue. The wide fields of rotten coral at Keeling Island, with the tips of their branches projecting above the surface of the lagoon, may be simply the result of the tides not rising so high as formerly since the closing, as reported by the inhabitants, of the channels between the islets, and of the lagoon being partially choked by the growth of corals. Here, so far from there having been elevation of the land, there is reason to see proofs of subsidence, to which may be added the manner in which Chain Atoll, in the Paumotu group, suffered from a storm, and the statement of Sir E. Belcher that after an interval of fourteen years a well-known island thereabouts had disappeared, and the lagoon at a particular spot had become deeper than before. Among other causes of change which might easily lead to a mistaken belief in the recent elevation of low coral formations, Mr. Darwin suggests that during some special season, the currents of the sea and the prevalent winds coinciding in direction, the waves would rise to a higher level, and that the corals would grow higher, the result being that these corals at a subsequent season would expose their dead summits, and give the appearance of the land having been slightly elevated. Should, however, the conclusion arrived at by so excellent an observer as Professor Dana be hereafter confirmed, the question, in Mr. Darwin's opinion, will be whether, seeing how vast an area has been thus affected, those geologists are not right who believe that the level of the ocean is subject to changes from astronomical causes. We understand him to speak here of Mr. Croll and those who take his view of the varying curve of the earth's orbit, and the increased angle of the inclination of her axis. He might have given a prior place to the growing conviction of the geological truth of what is known as the equatorial bulge in the figure of the earth.

On the fringed coasts manifold and unmistakable proofs of recent and active elevation are readily accumulated, and, as Mr. Darwin shows, corals attached to a rising coast would necessarily form a fringing reef. The areas including reefs of this kind, and their connexion with active volcanoes, are well shown by means of the coloured map, as well as by the details of evidence brought to bear upon this point in the appendix. In revising this map, which must have been the result of much patient labour, one new volcano has been inserted on the north-eastern side of New Caledonia, whilst that in Torres Straits has been omitted. Some broad generalizations of great value have been added regarding the subsiding areas marked blue on the map, as indicating the presence of atolls or barrier reefs, and the rising or stationary areas marked red, as known by upraised organic remains or inferred from the presence of fringing reefs. If the existence of continents shows that the areas which have been upheaved are immense, the proofs which are brought forward in support of Mr. Darwin's theory show that the areas which have subsided have been not less immense. We may follow in imagination the spaces held by wide continents and lofty mountains sinking beneath the sea, with a movement so slow as to allow the corals to grow up to the surface, where the atolls now stand like monuments, marking the place of burial.

#### VON HELLWALD'S RUSSIANS IN CENTRAL ASIA.\*

WE have had occasion lately to review several works on the subject of the ceaseless flow of Russian enterprise or ascendancy over the steppes and Khanates of Central Asia. These books have much of the interest and animation of a trial at Bar. M. Vambéry plays the part of counsel for the plaintiff, and roundly asserts the innocence of the lamb and denounces the apathy of the shepherd as against the wolf. The Russian apologist, through the mouth of Captain Spalding, endeavours to show that the fable is of no application. The author now before us, after hearing the arguments of both parties, analyses the evidence, reviews the proceedings, and closes the suit by dismissing Great Britain with a warning, and condemning her in costs for *laches* in the case. Amongst the various contributions made towards an accurate comprehension of the exact aim and position of Russia in Asia, this book of Herr von Hellwald must take a high rank. He has gone far and wide in search of facts. Scientific disquisitions, records of perilous adventures, the official returns of Russian naval officers, the speeches of members of our own Parliament, the opinions of Continental writers on disputed points of geography and politics, the statesmanship of Lord Lawrence, and the views of Mr. Grant Duff, have all been laid under requisition, and have respectively contributed to the

\* *The Russians in Central Asia: a Critical Examination down to the Present Time of the Geography and History of Central Asia.* By Frederick von Hellwald, Member of the Geographical Societies of Vienna, Mexico, Paris, Geneva, New York, &c. Translated from the German by Lieut.-Col. Theodore Wiegman, LL.B. With a Map. London: Henry S. King & Co. 1874.