

 On Certain Areas of Elevation and Subsidence in the Pacific and Indian Oceans, as Deduced from the Study of Coral Formations¹

The author commenced by observing on some of the most remarkable points in the structure of Lagoon islands. He then proceeded to show that the lamelliform corals, the only efficient agents in forming a reef, do not grow at any great depths; and that beyond twelve fathoms the bottom generally consists of calcareous sand, or of masses of dead coral rock. As long as Lagoon islands were considered the only difficulty to be solved, the belief that corals constructed their habitations (or speaking more correctly, their skeletons), on the crests of submarine craters, was both plausible and very ingenious; although the immense size, sinuous outline, and great number, must have startled any one who adopted this theory. Mr. Darwin remarked that a class of reefs which he calls "encircling" are quite, if not more, extraordinary. These form a ring round mountainous islands, at the distance of two and three miles from the shore; rising on the outside from a profoundly deep ocean, and separated from the land by a channel, frequently about 200 and sometimes 300 feet deep. This structure as observed by Balbi² resembles a lagoon, or an atoll, surrounding another island. In this case it is impossible, on account of the nature of the central mass, to consider the reef as based on an external crater, or on any accumulation of sediment; for such reefs encircle the submarine prolongation of islands, as well as the islands themselves. Of this case New Caledonia presents an extraordinary instance, the double line of reef extending 140 miles beyond the island. Again the Barrier reef, running for nearly 1000 miles parallel to the North-East coast of Australia, and including a wide and deep arm of the sea, forms a third class, and is the grandest and most extraordinary coral formation in the world.

The reef itself in the three classes, encircling, barrier and lagoon, is most closely similar; the difference entirely lying in the absence or presence of neighbouring land, and the relative position which the reefs bear to it. The author particularly points out one difficulty in understanding the structure in the barrier and encircling classes, namely, that the reef extends so far from the shore, that a line drawn perpendicularly from its outer edge down to the solid rock on which the reef must be based, very far exceeds that small limit at which corals can grow. A distinct class of reefs however exists, which the author calls "fringing reefs," which extend only so far from the shore, that there is no difficulty in understanding their growth. The theory which Mr. Darwin then offered, so as to include every kind of structure, is simply that as the land with the attached reefs subsides very gradually from the action of subterranean causes, the coral building polypi soon again raise their solid masses to the level of the water; but not

so with the land; each inch lost is irreclaimably gone:—as the whole gradually sinks, the water gains foot by foot on the shore, till the last and highest peak is finally submerged. Before explaining this view in detail, the author offered some considerations on the probability of general subsidences,—such as the small portion of land in the Pacific, where many causes tend to its production, an argument first suggested by Mr. Lyell, and the extreme difficulty (with the knowledge that corals grow at but limited depths) in explaining the existence of a vast number of reefs on one level, without we grant subsidence, so that one mountain top should be submerged after another; the zoophytes always bringing up their stony masses to the surface of the water. Subsidence being thus rendered almost necessary, it was shown by the aid of sections, that a simple fringing reef would thus necessarily be converted by the upward growth of the coral into one of the encircling order, and this finally, by the disappearance through the agency of the same movement of the central land, into a lagoon island. In the same manner a reef skirting a shore would be changed into a barrier extending parallel to, but at some distance from, the mainland.

Mr. Darwin then showed, that there existed every intermediate form between a simple well characterized encircling reef, and a lagoon island; that New Caledonia supplied a link between encircling and barrier reefs; that the different reefs produced by the same order of movement were always in juxtaposition, of which the Australian barrier associated with encircled islets and true lagoons, affords a good example. He then proceeded to show that within the lagoon of Keeling Island, proofs of subsidence might be deduced from many falling trees and a ruined storehouse; these movements appearing to take place at the period of bad earthquakes, which likewise affect Sumatra, 600 miles distant. It was thence inferred as probable, that as Sumatra rises, (of which proofs are well known to exist,) the other end of the lever sinks down; Keeling Island thus acting as an index of the movement of the bottom of the Indian Ocean. Again at Vanikoro,³ where the structure indicates according to the theory recent subsidence, violent earthquakes are known lately to have occurred.

The author then removed an apparent objection to the theory, namely, that subsidence would form a disc of coral but not a cup-shaped mass or lagoon, by showing that the corals which grow in tranquil water are very different from those on the outside, and less effective; and that as the basin becomes shallower they are subject to various causes of injury. The lagoon nevertheless is constantly filling up to the height of lowest water spring tides, (the utmost possible limit of living coral,) and in that state it long remains, for no means exist to complete the work. Mr. Darwin then proceeded to the main object of the paper, in showing that as continental

elevations act over wide areas, so might we suppose continental subsidences would do, and in conformity to these views, that the Pacific and Indian seas could be divided into symmetrical areas of the two kinds; the one sinking, as deduced from the presence of encircling and barrier reefs, and lagoon islands, and the other rising, as known from uplifted shells and corals, and skirting reefs. The absence of lagoon islands in certain wide tracts, such as in both the West and East Indies, Red Sea, &c., was thus easily explained, for proofs of recent elevation are there abundant. In a like manner, in very many cases where islands are only fringed with reefs, which according to the theory had not been subsiding, actual proofs of elevation were adduced. Mr. Darwin remarked that, excepting on the theory of the configuration of reefs being determined by the order of movement, the circumstance that certain classes which are characteristic and universal in some parts of the sea, being never found in others, is quite anomalous, and has never been attempted to be explained.

Mr. Darwin then pointed out the above areas both in the Pacific and Indian Oceans, and deduced the following as the principal results. 1st. That linear spaces of great extent are undergoing movements of an astonishing uniformity, and that the bands of elevation and subsidence alternate. 2. From an extended examination, that the points of eruption all fall on the areas of elevation. The author insisted on the importance of this law, as thus affording some means of speculating, wherever volcanic rocks occur, on the changes of level even during ancient geological periods. 3. That certain coral formations acting as monuments over subsided land, the geographical distribution of organic beings (as consequent on geological changes as laid down by Mr. Lyell) is elucidated, by the discovery of former centres whence the germs could be disseminated. 4. That some degree of light might thus be thrown on the question, whether certain groups of living beings peculiar to small spots are the remnants of a former large population, or a new one springing into existence.⁴ Lastly, when beholding more than a hemisphere, divided into symmetrical areas, which within a limited period of time have undergone certain known movements, we obtain some insight into the system by which the crust of the globe is modified during the endless cycle of changes.

1. [Presented at the meeting of 31 May 1837.] *Proceedings of the Geological Society of London* 2(1838):552-54. †

2. Gasparo Balbi, "Gasparo Balbi's Voyage to Pegu, and Observations There Gathered from His Own Italian Relation," in John Pinkerton, ed. *A General Collection of the Best and Most Interesting Voyages and Travels . . .*, 17 vols., vol. 9, pp. 395-405 (1811) (London: Longman, Hurst, Rees, and Orme, 1808-14). †

3. Solomon Islands, east of Guadalcanal. †

4. Darwin's first published hint of his belief in evolution. See transcriptions of

his 1837-39 transmutation and metaphysics notebooks in Howard E. Gruber and Paul H. Barrett, *Darwin on Man* (New York: Dutton, 1974).†