II. Geology and Natural History.

1. *Notes on the new edition of Mr. Darwin's work on the Structure and Distribution of Coral Reefs* (1874); by James D. Dana.* —Mr. Darwin, in the new and much improved edition of his work on Coral Reefs, mentions some points in the subject, on which he still finds reason to differ from the writer. I think that with regard to one or two of these points he has not fully understood my views; and, as to the others, that the arguments and facts which I have brought out have not received all the consideration they deserve. A review of some statements in his work may, therefore, be profitable. I follow the order of his criticisms as briefly stated in the first half of his preface.

* *The Structure and Distribution of Coral Reefs*, by Charles Darwin, M.A., F.R.S., F.G.S. Second edition, revised. 263 pp. 12mo, with three plates. London, 1874. (Smith, Elder & Co.)

(I.) The second sentence of the Preface is as follows:

"In this work [Dana's Corals and Coral Islands] he [the author] justly says that I have not laid sufficient weight on the mean temperature of the sea in determining the distribution of coral reefs; but neither a low temperature nor the presence of mud banks accounts, as it appears to me, for the absence of coral reefs throughout certain areas; and we must look to some more recondite cause."

The first two clauses of this sentence are true—the *but* between them being removed, as it may lead some readers to suppose the alternative mine. Yet Mr. Darwin's work does not show that even now he appreciates the influence of oceanic temperature on the distribution of coral reefs. In his discussions on the distribution of reefs and the causes limiting the same, this agency, the chiefest with marine life, both for depth and surface, according to all zoologists, is scarcely mentioned. There is one allusion to the subject on page 81. Mr. Darwin says: "I at first attributed this absence of reefs on the coasts of Peru and of the Galapagos Islands to the coldness of the currents from the south, but the Gulf of Panama is one of the hottest pelagic districts in the world;" and a note is added, giving some sea temperatures of the region referred to. Thus the cause is set aside even for the seas along the Peruvian coast, although the mean winter temperature of the water there is lower than exists in any reef region in the world, and is therefore sufficient of itself to exclude reefs. The fact that there are only small patches at Panama, where the temperature is tropical, does not annul the fact that the seas of Peru and the Galapagos are too cold for corals. Where temperature excludes, there is no use in discussing other unfavorable conditions.

The causes limiting growth and the distribution of reef-making corals and coral reefs, which I have discussed and applied in my work, are *seven* in number.

(1.) Marine temperature.

(2.) Fresh and impure waters from the entrance of large rivers; and muddy bottoms.

(3.) Deposition of sediment borne by rapid tidal currents.

(4.) The depth of water along coasts exceeding 100 feet, that is, exceeding the depth to which reef-corals may grow—a common condition along bold coasts, and often explaining, as I have found, the contrasts between the reef-bordered and open coasts of the same island.

(5.) Exposure to the heat of submarine volcanic eruptions (pp. 299–317).

(6.) The progressing coral-island subsidence too rapid for the polyps to keep the reef well at the surface, if at all (p. 270): which cause may lead, in atoll seas, to very narrow fringing reefs; to small sizes in coral atolls and a more or less complete obliteration of the lagoon; and to a submerging of the coral island beneath the surface; or, finally, to a complete disappearance of the island (pp. 332, 369).

(7.) The direction and temperature of oceanic currents (p. 112): this cause accounting for the non-distribution of central-Pacific species of corals to the Panama coast, and the paucity of species there, with the absence of the large Astræa group and the Madrepores.

On this last point I say in explanation, on page 112: "Owing to the cold oceanic currents of the eastern border of the Pacific—one of which, that up the South American coast, is so strong and chilling as to push the southern isocryme [the line passing through points of equal mean oceanic temperature for the coldest month of the year] of 68°, the coral-sea boundary, even beyond the Galapagos, and north of the equator—the coral-reef sea, just east of Panama, is narrowed to 20°, which is 36° less of width than it has in mid-ocean; and this suggests that these currents, by their temperature, as well as by *their usual westward direction*, have proved an obstacle to the transfer of mid-ocean species to the Panama coast." For the same reason, the transfer of corals—warm-water species—from the West Indies or Bermudas, eastward, to *western Africa*, is impossible. The width of the coral reef region on the African side of the Atlantic is only 15°, while it is 48° toward the American coast, and the tropical current is *eastward.*

A proper understanding of the action of the various causes influencing the growth and distribution of polyps and reefs, which have been mentioned in the preceding paragraphs, may leave much less than has been imagined for that "more recondite cause."

I did not think to include among the causes a too rapid *upward* change of level—on which Mr. Darwin lays much stress. But I recognized the fact that when a rise, like that which has occurred at the island of Oahu [putting an extended range of reef thirty feet out of water], takes place, and so divides the area of reef into an elevated and non-elevated portion, the latter will be, on this account, narrower than it would have been had the land been stationary. But the cause does not appear to me to have very many examples.

(II.) The third sentence of the Preface reads thus:

"Professor Dana also insists that volcanic action prevents the growth of coral reefs much more effectually than I had supposed; but how the heat or poisonous exhalations from a volcano can affect the whole circumference of a large island is not clear." And this is followed by the remark: "Nor does this fact, if fully established, falsify my generalization that volcanos in a state of action are not found within the area of subsidence, whilst they are often present within those of elevation."

In my discussion of this subject I have attributed the destruction here referred to about islands of active, or recently active, volcanos, not to aerial eruptions, as might be suspected from Mr. Darwin's words, but to *submarine;* and I happen to have said nothing about "exhalations." I have drawn my conclusions especially from four examples (pp. 302, 305, 306), the island of Hawaii

(Sandwich Islands), about which recent eruptions, and partly submarine, have taken place on the east, southeast, south and west slopes of the island, or through more than half of its circumference; Savaii, the largest of the Samoan or Navigator Islands, and the last of the group to become extinct, as its lava streams show; the eastern half of Maui, whose great crater must have been recently in action, while the western half bears the fullest evidence of long extinction; and the northern extremity of the Ladrones. I state that reefs often occur on favored parts of even such volcanic islands, as they well might if submarine eruptions were the cause, and I mention examples; thus agreeing with Mr. Darwin's criticism that "the existence of reefs, though scantily developed, and, according to Dana, confined to one part of Hawaii, shows that recent volcanic action does not prevent their growth." My statement about that Hawaiian reef is worded thus: "the only spot of reef *seen* by us was a submerged patch off the southern cape of Hilo Bay." Mr. Darwin cites an observation with regard to the occurrence also of reefs on the northern coast of Hawaii, which accords precisely with the principle I have laid down, since the northern part of the island is, as I state in my Geological Report of the island, that which was earliest extinct, and is oldest in all its features, and therefore that which would not have been reached by the submarine eruptions. The western peninsula of Maui, or the old part, has its coral reefs, while the eastern, or part recently active, has almost none. Savaii, in like manner, has coral reefs on its western and northern shores, while elsewhere without them.

I failed to find evidence in the case of either of these volcanic regions that they are situated within areas of elevation rather than subsidence. *Only ten miles* west of Savaii lies the large island of Upolu, having very extensive reefs—on some parts of the north side three-fourths of a mile wide; and it has not seemed safe to conclude that, while Upolu thus bears evidence of no movement or of but little subsidence, Savaii was one of elevation; or that the north and west sides of Savaii have differed in change of level from the rest of the island. In the island of Maui, having reefs on its old western half, it can hardly be that the eastern peninsula has changed its level quite independently of the western. In the linear group of the Ladrones the active volcanos are at the north end; the islands of the group are very small at that end, without coral reefs, while large at the other and with broad reefs. One of them, Assumption Island, near which our Expedition passed, is only a small, steep, cinder cone, the vent of a submerged volcanic mountain. Such facts afford, therefore, some reason for my statement that "the Ladrones appear to have undergone their greatest subsidence at the northern extremity of the range;" and no observations yet made suggest the contrary view.

The general proposition, that active volcanos are absent from areas of subsidence appears to me to need better proof than it has received. As regards the Pacific Ocean, I have found nothing to sustain it. The subsidence of the coral island area of the ocean was one of so vast extent—the breadth 4000 miles, according to

Mr. Darwin—that the sinking could have been no obstacle to the existence and cotemporaneous working of volcanos.

(III.) The next point in the Preface is a right correction of a misunderstanding on my part of one of Mr. Darwin's statements. It says: "Professor Dana apparently supposes (p. 320) that I look at fringing reefs as a proof of the recent elevation of the land, but I have expressly stated that such reefs, as a general rule, indicate that the land has either long remained at the same level, or has been recently elevated. Nevertheless, from upraised recent remains having been found in a large number of cases on coasts which are fringed by coral reefs, it appears to me that, of these two alternatives, recent elevation has been much more frequent than a stationary condition.."

When my work passes to a second edition, I shall make the needed correction.

But I still hold that, while barrier reefs, as Mr. Darwin urges, are proofs of subsidence, small or fringing reefs are in themselves no certain evidence of a stationary level, and are often evidence of subsidence, even a greater subsidence than is implied by barrier reefs. I have already stated that one cause limiting distribution of reefs is bold shores, a wall of rock of even a hundred and fifty feet producing a complete exclusion. If Tahiti were to subside two thousand feet, it would be an island of precipitous shores all around, like the Marquesas, instead of one with broad shore planes. Such bold shores are evidence of subsidence; and as only very small reefs, if any, could find footing about such an island, the narrow reef would be another consequence of the subsidence, and no evidence of a stationary condition. Again, the gradual sinking of an atoll, like the Gambier group, or of a Tahiti with its barrier reefs, at a rate a little fast for the growing corals, would necessarily contract the reef region, reduce the barrier reefs of a Tahiti to narrow fringing reefs; and make an atoll, however large, a small atoll with the reef-border narrow and the lagoon perhaps obliterated. An atoll thus reduced to a sand bank is an example of the effects of subsidence, and affords no evidence of elevation or of a long stationary condition of the region; and the same may be true of a region of narrow fringing reefs. I landed on two of the small coral islands of the equatorial Pacific which are in just the condition here described; and my book contains descriptions of others from a good observer, J. D. Hague, who resided on them several months "for the purpose of studying the character and formation of the deposits" of guano. I found the depression of the old lagoon, in one case partly, in the other wholly, dry; and I found also that the living reefs around were narrow. Mr. Darwin inclines to regard islands of this kind as either evidence of no movement, or, of elevation. On the contrary, since the coral-islands of the south Pacific diminish in size toward the region of these small islands, and since the region just beyond, to the north and northeast, is free from islands, and since all the features are such as would come to them from a continuation of the coral island subsidence to its nearly fatal end,

I believe still that I was right in considering the ocean bottom in this part to have undergone a general subsidence greater than that to the south, southwest and west, where the atolls and barrier reefs are large.

Again, if submarine eruptions are destructive, narrow reefs may exist about volcanic islands that are undergoing a subsidence. Making a reef is slow work; and, judging from the eruptions of the present century about Hawaii, reefs would have had a poor chance in the past to form, except along the coasts that were out of reach of the submarine action.

With so many causes for the existence of narrow or fringing reefs, or of small patches of corals, it is assuredly unsafe to make them, without other corroborating testimony, evidence of a stationary condition of a region, or of an elevating movement rather than a subsiding.

(IV.) The next point in the Preface is stated as follows:

"Profesor Dana further believes that many of the lagoon islands in the Paumotu or Low Archipelago and elsewhere have recently been elevated to a height of a few feet [elsewhere stated, two or three feet] although formed during a period of subsidence; but I shall endeavor to show, in the sixth chapter of the present edition, that lagoon-islands which have long remained at a stationary level often present the false appearance of having been slightly elevated." And, in the body of the work, where the subject is taken up (p. 168), Mr. Darwin remarks that my belief in these small local elevations is grounded chiefly on the shells of Tridacnas embedded, in their living positions, in the coral rock at heights where they could not now survive.

The catalogue of such elevations which I give—after a dozen pages devoted to a discussion of the evidence respecting each—is as follows:

Paumotu Archipelago,	Honden,	2 or 3
" "	Clermont Tonnerre,	2 or 3
" "	Nairsa or Dean's,	6
" "	Elizabeth,	80
" "	Metia or Aurora,	250
" "	Ducie's,	1 or 2?
Tahitian Group,	Tahiti,	0?
" "	Bolabola,	?
Hervey and Rurutu Groups,	Atiu,	12?
" " " "	Mauke,	somewhat elevated
" " " "	Mitiaro,	" "
" " " "	Mangaia,	300
" " " "	Rurutu,	150
" " " "	Remaining Islands,	0?
Tongan Group,	Eua,	300?
" "	Tongatabu,	50 to 60
" "	Namuka and the Hapaii,	25
" "	Vavau,	100
Savage Island,		100
Samoan or Navigator Islands,		0
North of Samoa,	Swain's,	2 or 3
" " "	Fakaafo, or Bowditch,	3
" " "	Oatafu, or Duke of York's,	2 or 3

Scattered Equatorial Islands,	Washington,	2 or 3?
" " "	Christmas,	?
" " "	Jarvis's,	8 or 10
" " "	Malden's,	25 or 30
" " "	Starbuck's,	?
" " "	Penrhyn's,	35
" " "	Flint's and Staver's,	?
" " "	Baker's,	5 or 6
" " "	Howland's,	?
" " "	Phœnix and McKean's,	0
" " "	Enderbury's,	2 or 3?
" " "	Newmarket,	6 or 8?
" " "	Gardner's, Hull's, Sydney, Birnie's,	0?
Feejee Islands,	Viti Levu and Vanua Levu, Ovalau,	5 or 6?
	Eastern Islands,	0?
North of Feejees,	Horne, Wallis, Ellice, Depeyster,	0?
Sandwich Islands,	Kauai,	1 or 2
" "	Oahu,	25 or 30
" "	Molokai,	300
" "	Maui,	12
Gilbert Islands,	Taputeuea,	2 or 3
" "	Nonouti, Kuria, Maiana and Tarawa,	3 or more.
" "	Apamama,	5
" "	Apaiang or Charlotte,	6 or 7
" "	Marakei,	3 or more.
" "	Makin,	?
Carolines,	McAskill's,	60
Ladrones,	Guam,	600
"	Rota,	600
Feis,		90
Pelews,		0?
New Hebrides, New Caledonia, Salomon Islands,		none ascertained.

Of the cases of elevation here included, in *only two* are shells of Tridacnas alluded to; these are Honden Island and Clermont Tonnerre, in the Paumotus. It is not necessary to go over the evidence for the several cases, as it is stated at length in my work.

Mr. Darwin, while speaking on the subject of local elevations, on p. 176, and discussing the facts as regards the Samoan (Navigator) Islands, adds that "in another place he [Mr. Dana] says (p. 326) that some of the [Samoan] islands have probably subsided." From the remark the reader would infer that this Samoan subsidence was a local subsidence, like the elevations under consideration. But in fact my statement is in a chapter on the general coral-island subsidence, and, on the page there referred to (p. 326), I cite Mr. Darwin's conclusions as to the Gambier Island subsidence, and put with it my own from the width of the reefs of Upolu and other reef-bordered islands. At the same place I allude to the greater subsidence of Tutuila—the island next to the west, as proved by its bold shores and small reefs.

In conclusion, if I differ widely, for the reasons above stated, from Mr. Darwin, as to the limits of the areas of subsidence and elevation in the Pacific, and believe that the new edition of his work shows little appreciation of some of the most important causes that have limited the distribution of coral reefs, I have, as

I say in my work, the fullest satisfaction in his theory for the origin of atoll and barrier forms of reefs, and in the array of facts of his own observation which illustrate the growth of coral formations.