

ART. XV.—*The Tertiary elevated Limestone Reefs of Fiji*; by ALEXANDER AGASSIZ.

DR. WILLIAM H. DALL has been kind enough to examine the fossil mollusks which I collected from the elevated limestone reefs in Fiji. He confirms the impression I had formed of their late Tertiary age.

Dr. Dall writes: "The fossils comprise Turbo, Cassis, Lithophaga, Macha, Tellina, Meretrix, Dosinia, Chama, Pholas and fragments of Pecten. None of the genera are extinct. The rock, however, looks decidedly too old for Pleistocene. I should say the fossils were younger than Eocene and might be either Miocene or Pliocene."

The boring which I started at Wailangilala Island in the atoll of the same name, was only carried to a depth of 85 feet. For 40 feet the tool passed through coral sand similar to that forming the shores of the island; from that depth down to 85 feet, the core consisted of a limestone similar in all respects to the limestone composing the elevated reefs we had observed at Ngele Levu, at Vanua Mbalavu, at Mango, at Yangasá, at Oncata, at Ongea, at Kambara, at Vatu Leile and at different points along the eastern, southern and western shores of Viti Levu. As at some points the elevated limestones attain a height of over 1000 feet (Vatu Vara Island, 1030 feet), nothing could be gained by continuing the boring at Wailangilala to obtain material which could be collected so readily in other localities; the boring was therefore abandoned.

The volcanic rocks underlying the elevated limestone reefs were observed at Vanua Mbalavu, at Mango, at Kambara and at several points along the southern and western coast of Viti Levu. To have continued to bore until we should strike the underlying rocks would have been equivalent to boring in localities where the base of the limestones had been but little elevated when it could be readily examined in the localities I have mentioned.

A renewed examination of the elevated reefs of the Paumotu, of the Friendly Islands, of the Gilbert, Ellice and other groups of atolls in the Pacific, will be needed to determine their age and correlation to the Fiji elevated limestones.

At any rate it is evident that the Tertiary coralliferous limestones of Fiji have not played any part in the formation of the atolls or islands encircled by recent coral reefs, beyond forming the substratum upon which the recent corals have grown and established themselves as a comparatively thin crust.

The underlying limestones have performed exactly the same part as the volcanic substratum in other islands of Fiji, such

as Totoya, Kimbombo, Wakaya, Makongai, Moala, Nairai, Ngau and others. In both cases the platform upon the top of which the corals grow has been prepared by extensive submarine erosion dating from the time when the limestones were elevated by the volcanic rocks which crop out everywhere in Fiji.

Professor David, of the University of Sydney, has been kind enough to assist me in obtaining the services of one of his students, Mr. E. C. Andrews, to collect fossils from the elevated reefs of Fiji. Mr. Andrews will spend a part of the summer in Fiji collecting material and exploring in detail some of the faces and slopes of the elevated reefs of the Archipelago, and I hope to obtain ample material to determine the age of these elevated limestones.

In the earlier discussions of the thickness of recent coral reefs by Darwin and Dana, no attention was paid to the possibility of the substratum of recent reefs consisting of Tertiary limestones. Elevated limestone containing corals of Tertiary age were considered as of recent origin and as pointing to a great thickness of modern reefs. It has been shown in Florida that the modern reef is not more than about 50 feet thick, and according to the borings from the artesian well at Key West is succeeded by Tertiary limestones, in which corals occur at intervals to a depth of 2000 feet.

It has been stated by Dana and others that the borings from the artesian wells at Honolulu to the rear of the shore line of the fringing reef of Oahu indicate a great thickness of modern reef corals. These statements are based upon the examination of samples of finely ground particles of limestone accompanied by an occasional fragment of coral, the age of which has not been determined. The statements are further supported by the evidence of Mr. J. A. McCandless, the engineer in charge of the boring, who asserted to Mr. Dana and myself that in boring all his wells the tool passed through a great thickness of corals, at various levels. During my recent visit at Honolulu I was fortunate to be on the spot when Mr. McCandless was boring a 10" well about 2500 feet from the shore line and perhaps 7 feet above high water mark. Down to a depth of 80 feet nothing but recent reef coral rock was encountered, but from that point to a depth of over 300 feet the limestone passed through was of a very different character. It contained but few corals, being composed almost entirely of the shells of mollusks, mainly bivalves. The rock was white, chalky and resembled in every way the rocks of the Vicksburg age of Florida and of Yucatan; but their age has not yet been accurately determined. Enough, however, is clear to show that the limestones which form the substratum upon which rests the recent fring-

ing reef of Honolulu do not belong to the present period. Mr. McCandless assured me that limestones like those I had the opportunity of examining while the boring was going on, are identical with those to which he called Mr. Dana's and my attention in 1888, and that until I pointed out to him that the white limestone was almost wholly made up of Mollusca he had only paid attention to the occurrence of occasional corals and supposed the lower limestone to form the continuation of the recent modern reef. But as I have stated, this lower limestone differs from reef rock both lithologically and in its being made up of fossil mollusks.

It is very clear that when boring in a coral reef district in which it is difficult or impossible from other data to determine what geological changes may have taken place or the probable age of any limestone we may pass through in boring, it may be very easy to draw wrong conclusions both as to the age of the limestones and regarding the position of the line of demarcation between the modern coral reef and the underlying older limestone substratum.

If my conclusion that such atolls in the Fiji as Wailangilala, Ngele Levu and many others to which I shall refer in my final report, are formed upon platforms of marine erosion of elevated Tertiary limestones is correct, and if further in similar atolls in the Paumotus, the Gilbert, Ellice and other groups, the substratum underlying the modern coral reef is likewise composed of Tertiary limestones, it will become apparent that such boring as that carried on at Funafuti will not help us in any way to solve the problem of the formation of atolls by modern coral reefs. Such a boring, even should it reach the underlying volcanic substratum, will only give us the thickness of the Tertiary limestone beds forming the substratum upon which the modern coral reef has grown, a thickness which in the Ellice group can only be ascertained by boring, while in Fiji it can be ascertained approximately from the height of the islands composed of elevated Tertiary limestones.

Under what conditions these Tertiary coralliferous limestones of great thickness have been deposited is a distinct question from that of the formation of atolls through subsidence by the upward growth of corals during the present geological period. Neither the borings through a coral reef growing upon a substratum of Tertiary limestone, nor the examination of the outer edge of a coral reef formed upon a substratum of volcanic rocks, has given us (in Fiji) any evidence of the great thickness of a modern coral reef. On the contrary, all the evidence I have gathered in Fiji tends to prove that a coral reef forms only a comparatively thin crust upon the platform of submarine erosion (whatever be its geological structure) upon which it may have found a footing.