*ALBATROSS EXPEDITION TO THE EASTERN PACIFIC.**

III.

We left the Galapagos (Wreck Bay) for Manga Reva on the tenth of January. On the northern part of this line we did but little work beyond sounding, as we were likely to duplicate our former work to the eastward. The fourth day out, in latitude 5° south, we began a series of trawl hauls, surface hauls and intermediate towings to 300 fathoms. In the northern part of the line to Manga Reva the hauls were remarkably rich as long as we remained within the influence of the western extension of the Humboldt Current, and as long as there poured from the surface masses of the radiolarians, diatoms and Globigerinæ living in the upper waters. Some of the hauls were remarkable for the number of deep-sea holothurians and siliceous sponges. Among the former I may mention a huge *Psychropotes,* 55 cm. long.

As we passed south and gradually drew out of the influence of the western current we entered the same barren region we passed through to the eastward when going to and from Easter Island. By the time we reached latitude 15° south the hauls became quite poor, and this barren bottom district extended to within a short distance of Manga Reva; and corresponding to it we found a most meager pelagic fauna, both at the surface and down to 300 fathoms—so poor that it could afford but little food to the few species, if any, living on the bottom in that region.

We arrived at Manga Reva on the twenty-seventh of January and found our collier awaiting our arrival.

While at anchor in Port Rikitea we examined Manga Reva, the principal island of the Gambier group, from its central ridge on the pass leading from Rikitea to Kirimiro on the west side of Manga Reva, as well as from the pass leading to Taku. On both these passes we obtained excellent views of the barrier reef to the west, north and east of the Gambier Islands, and we could trace in the panorama before us the western reef extending in a northeasterly direction parallel to the general trend of Manga Reva Island for a distance of about 5½ miles.

From the northern horn to nearly opposite Kirimiro Bay the barrier reef has only three small islets. It is narrow, of uniform width, about one third of a mile, plainly defined, submerged in places, and passing north bounds a large northern bight dotted with numerous interior coral patches from a quarter of a mile to a mile in diameter or length, with from 7 to 11 fathoms. The southern part of the western barrier lagoon off Manga Reva is irregularly dotted with many small patches of reef, with an occasional deep hole of from 15 to 20 fathoms near Manga Reva Island. From the islet to the west of Kirimiro there are but few coral patches, indicating a reef which dips gradually in a distance of a mile to a deep channel of from 4 to 6 fathoms, which separates the northern and western reef from the great reef flat lying to the southwest of Tara Vai. This flat has a width of nearly 2 miles, is about 4½ miles long, and is marked at its southwest extremity by a series of low islets arranged in a somewhat circular line, formed by three deep bays and spurs from the outer line of islets, as so frequently occurs on wide reef flats in atolls of the Pacific.

This part of the reef is called Tokorua. It shelves very gradually from 3½ to 4 fathoms on the west face to 7, and connects with the plateau upon which stands Tara Vai and Aga-kanitai. From Tokorua

* Extract from letter No. 3, from Alexander Agassiz to Hon. George M. Bowers, U. S. Commissioner of Fisheries, on the cruise of the Fisheries Steamer *Albatross,* in the Eastern Pacific, dated Acapulco, Mexico, February 24, 1905.

the reef extends in an indefinite narrow ridge 8 miles long, with from 3 to 8 fathoms, in a southeasterly direction. The western edge is steep to, and the eastern face passes gradually into the lagoon, which at that point has a general depth of 8 to 20 fathoms. The deepest part of this region is at the foot of Mt. Mokoto between it and Tara Vai, though Tara Vai is united with Manga Reva Island by a plateau varying in depth from $3\frac{1}{2}$ to $4\frac{1}{2}$ fathoms.

At the southeastern point of the reef it passes into a wide plateau with from 9 to 10 to 15 fathoms. This plateau is about 9 miles wide southwest of Tekava. That part of the atoll has not been well surveyed, so that the position of the reef flat has not been ascertained further west on that part of the east face; but the southeast passage indicates $5\frac{1}{2}$, 6 and $6\frac{1}{2}$ fathoms, where it probably marks the southwestern extension of the eastern barrier reef, separating the lagoon from the southern plateau to the south of the encircling reef.

The western face of Manga Reva and of Tara Vai are indented by deep bays, which are formed by spurs running from the central ridge of these islands, the remnants probably of small craters which flanked the large crater, of which Manga Reva forms the western rim and Au Kena is the remnant of the southeastern edge, the former extension of this rim being indicated by the spits uniting the base of Mt. Duff with Au Kena; and by the projection of Au Kena towards the outer barrier reef, and of the numerous patches of coral reef off the northeast point of Manga Reva towards the outer line of motus until they almost unite with the barrier reef.

The whole of the western bays of Manga Reva Island is filled with fringing reefs which leave but here and there a deeper pass to the shore. The south face at the foot of the bluff of Mt. Mokoto and Mt. Duff is edged by a flourishing fringing reef, which extends nearly half a mile on the plateau at their base. The port of Rikitea is a reef harbor formed within the large fringing reef which occupies the whole of the southern bay of Manga Reva Island. The east face of Tara Vai and part of the east and of the west face of Aga-kanitai are also fringed with reefs.

The islets and the islands of Aka Maru, Makiro and Makapu are within a fringing reef flat which runs around the west face of Aka Maru; Au Kena is also fringed by an extensive reef which runs out in a spit of more than half a mile in a northeasterly direction almost to the outer line of motus, which are nearly united with it by these irregular patches. To the west of Au Kena a huge spit of 2 miles in length extends towards the base of Mt. Duff and almost unites with the fringing reef off the Cemetery, leaving a narrow but deep pass for the entrance of ships into the inner harbor of Rikitea. There is only 1 to $2\frac{3}{4}$ fathoms of water on these two spits.

The depth of the basin within this area with from 25 to 31 fathoms would be naturally explained as being part of an ancient crater, as in Totoya in Fiji; its northeastern rim is also, perhaps, further indicated by the comparatively shallow flat of the lagoon to the west of the barrier reef, with from 5 to 11 fathoms of water.

The principal islands of the group are in the central part of the lagoon. The four larger islands are Manga Reva, Tara Vai, Au Kena and Aka Maru. Tara Vai is flanked by Aga-kanitai and another islet to the west called Topunui; Aka Maru is flanked by Mekiro to the north and by Maka-pu to the south. The southeast face of Aka Maru is an extinct crater, of which Maka-pu forms the south rim. The main ridge of Tara Vai is the edge of parts of three craters now opening to the west. The four small volcanic islands in the southern

part of the lagoon are isolated fragments, steep, greatly weathered and disintegrated. No soundings exist to show their relation to the other islands of the group.

The soundings thus far made indicate in the southern part of the lagoon a depth of about 23 fathoms, with an occasional hole of from 38 to 40, and a gradual slope towards the outer sunken reef. To the south of the old crater of Manga Reva the general depth of the bank varies from 6 to 11 fathoms, with a deeper channel varying from 20 to 40 from southwest of Au Kena towards Tara Vai. The lagoon seems to form a western basin where the depth varies from 10 to 20 fathoms. To the west of Au Kena and Aka Maru, lying between them to the line of the outer barrier reef islets, a similar but shallower and flat basin exists, off the northern end of Manga Reva, between it and the northern horn of the barrier reef, with from 7 to 11 fathoms. Its rim is formed by a ring of reef patches of varying size.

On two occasions we visited the outer barrier reef and examined the outer line of islets of the eastern face of the Gambier Islands. The position of the islets as marked on the chart is not that of to-day, and the position of the reef flats is not accurate. The position of Tekava and Tauna appears to be correct. Opposite Au Kena and in its extension, the east face of the barrier reefs projects sharply to the east, forming an angular horn with one island south of the horn and the other north, running at sharp angles with it, so as to form a triangle which makes a deep bight opening westward to such an extent that when off the northern side of the horn we could see Tekava far to the westward of it. The second island is followed by a third and then by an island (Taraururoa) nearly 2 miles long; these are separated by small gaps. Then comes a larger island (Amou) followed by three small islands separated by deep gaps.

At Vaiatekeue (not the Vaiatekeua on the chart) the reef flat becomes quite narrow; it is hardly more than 100 yards wide; the islets perhaps 50. The northern islets are small and separated by long stretches of low shingle and carry but little vegetation and very few cocoanut trees. There are but two short sand beaches all the way from the northeastern to the eastern horn of the eastern face of the encircling reef of Manga Reva. A regular dam of shingle from 10 to 14 feet high, on the top of which the usual coral reef vegetation flourishes, extends along the inner face of the reef flat, which varies from 50 to 150 yards in width, and is flanked at the base by low buttresses of modern elevated coral reef rock and of breccia, in places all more or less weather beaten and honeycombed.

The islets and their formation and their junction or division into larger or smaller islets and the gaps which separate them; the mode of formation of the buttresses, of the planed-off, hard, nearly level reef flat, of the coralline mounds of the outer edge—all these differ in no way from what has been described in other barrier reef islands and atolls of the Pacific.

The beaches of the lagoon are steep, and corals do not seem to thrive in those parts of the lagoon to which the sea does not have access or at some distance from shore. This is well shown by the vigorous growth of corals in the fringing reef to the south of Mt. Duff on the outer edges of the reef patches of Port Rikitea, and on the spits which connect Au Kena with Manga Reva, in contrast with those along the west face of the lagoon flats to the west of the eastern barrier reef.

There is a northeast horn of the eastern barrier reef in the extension of Manga Reva Island, forming the northern cul-

mination of the central bight of the eastern face of the barrier reef. From that point the reef flat runs westerly to form the northern horn about 3 miles north of Manga Reva Island. The position of the outer reef can not be correct on the chart (H. O. No. 2024). On leaving Manga Reva we made three soundings close off the reef flat line of breakers—one off Tekava, at the most one third of a mile from the reef, in 225 fathoms. Our position, plotted by tangents to the volcanic islands or by their summits, indicated in this case, on the chart, a distance of 1½ miles. A second sounding of 245 fathoms off the eastern horn at less than one half mile indicated on chart No. 2024 a distance of 2 miles from the horn; and a sounding of 241 fathoms one fourth of a mile off the point which we had visited (Vaiatekeue) indicated a distance of three fourths of a mile on the chart.

The slope of the Gambier Archipelago to the east is steep. On coming in sight of Manga Reva we sounded in 2,070 fathoms at a distance of 11 miles from Mt. Duff, that is, 6 miles from the outer edge of the reef bearing southwest; and on coming out we sounded again half-way to that point at a distance of 3¼ miles from the breakers in 1,394 fathoms.

One can not fail to be struck with the similarity of the Manga Reva Archipelago with the great atoll of Truk. If I remember rightly, Darwin also called attention to this from a study of the charts. Yet, owing to the great size of Truk, no less than 125 miles in circumference, and the great distance of the barrier reef from the encircled volcanic islands, the effect as one steams into Manga Reva is totally different from that produced by Truk. In the latter some of the islands, though large, and of the same height as those of Manga Reva, are much more scattered, and seem of comparatively small importance in the midst of the huge lagoon which surrounds them. The barrier reef islets of Truk are from 11 to 15 miles distant from the encircled volcanic islands. In Manga Reva, which is only 45 miles in circumference, after passing the small islands in the southern and open part of the lagoon when once off Maka-pu, we can fairly well take in the atoll as a whole. The western island (Tara Vai) is only 5 miles off; Manga Reva and Au Kena are about 3, as are also the islets of the east face of the barrier reef; these distances, as you approach the entrance to Rikitea, are constantly growing less, so that when in the gap between Manga Reva Island and Au Kena, at the foot of Mt. Duff, none of the larger islands is more than 3 miles off; and the islets of the eastern face of the barrier reef are seen to the northeast about 4 miles off. When on the summit of the central ridge of Manga Reva one can, in a radius of a little more than 4 miles, take in the whole panorama of Manga Reva, and get an impression of the relations of its different parts far better than can be conveyed by the chart, for the whole of the visible part of the archipelago is included in a line drawn east and west, south of Maka-pu; south of that line the position of the southwestern reef can be traced only by the discoloration of the waters.

Manga Reva is an intermediate stage of erosion and denudation, between a lagoon archipelago such as Truk and a barrier reef island like Vanikoro, and other islands in the Society groups such as Bora Bora,* Huaheine, Raiatea, Eimeo, in which the surrounding platform has comparatively little width and the barrier reef is close to the principal island and often becomes part of its fringing reef. Manga Reva is open to the south and to the west, Vanikoro to the east, while the volcanic islands of Truk

* See A. Agassiz, 'The Coral Reefs of the Tropical Pacific,' plates 210 and 231.

are completely surrounded by the outer encircling barrier reef, as are the Society Islands just mentioned, which have several wide passages into the lagoon through the wide barrier reef.

One is tempted to reconstruct the Gambier archipelago of former times, and to imagine it with a great central volcano, of which Manga Reva and Au Kena are parts of the rim which once were connected from the southeast point of Manga Reva to Au Kena, and thence along the line of the outer islets to the northeast end of the former island with a deep crater of more than 34 fathoms. On the west face it was flanked by smaller craters extending to the western islets of the barrier reef, of which the bays of Taku, Kirimiro and Rumaru, and the bays of the west side of Tara Vai are the eastern ridges. There were probably also other secondary volcanoes, of which Aka Maru and the islets of the south part of the lagoon are the remnants, the latter all being situated on the gentle slope of the southern part of the Manga Reva plateau; this may have been the southern slope of the principal volcano of the group, on the face of which have grown up the outer lines of the barrier reef and its islets.

The existence of a great central volcano would readily explain the great depth of the lagoon in its different regions, as well as the great depth off the outer face of Manga Reva, depths showing slopes which are no steeper nor more striking than the height and slopes of the southern part of Manga Reva or Tara Vai, of Aka Maru and of Maka-pu, supposing them to be extended into the sea.

Mt. Mokoto and Mt. Duff drop precipitously for more than one third their height and in less than a quarter of a mile fall from over 1,300 feet to the level of the sea. Similar slopes are found along the volcanoes of Easter Island where there are no coral reefs. The edge of the crater of Rana Kao drops perpendicularly a height of nearly 1,000 feet in less than one eighth of a mile horizontal distance; and the eastern face of the crater of Rana Roraka rises vertically about 800 feet above the plain of Tangariki.

It is interesting to note how poor is the flora of the Manga Reva archipelago as compared with that of the more western volcanic islands like the Marquesas and the Society Islands and some of the western elevated Paumotus. In the Gambier Archipelago the forests are reduced to a few patches extending along the small valleys of the slopes of the volcanic spurs. I am informed that even in the thirties of the last century, when the missionaries first landed at Manga Reva, the forest trees, while more numerous, yet never attained the luxuriance of growth that they attain in the Society and Marquesas Islands. At the present day, with the exception of the forest patches just mentioned and a few trees which have been introduced for cultivation, the islands of the group are in great part thickly covered with a species of cane closely resembling that of our southern states. The fauna of Manga Reva is also extremely poor. There are no mammals, and with the exception of a 'sandpiper' no indigenous birds. Sea birds are few in number, and in our trip in the eastern Pacific we rarely had more than three or four birds accompanying us; often only one, and frequently none was visible for days. There are a few lizards on the islands, apparently of the same species as those in the Society Islands.

We left Port Rikitea for Acapulco on the fourth of February to anchor off Aka Maru; on the fifth we left our anchorage, sounded off the east face of Manga Reva, and took photographs.

On our way north from Manga Reva to Acapulco we did not begin to trawl or tow until warned by the surface nets that the

surface was becoming richer in animal and vegetable life and also by the surface temperatures indicating that we had reached the southern edge of the cold western equatorial current. A little north of 10° south latitude we made our first haul and deep tow, and found a very rich fauna down to the 300-fathom line, recalling the pelagic fauna of the eastern lines and fully as rich. On trawling we found, as we expected, a very rich bottom fauna.

Among the animals brought up in the trawl there were some superb *Hyalonema,* siliceous sponges, *Benthodytes* and other deep-sea holothurians, fine specimens of *Freyella,* and some large ophiurans. This haul is interesting as showing that in the track of a great current, with abundance of food, we may find at a very considerable depth (2,422 fathoms) an abundant fauna at very great distances from continental lands. We were, at this station, about 2,140 miles from Acapulco, 1,200 miles from Manga Reva, 1,700 miles from the Galapagos and about 900 miles from the Marquesas.

Another haul made under the equator near the northern edge of the cold current in 2,320 fathoms gave us the same results. The pelagic fauna was very abundant, the surface teemed with radiolarians, diatoms and Globigerinæ, and swarmed with invertebrates. The trawl contained a superb collection of bottom species of holothurians, *Brisinga, Hyalonema, Neusina,* and on this occasion we brought up the only stalked crinoid collected during this expedition—parts of the stem of two specimens of *Rhizocrinus,* of which, unfortunately, the arms were wanting.

Our progress, which was excellent during the first days of our journey after leaving Manga Reva, has for the past six days been greatly impeded by head winds in the region where we ought to have been in the full swing of the southeasterly trades. This led us, with great reluctance, to abandon all idea of further work in the equatorial belt of currents; to give up our proposed visit to Clipperton, and on account of our limited coal supply, to make for Acapulco, merely sounding every morning. This was a great disappointment to me, as we had every reason to expect to be able to spend some time in the region of the equatorial current belts and settle more conclusively than we have been able to do the question of their influence upon the richness of the fauna living in their track far from continental shores or insular areas.

The presence of diatoms in all parts of the Humboldt Current, which we crossed from south of Callao to the equator at the Galapagos and west towards Clipperton, shows how far the track of a great oceanic current can be traced, not only by its temperature but also by the pelagic life within or near it. When once in the warm westerly equatorial current the diatoms disappear and the bottom samples show only surface radiolarians and Globigerinæ.

We took a number of serial temperatures in the line Galapagos-Manga Reva, passing from the colder water of the Humboldt Current to the warmer waters south toward Manga Reva. The temperatures at 200 fathoms became nearly identical. North the great change in temperature took place between 25 and 200 fathoms, where there was a difference of 24°. South the warm water extended 100 fathoms, a great change occurring between 100 and 200 fathoms, a drop of 16°. The serial temperatures taken at the southern and northern edges of the cold current on the line Manga Reva-Acapulco agreed well with those taken in the same current to the east.

The samples of the bottom obtained by the soundings taken by the expedition or gathered in the mud-bag and in the trawl

indicate that an immense area of the bottom of the eastern Pacific is covered with manganese nodules, and that they play an important part in the character of the bottom, not only in the area covered by this expedition; the area of manganese nodules probably extends to the northwest of our lines to join the stations where manganese nodules were found by the *Albatross* in 1899 in the Moser Basin, on the line San Francisco-Marquesas. This area may also extend south of our lines Callao-Easter Island, and join the line west of Valparaiso, where the *Challenger* obtained manganese nodules at many stations. I do not mean to imply that the manganese nodules are present to the exclusion of radiolarians and of Globigerinæ. It is probable that the layer of nodules is partly covered by them, and by the thick, sticky, dark chocolate-colored mud which is found wherever manganese nodules occur.

During this expedition we sounded every day while at sea and developed very fairly that part of the eastern Pacific which lies to the south and west of the line from Cape San Francisco to the Galapagos and west of a line from Galapagos to Acapulco, limiting an area occupied by the *Albatross* in 1891. The area developed by us is included by a line 3,200 miles in length from Acapulco to Manga Reva and the area north of a line from Manga Reva to Easter Island and from Easter Island to Callao. We developed on our line Galapagos to Manga Reva the western extension of the Albatross Plateau, and found it of a depth varying from 1,900 to somewhat less than 2,300 fathoms in a distance of nearly 3,000 miles; but about half-way from the Galapagos to Manga Reva we came upon a ridge of about 200 miles in length with a depth of 1,700 to 1,055 fathoms, dropping rapidly to the south to over 1,900 fathoms. I propose to call this elevation Garrett Ridge.

Our line from Manga Reva to Acapulco continued to show the western extension of the almost level bottom of the eastern Pacific. In a distance of 3,200 miles the depth varied only about 400 fathoms. This great area was practically a *mare incognitum*. Three soundings in latitude 20° south towards the Paumotus and five soundings in a northwesterly trend from Callao to Grey Deep are all the depths that were known previously of this great expanse of water. This existence of the great plateau dividing Barber Basin along the South American coast from Grey and Moser Basins to the west is most interesting. It recalls the division of the southern Atlantic into an eastern and western basin by a central connecting ridge. The Albatross Plateau joins the western extension of the Galapagos Plateau as developed by the *Albatross* in 1891.

The existence of a sounding of 2,554 fathoms near the equator in longitude 110° west would seem to indicate a small basin included in this plateau disconnected from Grey Deep and Moser Basin by its extension to the west. How far west towards these basins that extension reaches no soundings indicate as yet. It is interesting to note that along the Mexican coast there are a number of deep basins lying disconnected close to the shore just as we found a number of disconnected deeps close along the South American coast extending from off Callao to off Caldera, Chili, opposite high volcanoes or elevated chains of mountains. These basins and a great part of the steep Mexican continental shelf are deeper than the Albatross Plateau to the south and form a deep channel separating in places the plateau from the steep continental slope. The steepness of the continental shelf is well seen, especially off Acapulco and Manzanilla. One of the small basins along the Mexican coast, with 2,661 fathoms, lies off Sebastian Viscaino Bay; another, with more than 2,900 fath-

oms, is to the west of Manzanilla Bay; a third, to the southeast of Acapulco, has about the same depth, and a fourth, with 2,500 fathoms, is off San Jose, Guatemala. Our last sounding off Acapulco about 29 miles south of the lighthouse, in 2,494 fathoms, showed the western extension of one of these deep holes to the east of Acapulco. These basins off the west coast, close to the shore at the foot of a steep continental slope, are in great contrast to the wide continental shelves which characterize the east coast of Central America and the east coast of the United States.

The collections made during the present expedition will give ample material for extensive monographs on the holothurians, the siliceous sponges, the cephalopods, the jelly-fishes, the pelagic crustaceans, worms and fishes of the eastern Pacific, as well as on the bottom deposits and on the radiolarians and dinoflagellates, diatoms, and other protozoans collected by the tow nets. Small collections of plants were made at Easter Island and Manga Reva which may throw some light on the origin and distribution of the flora of the eastern Pacific.

SCIENTIFIC BOOKS.

Radioactivity. By E. RUTHERFORD, D.Sc., F.R.S., R.R.S.C., MacDonald Professor of Physics, McGill University, Montreal; Cambridge Physical Series. Cambridge, University Press, 1904.

Within recent years books dealing specifically with radioactivity or the cathode rays have naturally not been infrequent. Beginning with the pioneering treatise of Stark ('Elektricität in Gasen,' 1902), Madam Curie's account of radioactive substances, Villard's 'rayons cathodiques,' G. C. Schmidt's 'Kathodenstrahlen' (1904), Besson and D'Arsonval's 'Le radium' (1904), Blondlot's 'rayons N' (1904) and others, have followed in quick succession. But Mr. Rutherford's book is on quite a different scale from most of these, and written in a way that betrays consummate mastery of the subject. One would have been grateful if he had given us merely a systematic account of his own researches. The book before us does much more than this, presenting a readable and most painstaking digest of the subject as a whole, or at least of that splendid part of it which owes its development chiefly to English genius.

In the introductory part separate chapters are devoted to radioactive substances, to the theory of ionization, and to methods of measurement. Then comes a long account of the nature of the radiations. The sharply articulated descriptions which follow, and the suggestions lavishly offered for the completion of most of them, are a feature of the book here and in succeeding chapters. The short account of the rate of emission of energy is absorbingly interesting, and would be startling if our expectation were not blunted by the expressions of astonishment so much in vogue in connection with this subject. In the chapter on radioactive matter, Mr. Rutherford develops the important principle that the activity of a product at any time is proportional to the number of atoms which remain unchanged at that time, a subject to which he has himself so prolifically contributed. This is supplemented by a long chapter on radioactive emanations, giving a succinct account of the work for which the Rumford medal of the Royal Society was recently awarded.

The interesting phenomenon of excited radioactivity, of which Rutherford shares the honor of discovery with the Curies, is next discussed in detail and leads naturally to the final résumé on radioactive processes, in which the full theory of atomic disintegration is developed. The consequences of this theory have been brilliantly substantiated, even in the more recent papers which Rutherford contributed to the congress at St. Louis and elsewhere. At the end of the chapter is a summary of the present state of our knowledge of the age of the sun and of the earth. The book closes with an account of the radioactivity of ordinary materials.

We have noticed but few misprints: p. 55, m for u; p. 265, t for n; p. 336, omission of dt. We should have been grateful, however, for a