uniform height throughout, and with no posterior oblique attenuation. In referring to the stratified Quaternary deposits at Ombos (= Kom Ombo), Leith Adams remarks that they measured 80 or 90 feet in height, but so far as he could ascertain yielded no organic remains. Mr. Willcocks' discovery of this new *Unio*, from probably the same spot at about 8 metres above the present high Nile, adds a further interest to this locality. The specimens were found associated with vertebrate remains (reptiles, fishes, etc.).

Horizon.—Post-Pliocene (Fluviatile Deposits).

Distribution.—Nubia: Second Cataract. Egypt: Kom Ombo (= Ombos of Leith Adams), lat. 24° 2′ 30″ N., at about 8 metres (= rather more than 26 feet) above present high Nile. Coll. Geol. Surv. Egypt (No. 647, Box No. 23*b*).

EXPLANATION OF PLATE XIX.

Alectryonia cucullata, Born, sp. Pliocene (Astian ?), Moluk Hill.

Fig. 1.—Front view of two lower valves, united laterally.
Fig. 2.—Back view of a lower valve exhibiting the plications.
Fig. 3.—Fragment of the ligamental region of another lower valve, rather longer than usual, and evidently belonging to an older form than the other specimens.
Fig. 4.—Upper valve, interior.
Fig. 5.—Upper valve, exterior, showing obsolete plications.

Planorbis Pfeifferi, Krauss. Post-Pliocene, near Farshut (× twice nat. size).

Fig. 6.—Profile of shell, showing the aperture.
Fig. 7.—Upper surface of shell, showing the depressed whorls.
Fig. 8.—Under surface of shell, showing the umbilicus and aperture.

Melania tuberculata, Müller, sp. Post-Pliocene, near Farshut.

Fig. 9.—Front view of largest specimen, showing aperture.
Fig. 10.—Back view of the same specimen.
Fig. 11.—Magnified view of sculpture.

EXPLANATION OF PLATE XX.

Unio Willcocksi, sp. nov. Post-Pliocene, Kom Ombo.

Figs. 1, 2. Interior and exterior of right valve.
Fig. 3.—Interior of a left valve.
Fig. 4.—Exterior of a left valve, showing impression of the early shell.

[Except where otherwise stated, the figures on both plates are drawn natural size.]

NOTICES OF MEMOIRS.

The Islands and Coral Reefs of Fiji. By Alexander Agassiz. (Bulletin of the Museum of Comparative Zoology, Harvard College, vol. xxxiii.) 8vo; pp. 168, with 120 plates. (Cambridge, Mass., U.S.A.; May, 1899.)

PROFESSOR ALEXANDER AGASSIZ deserves the thanks of all naturalists for this splendid contribution towards the recently much disputed subject, the origin and mode of formation of coral reefs. This is an age of critical examination, and no man, however beloved and esteemed amongst his fellow scientific men, can propound a theory which shall long remain unchallenged. That Darwin's theory remained accepted and undisputed for fifty years

speaks well for the careful and thoughtful observations on which it was based, and, like all the work of this illustrious naturalist, it commended itself to everyone by its clearness and simplicity.

Before proceeding to give an account of his expedition to Fiji Alexander Agassiz devotes a few pages to an examination of some of the literature of coral reefs.

The Literature of Coral Reefs.

"In many quarters" (writes Agassiz) "it has become a question of creed to uphold the Darwinian theory of subsidence as essential to the formation of atolls and of barrier reefs. Facts and arguments supporting other explanations are ignored or explained away in the most extraordinary manner. Regions which are cited by Darwin and Dana as typical become exceptions when shown to be no longer characteristic regions of subsidence. Typical barrier reefs become patch reefs, atolls are dubbed pseudo atolls; so that the regions where true barrier reefs or typical atolls, which owe their origin to subsidence, can be examined, are little by little becoming very restricted. In fact, if we are to judge of the regions not yet examined, and which have not been examined by Darwin and Dana, there remain as extensive regions of possible subsidence only such islands as the Marshall and Carolines, some of the atolls of the Gilbert and Ellice groups, and of the Paumotus. Yet, judging by analogy, of the adjoining districts of Fiji and Tonga, and of the descriptions given by Dana of the Paumotus, and by what we may gather from the charts in the light of our own exploration, it would not be launching a very doubtful proposition to assert that even in these island groups we shall find that the explanation we have given of the formation of atolls and of barrier reefs applies equally well to them. This still leaves the field open for observations in some of the coral regions of the Indian Ocean, and of the East Indian Archipelago. But in the districts which have been described as typical by both Darwin and Dana, recent observations have shown that other and more natural explanations than the theory of subsidence are sufficient to account for the formation of atolls and of barrier reefs.

"As is well known, Darwin's experience among coral reefs was limited to a part of Tahiti, to the west side of Mauritius, and to the Keeling Atoll. Though he passed through the Paumotus without examining any of the islands; according to the narrative of the 'Beagle,' Darwin saw in the distance Honden Island, passed by Taiaro along the shore of Kauehi and sailed between Elizabeth Island and Fakarava (Wittgenstein) to Otaheite. Captain Fitzroy also sailed through the Navigator, Friendly, and Fiji Islands without anchoring anywhere. Dana worked among the reefs at Tahiti, Samoa, and the Feejees, though he did not visit the Eastern Archipelago, limiting his observations to the larger islands, Viti and Vanua Levu and Ovalau. He 'twice visited the Hawaian Islands, landed and gathered facts from fifteen coral islands, some of them in the Paumotu Archipelago; one, Tongatabu, in the

Friendly group; two, Taputeaua and Apia, in the Gilbert group, and five others near the equator, east of the Gilbert group; Swain's Fakaofu, Oatafu, Hull and Enderbury Island, as well as the reef region of the Sooloo Sea and of the Straits of Malacca.'

"In my account of the coral reefs of the Sandwich Islands, I have given a short résumé of the results of the principal investigations on coral reefs since the days of Darwin and Dana down to 1889. What has been done since that time will be found referred to in Bonney's edition of Darwin's Coral Reefs,[1] in Kent's 'Great Barrier Reef,' in Langenbeck's sketches of recent work on the subject, as well as in the reports of the explorations I have carried on in the Bahamas and Cuba, the West Indies, Florida, and the Bermudas in the Atlantic, and of the expeditions I have made to the Galapagos, the Great Barrier Reef of Australia, and Fiji.

"An excellent account of the Samoan Reefs has been published by Dr. Krämer, supplementing the earlier short notice of Dr. Graeff on the reefs of the group; also interesting notes by Admiral Wharton, on Submarine Banks of the Pacific. A careful account of the geology of the Friendly Islands by Lister, published in 1891, seems to have escaped the attention of writers on coral reefs. A few notes on the reefs of some of the islands of the Bismarck Archipelago have been published by Dr. Dahl, but the evidence he gives does not seem to me to warrant his conclusions. The great thickness of elevated reef he found (570 m.) may (as is the case elsewhere in the Pacific) not belong to the present epoch, as he takes it for granted, and no one supposes that elevation has necessarily always taken place uniformly either in time or space over any great stretch of territory.

"The articles by Heilprin and by Ortman on what they call 'Patch Reefs,' do not seem to me to have any special bearing on the general theory of coral reefs. The existence of such 'patches' has long been known and referred to by Darwin, and by many writers on coral reefs, as reef patches. These patches occur in localities where fringing reefs for local causes would not flourish except at a little distance from shore and play a very subordinate part in the

[1] Professor Bonney ("Coral Reefs," Darwin, 1889, 3rd ed., Appendix ii, p. 290), has evidently confounded the views of Professor L. Agassiz on the extent of the formation of the southern extremity of Florida by coral reefs, dating back to 1854, with those which I have published in 1877, in 1880, in 1888, and again in 1896. Neither Dall or Heilprin has examined the Florida reefs; their studies have been devoted to other parts of the peninsula, and did not extend south of the northern limit of the Everglades. Their criticisms in both cases apply to the views of Professor L. Agassiz, as my observations were limited to the reef region, and did not encroach on the area examined by Dall or Heilprin. But I have plainly shown by the borings at Key West that the recent coral formation is of moderate thickness, not more than about fifty feet, and that it is underlaid by a substratum of Tertiary limestones, occasionally coralliferous, of a thickness of nearly two thousand feet. The area probably covered by the coral reef of Florida at the time of its greatest expansion is approximately shown on plate xvii, Bull. Mus. Comp. Zoöl., vol. xxviii (1896), No. 2. I never made the statement quoted by Bonney that the recent coral reefs extended over any part of Florida north of the Everglades. On the contrary, I said in the conclusion of my memoir on the Tortugas and Florida Reefs (Mem. Am. Acad., vol. xi, 1883, p. 116), "All this evidence tends to show that the coral reefs had little, if anything, to do with the building up of the peninsula of Florida, north of Cape Florida."

physiognomy of the coast. I am at a loss to understand the statements of Ortman regarding the reefs of Kaneohe Bay on the north shore of Oahu. The accurate observations of Hartt and of Rathbun on the moderate thickness of coral reefs off the coast of Brazil seem to have escaped Heilprin and Ortman, as well as other writers on coral reefs. Rathbun has described the reefs along the Brazilian shore, and finds them all as 'having very little height, but from the surface looking like massive structures.' Hartt and Rathbun have described the formation of extensive coral patches and the mode of building up columnar masses which may eventually reach the surface forming mushroom- or even bell-shaped structures, of which enlarging rims may meet, 'resulting in the formation of a connected reef surface supported by many upright pillars underneath from forty to fifty feet high,' the so-called 'chapeirões' of the Portuguese. These patches frequently occur near the shore along the margin of a fringing reef, but are best developed in the deeper water of the Abrolhos regions and between these and the city of Bahia, growing upon the submerged rocky ledge. The number of reef building corals in Brazil is quite small, and Nullipores seem, according to Rathbun, to play a very important part in the building up of the limestone reefs.

"Professor Bonney summarizes the position of the theory of coral reefs as now left (1889) in the following terms: 'That this theory may have been expressed in terms a little too comprehensive, that there may be a larger number of exceptional cases than was at first supposed, is quite possible. . . . . It may very possibly be found that, as remarked by Mr. Bourne, the history of coral reefs is more varied and complicated than was at first supposed, but it seems to me that, as the evidence at present stands, it is insufficient to justify a decision adverse to Mr. Darwin's theory as a general explanation.'

"Professor Bonney, in spite of his intention to present an absolutely unbiassed expression, has, in common with most geologists not familiar with coral reefs, retained the view of the correctness of Darwin's theory. It can scarcely be said that the earlier examinations of coral reefs were made with the detail which has characterized the later explorations. The original work of Darwin was limited to a narrow field, and supplemented by data derived from charts and descriptions. Its correctness depends wholly upon the existence of masses of coral reefs of great thickness, where coral reefs exist as barrier reefs or atolls, and having assumed this the rest naturally followed. For no one will deny that subsidence is one of the possible modes of formation of masses of limestone of great thickness. But subsequent observers showed most distinctly that both atolls and barrier reefs occurred in regions of elevation. These exceptions are not limited to a single area. They occur in regions of the globe widely separated. While it undoubtedly is true, as remarked by Professor Bonney, that Darwin has noticed most of the causes on which stress is laid by his critics, it should also be remembered that Darwin did not observe the phenomena subsequently examined,

but merely suggested them as possibilities, and his critics may be excused for giving their observations a relatively greater value than to his theoretical views.

"The whole argument of the great thickness of coral reefs based upon the analogy of the so-called raised reefs of Cuba, described by Professor Crosby and myself, or of the fossil reefs, is of little value, as it has been pretty conclusively shown that these elevated reefs, not only in Cuba but in the Pacific, are beds of Tertiary limestone intercalated with beds of moderate thickness in which corals are found, and the same is true of older fossil reefs. Furthermore, these huge masses of Tertiary limestone which form the substratum upon which both in Cuba and in the Pacific recent corals have found a footing, have played no part in the shaping of the barrier or encircling reefs, or atolls, which, as we have attempted to show, owe their origin in the main to mechanical causes.

"Professor Bonney states that 'Much stress is laid upon the fact that many coral islands afford evidences of a certain amount of upheaval; this amount, in most cases, is but slight, and its significance appears to me to have been exaggerated'; and he considers these indications to prove only oscillation. As far as the Fijis are concerned, the elevation extended over the whole group, and has been shown to amount to more than a thousand feet. In Australia it extended along the whole east coast of Queensland for more than a thousand miles, and was more than twenty-five hundred feet in height! He further says, 'If the coral reef be only a sort of cap concealing a hill of pre-existent rock, we may reasonably be surprised that the "ashlar rock" of coral limestone has in no case so far yielded to the action of the atmospheric agencies as to lay bare its inner support.' We can answer this point most decidedly. In Florida the substratum underlying the recent coral reefs crops out at many places, and the highest points of some of the Keys consist of it. So do some of the hummocks in the southern part of the Everglades near Key Biscayne. In the Bermudas the greater part of the land of that group consists of the æolian rocks which underlie the recent coral reef. In the Bahamas the same is the case, and along the northern coast of Cuba the Tertiary limestone forming the substratum of the recent reefs crops out in all directions, while in Australia rocks underlying the Great Barrier Reef can be traced as islands, islets, or negro-heads all along its line for more than a thousand miles. Finally, in the description of the islands of Fiji this substratum appears over and over again, either composed of volcanic rocks or of great Tertiary limestone banks. No better example can be found of the appearance of the substratum of the recent reefs than in Kaneohe Bay, Oahu, at the Sandwich Islands, where the reef is studded with islets and negro-heads consisting of volcanic rocks.

"That corals grow in lagoons is well ascertained, and nowhere is it better seen than in Fiji, where nearly all the islands enclosed by barrier reefs are edged with fringing coral reefs. But why that should prevent a lagoon from being formed I cannot see. A lagoon

is not bounded by a reef forming a closed wall rising well above the level of the sea. The greater part of the reef of many a lagoon of an atoll or barrier reef has from two to three fathoms of water upon it at high tide. The reef is also riddled on all sides with narrow channels or openings with from one to two fathoms or more at low tide, in addition to the wider and deeper passages to leeward, through which access is gained into the lagoon. But for all this the lagoon exists, while it may not have more than a few fathoms in maximum depth. This, however, does not prevent the coral heads on the inner slope of the reef from gradually becoming connected with the reef, and from encroaching little by little, but very slowly, upon the outer margin of the lagoon to a depth of seven or eight fathoms, at which the growth is checked either from the sediment accumulating on the floor, or from the strength of the currents scouring the bottom of the lagoon. The amount of dead coral which is ground up upon a reef flat is considerable. Much of it is cemented together and forms a breccia in the cavities of the coral heads, or in the open spaces between them. Still more of it is changed into sand and mud, which cover the floor of the lagoons of barrier reefs and of atolls, and finally a quantity is carried off in solution after the dead coral has become thoroughly rotten and crumbling.

"Darwin also visited the western side of Mauritius, where, he says: 'It is probable that a reef on a shelving shore, like that of Mauritius, would at first grow up not attached to the actual beach, but at some little distance from it; and the corals on the outer margin would be the most vigorous. A shallow channel would thus be formed within the reef, and this channel could be filled up only very slowly with sediment, for the breakers cannot cut on the shores of the island, and they do not often tear up and cast inside fragments from the outer edge of the reef, while every streamlet carries away its mud through breaches in the reef. . . . . A fringing reef, if elevated in a perfect condition above the level of the sea, would present the singular appearance of a broad dry moat bounded by a low wall or mound.'

"Darwin, when meeting Semper's objection that the existence of atolls or barrier reefs in a region of elevation was a fatal argument against his (Darwin's) views, is obliged to say that therein 'seems to me no improbability in their having originally subsided, then having been upraised . . . . and again having subsided.' He further says, 'The existence of atolls and of barrier reefs in close proximity is manifestly not opposed to my views.' Certainly not, but their existence in an area of elevation as claimed by Semper is. Darwin also says that, 'When the land is prolonged beneath the sea in an extremely steep slope, reefs formed there during subsidence will remain closely attached to the shore, and will be undistinguishable from fringing reefs.' This seems to me impossible. The disintegration of the inner edge of the fringing reef, the action of the sea upon this disintegrated material, the solvent action of sea water, all will tend to form a channel between the outer parts of the

reef and the shore, as is evidently the case in almost all fringing reefs, which show either an incipient channel where boats may circulate at high water, or a belt of considerable width in which the coral fringing the land has been killed by the silt brought down from the adjacent slopes, and has been decomposed, and, crumbling to sand or mud, is gradually being carried off at each high tide, forming a channel which when wide enough and deep enough becomes sufficiently prominent to change the fringing reef into a barrier reef.

"The difficulties encountered in attempting to meet the many suggestions made by Darwin regarding reefs which he did not examine are well exemplified in the account which he gives of Rose Island, one of the Samoa group.

"Bonney similarly takes Dana's account of the eastern half of the Fiji Archipelago, as if it were based upon actual observations. Dana did not visit that part of Fiji, but derived his information from the surveys of these islands made by the officers of the United States Exploring Expedition. His statements are derived from the charts."

General Sketch of the Fiji Islands and Coral Reefs.

The following is a general sketch by Professor Alexander Agassiz of the Fiji Islands and coral reefs:—

"I went to the Fijis under the impression that I was to visit a characteristic area of subsidence; for according to Dana and Darwin there is no coral reef region in which it is a simpler matter to follow the various steps of the subsidence which has taken place. Dana, in his last discussion of the coral reef question, states that it is impossible to find a better series of islands than the Fijis to illustrate the gradual changes (brought about by subsidence) which take place in transforming a volcanic island with a fringing reef to one with a barrier reef, or to one with an encircling reef ring, and finally to one in which the interior island has disappeared and has left only a more or less circular reef ring. For these reasons one of the Fiji atolls promised to be an admirable location for boring and settling the question of the thickness of the coral reef of an atoll.

"My surprise was great, therefore, to find within a mile from Suva an elevated reef about 50 feet thick, and 120 feet above the level of the sea, the base being underlaid by what is locally called 'soapstone,' a kind of volcanic mud. The western extension of this reef can be traced at points along the north side of the harbor of Suva, the islands of Lambeko, Vuo, and Dra-ni mbotu, which are respectively sixty to seventy feet in height, being parts of an elevated reef extending to low water mark, and now planed off. It was this elevated reef or its extension westward which we traced from the Singatoka River to the Nandi Waters. A short distance inland from the mouth of the Singatoka there is a bluff of about 250 feet in height, composed of coralliferous limestone. This bluff is the inner extension of the elevated patches and limestone bluffs visible on the shore of Viti Levu. I am informed by Dr. Corney

that the islands of Viwa and Asawa i lau, to the northward of the Nandi Waters, are also remnants of this elevated limestone.

"But the traces of extensive elevation are not limited to the island of Viti Levu. I found that the islands on the rim of the atoll of Ngele Levu consisted entirely of coralliferous limestone rock, elevated to a height of over sixty feet on the larger island. The northern sides of the smaller islands Taulalia and Tai ni mbeka, as well as the north shore of Ngele Levu, were on the outer edge of the rim of the lagoon, deep water running up to the shore line. We next found that at Vanua Mbalavu the northern line of islands were parts of an elevated reef, forming vertical bluffs of coralliferous limestone rock which had been raised by the central volcanic mass of the main island to a height of 510 feet at Ngillangillah, at Avea to 600 feet, at the Sovu Islands to 230 feet, and on the main island to a height of nearly 600 feet, while on the south of the main island the coralliferous limestone bluffs are very much lower, and those of Malatta and of Susui reach a height of 420 to 430 feet. Going farther west and south we find at Mango vertical bluffs of an elevated coralliferous limestone of over 600 feet underlaid by volcanic rocks at the sea level. At Tuvuthá the limestone bluffs are probably nearly 800 feet high. At Naiau they are more than 500 feet. At Lakemba they reach a height of about 250 feet on the south-west side of the island, the greater part of the rest of the island being of volcanic origin. On the island of Aiwa the elevated limestone is fully 200 feet thick. In the Oneata group the highest point of the elevated bluffs is about 160 feet. South of the volcanic island of Mothe and enclosed within the same barrier on the island of Karoni, the reef is about 120 feet thick.

"On the three islands of the Yangasá group the elevated limestone attains a thickness of 240, 300, and 390 feet, and on Ongea, the most south-easterly cluster we visited, it attains a thickness of nearly 300 feet. At Fulanga the elevated limestone attains a thickness of 360 feet, at Kambara it is about 200 feet thick, and at Wangava it is perhaps over 300 feet; these islands may be in part volcanic. Finally, at Vatu Leile, the most westerly island we examined, the elevated reef forming the island is fully 110 feet thick.

"All this plainly shows that the western and southern part of Viti Levu, as far south as Vatu Leile, and the whole length of the windward islands of the Fiji group, from Ngele Levu on the north to Ongea on the south, have been subject to an elevation of at least 800 feet; and there is abundant proof that the greater part of the thickness of the elevated coralliferous limestones has been eroded so as to reduce it in certain localities to the level of the sea, or in others to leave the bluffs and islands and islets of limestone which we have traced at so many points.

"Unfortunately there are as yet but few soundings among the islands of Fiji. There is a line extending from Nanuku Passage to the Kandavu Passage, and a number of soundings to the north of Wailangilala and towards Thikombia, which have developed the

existence of an extensive plateau with a depth of between 300 and 400 fathoms, from which rise all the islands forming the north-eastern extremity of Fiji. The soundings between Ngau and Viti Levu also indicate shallower water to the west of that island than is found either east or south of it. The deep water extends north-westerly in the passage, parallel with Kandavu. Deep water (1,200–1,700 fathoms) is found in the triangle formed by Moala, Totoya, and Matuku, showing the steep slope of Moala, from 1,200 fathoms at a distance of six miles, and of Matuku of 1,400 fathoms at a distance of five miles.

"The deep channel passing through the centre of the Koro Sea gradually deepens towards the south until it attains a maximum depth of over 1,400 fathoms east of Nairai and Ngau, becoming shallower towards Viti Levu. The water gradually deepens also in the Kandavu Passage from over 1,100 fathoms north of North Astrolabe Reef to over 1,900 fathoms south-west of Kandavu. The soundings to the north of Naitamba indicate a ridge with somewhat over 500 fathoms in depth connecting the plateaus on the two sides of Nanuku Passage. There are no soundings showing the depths between the larger clusters composing the Lau or eastern group of Fiji. It would add greatly to our knowledge of the connection of these groups to have lines of soundings connecting the different island clusters of Lau.

"All the evidence to be gathered in Fiji tends to prove that preceding the present epoch there was an extensive elevation, which lifted the great masses of coralliferous limestone resting upon the flanks of the islands to a considerable height, in some cases as high as 1,000 feet. The base of the limestone masses rests upon volcanic rocks, as can be seen at Suva, at Kambara, at Mango, at Lakemba, at Naitamba, and at Vanua Mbalavu it shows the thickness of the elevated reefs to have been over 800 feet. During this period of uplift the physiognomy of the islands of the group must have been greatly changed, and still further modified by the denudation and erosion which have taken place since the elevation of the ancient limestones. It is to the changes brought about by the elevation and the subsequent erosion and denudation that we must look for the causes which have fashioned the steep slopes of the islands and reefs, and not to the growth of the thin crust of corals which thrive upon the reef flats forming the substratum of the modern reef—a substratum which in Fiji may be of volcanic origin or composed of elevated limestone, the sea face of which is the extension of the former land mass and follows its ancient slope, being only slightly modified by the growth of the crust of recent corals found upon it.

"Similar elevated reefs (probably composed of the same Tertiary limestone as those of Fiji) have been described by Clark at the Loyalty Islands, and also by Chambeyron and Pelatan. Chambeyron gives figures of the elevated terraces of Lifou and Ouvea composed of coralliferous limestone, and there is an excellent photograph taken by Pelatan of the elevated coral reefs of Lifou, and reproduced in Bernard's 'Nouvelle Calédonie,' p. 45. While

Maré is said by Pelatan to have five terraces of elevated coralliferous limestone, and to be riddled with caverns, Clark considers the elevated coralliferous limestones of the Loyalty Islands probably to be Pleistocene.

"In the Solomon Islands Guppy has traced extensive elevated reefs, which, however, he considers as belonging to the present epoch. Elevated coralliferous limestones also exist in the New Hebrides, as well as on the southern shore of New Guinea.

"The time of this Fijian elevation we cannot at present ascertain. It is not unnatural to assume that it was coincident with the elevation of Northern Queensland, and that the area of elevation included New Guinea, the islands to the east of it as far south as New Caledonia, and as far east as the most distant of the Paumotus (Gambier Islands), and extended northward of that line to include the Gilbert, Ellice, Marshall, and Caroline Islands; and that since this epoch of elevation the islands within that area have been, like Northern Australia, subject to an extensive denudation and erosion, many of them being reduced to mere flats but a few feet above the surface of the sea, others worn away to represent to-day but a small portion of their former extent. It is upon the reef flats thus eroded, or around the islands and islets which are the remnants of a former period, that the corals of to-day have obtained a foothold. And further, by the mechanical action of the sea combined with that of the trade winds, channels have been excavated out of the substratum underlying the coral reefs to form the lagoons of the barrier reefs and atolls of Fiji.

"So that, as far as we can judge from the case of the Fiji Islands, the shape of the atolls and of the barrier reefs is due to causes which have acted during a period preceding our own. The islands of the whole group have been elevated, and since their elevation have, like the northern part of Queensland, remained nearly stationary, and exposed to a great and prolonged process of denudation and of aerial and submarine erosion, which has reduced them to their present height; the submarine platforms upon which the barrier reefs have grown being merely the flats left by the denudation and erosion of the central island, while the atolls are similar flats from the surface of which the islands have at first disappeared and the interior parts of which have next been removed by the incessant scouring of the action of the sea, the ceaseless rollers pouring a huge mass of water into the lagoon, which finds its way out of the passages leading into it or over the low outer edges of the lagoon. These atolls and islands, surrounded in part or wholly by encircling and barrier reefs, have not been built (as is claimed by Dana and Darwin) by the subsidence of the islands they enclose. They are not situated in an area of subsidence, but, on the contrary, in an area of elevation. The theory of Darwin and Dana is therefore not applicable to the Fiji Islands.

"The evidence of elevation is not limited to that furnished by the remains of the elevated coralliferous limestone just mentioned, and it is natural to assume that the elevation we have just traced was

but a part of a more general elevation, which perhaps took place in late Tertiary times, and in which the whole group was involved. It is plain that there must have been most extensive denudation and submarine erosion going on throughout the group for a very considerable time, geologically speaking. The outlines of the islands, deeply furrowed by gorges and valleys, the sharp or serrated ridges separating the valleys, the fantastic outlines of the peaks and chains of Viti Levu, Vanua Levu, and Ovalau, all attest to the great work of atmospheric agency which must have been going on for so long a period.

"The extent of the separation of the islands, islets, or isolated rocks from the points or spurs of the larger islands also bears witness to the great length of time during which submarine erosion and denudation have been at work.

"The platforms of submarine erosion constitute the characteristic features of the islands of Fiji. A glance at the sketch map of Fiji and at the detailed charts of different portions of the group cannot fail to show how extensive this action has been.

"Add to this the fact that we are in a region of a former powerful and extensive volcanic activity, the traces of which can still be seen in all directions, and which has undoubtedly played a great part in the lifting of the island masses and their subsequent shaping to their present outlines. From this evidence I am inclined to think that the corals of to-day have actually played no part in the shaping of the circular or irregular atolls scattered among the Fiji Islands; that they have had nothing to do in our time with the building up of the substructure of the barrier reefs encircling either wholly or in part some of the islands; that their modifying influence has been entirely limited in the present epoch to the formation of fringing reefs; and that the recent corals living upon the outer margin of the reefs, either of the atolls or of the barriers, form only a crust of very moderate thickness upon the underlying base. This base may be either the edge of a submarine flat, or of an eroded elevated limestone, or of a similar substructure composed of volcanic rocks, the nature of that base depending absolutely upon its character when elevated in a former period to a greater height than it now has; denudation and erosion acting of course more rapidly upon the elevated coralliferous limestones than upon those of a volcanic character. It is therefore natural to find that the larger islands, like Kandavu, Ovalau, and Taviuni, are of volcanic origin, while the islands which once occupied the area of the lagoons of Ngele Levu, Nanuku Reefs, Vanua Mbalavu, the Argo Reefs, the Oneata, Yangasá, Aiwa, Ongea, and Vatu Leile clusters, were composed of elevated coralliferous limestones. They have disappeared almost entirely, leaving only here and there a small island to attest to the former existence of a more extensive elevated limestone, once covering the whole area of what is now an atoll. Smaller volcanic islands, like Matuku, Moala, Ngau, Nairai, and Koro, also show the greater or smaller extent to which each has been eroded after its elevation, being least in Koro and Matuku, and somewhat more in Moala and

Ngau, and still more in Nairai; while in such volcanic islands with atolls as Mbengha, Wakaya, and Makongai the denudation and submarine erosion have been still greater, the islands covering but a comparatively small area of that once covered by the island originally occupying the area of the lagoon; this denudation having been carried to a still greater extent in the Kimbombo cluster, in Komo, and the islands of Duff Reef. This process of denudation and submarine erosion may have gone so far as to leave no trace in an atoll of its volcanic or of its limestone (elevated) origin, its shape to-day being entirely due to mechanical action, and having nothing to do with the growth of the corals which have found a footing upon the flats due to submarine erosion and to denudation and to the action of the atmosphere and of the sea.

"It seems to me as if the position of an island left on the western or lee edge of a lagoon depended upon the original position of its highest point. This appears in the case of Makongai and Wakaya. The crest of the former was probably near the eastern edge, while the highest point of Wakaya was perhaps nearest the western side of the original island. Similarly the highest summit and ridge of Vatu Leile, if our views are correct, was on the western face of the original land mass. The highest ridge of Rambe lies on the north-western side of the submarine plateau; the islands of Budd Reef indicate its highest land to have been on the northern part of the plateau.

"Admiral Wharton has suggested 'the cutting down of volcanic islands by the action of the sea, and that this action has a far greater share in furnishing coral foundations than has been generally admitted.' From our experience in Fiji we may safely modify this to the cutting down, not only of volcanic islands, but also of other elevated islands, and their cutting down not only by submarine erosion but also by denudation and atmospheric agencies, and thus preparing the foundations upon which recent corals have established themselves. Add to this the elevation of banks composed of volcanic rocks or of sedimentary rocks up to heights at which corals or corallines can begin to grow, and we have in addition to their increment in height from the increase due to pelagic organisms and the decay of other calcareous invertebrates living upon their surface all the elements needed for the preparation of a set of foundations from very different causes.

"I have already on other occasions called attention to the powerful scouring effect produced upon the interior of an atoll or lagoon, or the channel of a barrier reef, by the mass of water poured into it from all sides as the huge ocean swells break over the outer rim. This mass of water can find no outlet against the incessant swell; it must escape to leeward through the openings in the outer reef flats, or laterally over the low parts of their outer edges. It will be noticed that the openings are usually on the west face of the atoll, the direction in which the prevailing trades drive the water of the lagoon. The water becomes charged with particles of lime or of other material, and we soon have all the elements of a modified

gigantic pothole, from which the churned material is carried out by the currents flowing through the entrances into the lagoon. It has long been known that there is a violent rush of water out of the lagoons, the velocity attained reaching sometimes four to five knots. In Fiji I have noticed these powerful currents flowing out of the passages leading into the lagoons of Fulanga, of Ngele Levu, of Wailangilala, of Vatu Leile, of Totoya, and racing along the interior channels of the great barrier reef stretching along the south coast of Viti Levu, especially at Lauthala Bay, Suva, and the reef harbors and passages between Suva and Serua, and out of the smaller atolls like Motua lai lai, Thakau Leka leka, Thakau Momo, and others.

"The strength of the currents in the channel separating the barrier reef and the shore has been noticed by Semper and by Möbius as bearing an important part in Mauritius. There is in the *Biologisches Centralblatt*, 1889-90, Bd. ix, p. 564, a short review of the third edition of Darwin's 'Coral Reefs,' showing the principal points in the discussion of the reefs to which Bonney has called attention. But this discussion is mainly theoretical, and adds no new factors in the problem. I would refer to what Gardiner says regarding the conditions affecting the growth of coral reefs in Fiji, where he shows the effect of tidal currents in the passages of reefs and inside of reefs. Strong currents prevent the coral larvæ from fixing themselves in localities which they scour, while the corals will thrive off the passages where the currents have lost their strength. The navigators and naturalists of the U.S. Exploring Expedition frequently speak of the rapid outward current passing through the openings of the reefs, especially during the ebbing tide. Dana had noticed the great strength of the tidal currents, and he well explains by their action the great diversity of distribution of material over the bottom of a lagoon or of a barrier reef channel.

"There seems to be no question that the action of the sea can cut out the lagoons of barrier reefs and of atolls at the depths at which they have been observed in the Fijis. Although there are individual atolls which show depths of thirty-five to fifty fathoms and even more, these are exceptional depths, which are readily explained as due to other causes than the scouring action of the sea.

"Admiral Wharton has given an excellent summary of cases showing to what depths the action of the sea in motion may be felt to a sufficient extent to move material at depths of fifty to sixty fathoms. As he justly says, 'The effect [of the action of the waves in an otherwise deep sea over which strong winds are continually blowing] will be to cut down an island more or less rapidly, according to its constitution, to a very considerable depth below the surface, the final result being a perfectly flat bank.'

"The sections plainly indicate the general flatness of the lagoons, with a slight inclination in the direction of the flow of the water in the lagoon toward the ship passages leading into the lagoon, and the outline of the islands which have first been cut down by atmospheric agencies show irregularities which disappear finally when they have come within the scope of submarine erosion,

resulting in such 'sunken' banks as the Penguin Bank. By 'sunken' we do not mean in any way to refer to subsidence as a factor in producing such a bank. The mass of water which is poured into a lagoon on the windward face of a reef, and transforms it into a gigantic pothole, is something enormous. The breakers follow one another incessantly, and the hydraulic head obtained is amply sufficient to account for the scouring of the lagoons after the reef has once established itself as a bank, and amply sufficient to wear away from the slope of the islands the platform upon which the coral reef is built. The topography of this platform is naturally much varied, depending upon the character of the shore line, the direction of the valleys of the shore hills, and their composition. A glance at the charts accompanying this Bulletin will show all possible conditions of submarine erosion in the cutting down of the submarine platforms of the islands of Fiji, and in the manner in which islands, islets, and rocks have been left, attesting their former greater extension in the various clusters of the Archipelago.

"When the principal openings are not on the lee side of the lagoons, as is the case with Vanua Mbalavu, and the Argo Reef or Totoya, Fulanga, and a few others, there is usually a simple reason, such as the lower elevation of the island once covering the area of the lagoon at some point not on the lee side, or the fact that the lagoon has been formed on a steep volcanic slope looking eastward or northward, so that deep ravines or tongues of deep water cut into the lagoons, and intercept the coral patches forming its rim on the weather side, and thus leave a windward passage. It is by some such orogenic condition that we must explain the existence of deep soundings within atolls, — soundings which in no way indicate a subsidence, as has been assumed by Darwin, and which according to him were not to be explained by any other hypothesis. Such deep ravines are of course also to be traced on the slopes of the larger islands where we find, crossing the shallow plateaus on which coral patches grow, valleys of considerable depth, which appear as deep soundings within the area of an outer reef flat such as in the great plateau off Viti Levu and Vanua Levu, or of Kandavu and Taviuni, which according to Darwin would indicate a subsidence, while, on the contrary, they are a part of the results of the elevation and lifting up of that region of Fiji.

"Nor are the great depths found close to narrow lines of corals an indication that the corals have grown up as a nearly vertical wall from a depth of two or three hundred fathoms or more. It merely indicates that the corals form a thin crust, at most 120 feet in thickness, over a sharp volcanic ridge, the summits or crest of which have either reached by elevation the depths at which corals can grow, or have been denuded by submarine erosion to form a platform below the level of the sea, where corals have found a footing upon them.

"My observations in Fiji only emphasize what has been said so often, that there is no general theory of the formation of coral reefs, either of barrier reefs or atolls, applicable to all districts, and that

each district must be examined by itself. At least such has been my experience in the Bermudas, the Bahamas, Cuba, Florida, the West Indies, the Sandwich Islands, and Australia. The results of this trip show plainly that Darwin's theory is not applicable to the Fiji Islands, notwithstanding the borings at Funafuti, and that, in all the cases I have examined, the reefs form but a thin crust upon the underlying base, the shape and composition of which is not in any way due to the growth of corals of the existing period."

It is only possible to allude to the clearness and excellence of execution of the charts and the beauty of the illustrations. The work will be sought after and appreciated by all who are interested in the great question of the origin and the formation of Coral Reefs.

REVIEWS.

I.—The Palæontographical Society of London: Annual Volumes (li and lii) for 1897 and 1898. Issued to subscribers of one guinea annually, paid on 1st January to the Hon. Secretary, the Rev. Professor Thomas Wiltshire, M.A., D.Sc., F.G.S., 25, Granville Park, Lewisham, S.E.

THE fiftieth volume issued by this Society, for the year 1896, was reviewed by us in March, 1897 (see the Geol. Mag., 1897, Dec. IV, Vol. IV, No. 393, pp. 134–8). Since that date, vols. li (for 1897) and lii (for 1898) have been issued to subscribers, and vol. liii, for the present year, might appear at any moment, having already gone to the printers.

The salient points of the monographs contained in the last two years' volumes may now be briefly touched upon.

I.—The fourth (concluding) part of the Monograph of the Foraminifera of the Crag (1897) has been written by T. Rupert Jones, assisted by his highly competent allies, Messrs. H. W. Burrows, C. D. Sherborn, F. W. Millet, and F. Chapman, who have long been authorities on the history of the Microzoa forming the subject of this monograph. This Part (pp, vii–xv, 315–402, woodcuts 24–30; there are seven plates in the foregoing Parts I–III, and their figures are largely elucidated in this last Part) treats of some of the Rotalian group, and all of the known British Nummulinidæ, including several *Nonioninæ* and *Polystomellæ*, and some representatives of *Amphistegina*, *Operculina*, *Nummulites*, and *Orbitoides*, but the specimens of the four latter genera have probably been derived from older strata and left in the Crag of Sussex, whence they were obtained. The whole series of Foraminifera as known fossil in the English Tertiaries is thus completed, as begun in Part I (1866), but restated and continued in Part II (1895) and Part III (1896). Having been carefully collated with past and current rhizopodal literature, this well-illustrated monograph must prove to be a valuable guide to further research. Geologists will fully appreciate Messrs. Burrows and Holland's elaborate "Table of the Distribution of the