American Mathematical Society may play in promoting further advances. With respect to these enquiries I should be loath to hazard a prediction or to offer advice. But there appears to be no reason for entertaining other than optimistic expectations. The routes along which exploration may proceed are numerous and attractive. We have only to follow the example set by Laplace, Poisson, Green, Gauss, Maxwell, Kirchhoff, Saint-Venant, Helmholtz, and their eminent contemporaries and successors. In commending the works of these great masters to the younger members especially of the American Mathematical Society, I would not be understood as urging the cultivation of pure mathematics less, but rather as suggesting the pursuit of applied mathematics more. The same sort of fidelity to research and the same sort of genius for infinite industry which enabled those masters to accomplish the grand results of the nineteenth century, may be confidently expected to achieve equally grand results in the twentieth century.

R. S. Woodward.
Columbia University.

CRUISE OF THE ALBATROSS.

II.

The following letter from Dr. Agassiz, dated Papeete Harbor, Tahiti Island, November 6, 1899, has been received by the United States Fish Commission and is here published by courtesy of Commissioner Bowers.

During our stay in Papeete some time was spent in examining that part of the barrier reef of Tahiti which had been surveyed by the *Challenger*. We found the condition of the outer slope of the reef quite different from its description as given in the *Challenger* narrative. The growing corals were comparatively few in number, and the outer slope showed nothing but a mass of dead corals and dead coral bowlders beyond 16 or 17 fathoms, few living corals being observed beyond 10 to 12 fathoms.

We also made an expedition to Point Venus, to determine, if possible, the rate of growth of the corals on Dolphin Bank from the marks which had been placed on Point Venus by Wilkes, in 1839, and by MM. Le Clerk and de Bénazé, of the French navy, in 1869. We found the stones and marks as described, but, in view of the nature and condition of Dolphin Bank, did not think it worth while to make a careful survey, as Captain Moser had intended to do. On examining Dolphin Bank in the steam launch I was greatly surprised to find that there were but few corals growing on it. I could see nothing but sparsely scattered heads, none larger than my fist, the top of the bank being entirely covered by nullipores. We sounded across the bank in all possible directions and examined it thoroughly, and at the stage of water at which we sounded, found about 18 inches difference from the soundings indicated by the charts. It is also greatly to be regretted that Dolphin Bank was not examined, neither in 1839 nor in 1869, and notes made of what species of corals, if any, were growing on its surface; for an excellent opportunity has been lost to determine the growth of corals during a period of 60 years. The choice of this bank as a standard to determine the growth of corals was unfortunate, as it is in the midst of an area comparatively free from corals.

Extensive collections have been made at Papeete during our visit by the naturalists of the *Albatross*.

After refitting and coaling here, we left on the 5th of October for a cruise in the Paumotus.

We steamed for Makatea, which we had visited on our way to Tahiti, and not only examined the island more in detail, but took a number of photographs of the cliffs on the east side, which, on our first trip, we passed late in the afternoon. We crossed the island from west to east, the path leading down from the summit of the cliffs bordering the island into a sink at least 40 to 50 feet lower than the rim of either face of the island. The sink occupies a little more than one-third the length of the island. It is deeper at its southern extremity, where it is said to be 75 to 100 feet below the rim of the adjoining cliffs.

It is difficult to determine if this sink is the remnant of the former lagoon of the island, or of a sound formed during its elevation; or if it has been formed by the action of rain and atmospheric agencies. The amount of denudation and erosion to which this island has been subjected is very great, as is clearly indicated by the small cañons, pinnacles, and walls of limestone, as well as by the crevasses which occur in the surface of the basin in all directions. The extent to which this action has penetrated into the mass of the island is also plainly shown by the great number of caverns which crop out at all levels along the sea face of the cliffs, some of which are of great height, and extend as long galleries into the interior of the island. It is, of course, difficult, in the face of this extensive denudation and erosion, to state positively what may be part of the ancient lagoon, or sound, and what has been carried away by atmospheric and other agencies since the elevation of the island. At the south end of the island, which is lower than the northern part, there are only two distinct terraces, while at the northern end four terraces can be traced. The southern extremity, however, is still higher than the deepest part of the central sink of the island.

From Makatea, we visited Niau, Apataki, Tikei, Fakarava, Anaa, Tahanea, Raroia, Takume, Makemo, Tekokota, Hikueru, Marokau, Hao, Aki-Aki, Nukutavake, going as far east as Pinaki, when we turned westward again to Nukutipipi.

On arriving at Pinaki we decided to give up the exploration of the eastern extremity of the Paumotus, and not to make our contemplated visit to the Gambier Islands, our time having been greatly curtailed by delays at Fakarava and Makemo, from bad weather and the non-arrival of our coal supply. We therefore reluctantly turned westward again and made for the Gloucester Islands. These, as well as Hereheretue, proved most interesting; they formed, as it were, an epitome of what we had seen on a gigantic scale in the larger atolls of the western and central Paumotus. We could see at a glance in such small atolls as Nukutipipi and Anu-Anurunga, the connection between structural features which, in an atoll 40 miles in length and from 10 to 15 miles in width, it was often difficult to determine.

Except at Nukutavake we found no village in which the habits of the natives had not been more or less modified by civilization. The Paumotu Islanders have practically given up building their own houses; they use European models and their roofs are composed in great part of galvanized iron. There are also but few of the original native canoes to be seen. In a few years all traces of their customs and crafts will have disappeared.

We also steamed by Kauehi, Tænga and Tuanaka. We anchored in Fakarava and Makemo lagoons, spending a number of days in both these atolls. We usually timed our visits to the islands where we could not anchor so as to spend the day, or the greater part of the day, at these atolls, making our passages at night, and sounding whenever practicable on the way.

After leaving Tahiti we made over 100 soundings. These have shown in a general way that the western islands are probably all on a great plateau connected perhaps by the 800-fathom line; that such islands as Anaa are probably on spurs or independent smaller plateau, separated from the main plateau by somewhat deeper water. The same may be the condition of Raroia and Takume and of Hao and Amanu, while such smaller and isolated peaks as Tikei, Aki-Aki, Nukutavake, and Pinaki, as well as the Gloucester Islands, rise from greater depths and are isolated peaks. At any rate, these soundings indicate, as do the soundings off the Fijis, that atolls do not necessarily rise from very great depths, and that in this characteristic atoll district, atolls are found, it is true, with steep slopes, but rising from moderate depths. The slopes of these atolls would probably resemble in every respect the slope of the elevated coralliferous limestone islands characteristic of the Lau Group in Fiji.

The deepest sounding among the Paumotus was on the line to the northward of Hereheretue in the direction of Mahetia, where we found a depth of 2524 fathoms, and a continuation of the red clay characterizing the soundings since we left Pinaki. In nearly all the soundings among the Paumotus, even at moderate depths not far from the atolls, we brought up manganese particles or small manganese nodules. The last haul, made in deep water on the way from Hereheretue, in 2440 fathoms, brought up at least half a ton of manganese nodules, the bottom being red clay.

We have now steamed about 2500 miles among the Paumotus, and although we had not the advantage of the accurate surveys of the English hydrographic charts, which made the exploration of Fiji so easy, yet from the structure of these atolls it was a comparatively simple task, by steaming around the islands and landing wherever practicable, to get a fairly good idea of their structure. We have seen nothing in this more extended examination of the group tending to show that there has anywhere been subsidence. On the contrary, the condition of the islands of the Paumotus cannot, it seems to me, be explained on any other theory except that they have been formed in an area of elevation; an area of elevation extending from Matahiva on the west to Pinaki in the east, and from the Gloucester Islands on the south to Tikei in the north, although the islands in the line of Mangareva to Tahiti are separated from the other Paumotus by a deep channel, nearly 200 miles wide and more than 2400 fathoms in depth, with scattered islets and atolls extending from Mangareva to Pinaki, and northward to Serle Island and beyond, islands which are not connected with the extensive plateau upon which the greater number of the Paumotu Islands to the westward of Hao rise.

All the islands we have examined are, without exception, formed of tertiary coralliferous limestone which has been elevated to a greater or less extent above the level of the sea, and then planed down by atmospheric agencies and submarine erosion, the greatest elevation being at Makatea (about 230 feet), and at Niau, where the tertiary coralliferous limestone does not rise to a greater height than 20 feet. At Rairoa it was 15 to 16 feet high. At other islands it could be traced only as forming the shore platform, from 50 to 150 feet wide, which forms the outer face of the Paumotus, and is so characteristic a feature of the atolls of the group. In other parts the old ledge could be traced cropping up in the interior of the outer rim, or in the open cuts connecting the lagoon with the outer sea face of the atolls. Everywhere the space between the outcropping of the old ledge, as I will call the tertiary coralliferous limestone, was filled with beach rock, or a pudding stone, or with a breccia or conglomerate of coralliferous material consisting in part of fragments of the old ledge and of fragments of recent corals and shells cemented together.

The appearance of the old ledge and of the modern reef rock is so strikingly different that it is very simple to distinguish the two, even when only comparatively small fragments are found.

We did not find in the Paumotus, as in Fiji, all possible stages of denudation and of submarine erosion between islands like Vatu Vara, Niau, Kambara, Fulanga, Ongea, Oneata, Ngele Levu, and Weilangilala, and atolls with a mere ring or surf to indicate their existence.

In the Paumotus the islands have been elevated to a very moderate height and probably to nearly the same height, for the old ledge forming the base of the modern structure is found exposed nearly everywhere at about low-water when it cannot be traced at a slightly greater elevation. This would readily account for the nearly uniform height of the islands throughout the group.

But there is another element which comes into play in this group, and has an important part in shaping the ultimate condition of these atolls. At the Fijis we have seen the submarine erosion continue until there is little left of many of the atolls beyond the merest small islet or rock to indicate its structure. In the Paumotus, in the great atolls which are evidently only the exposed summits of parts of ridges or spurs of an extensive tertiary coralliferous limestone bed, the rim of the atoll is, after having been denuded to the level of the sea, again built up from the material of its two faces which is thrown up on the wide reef flats both from the sea face and from the lagoon side. We do not find in the Fijis such huge reef shelves to supply such masses of material from the breaking up of the outer and inner edges of the tertiary limestone platforms, in addition to the fragments of recent corals growing upon the flat and its edges, which, when dead, are thrown up and formed into shingle and sand to form a pudding stone, or a conglomerate, or breccia, with the fragments of the old ledge on the top of the reef flats.

This pudding stone, or beach rock, is found on all the reef flats of the islands of the group. It forms great bars, at right angles usually to the shore-line, and upon the sea-face of these bars is thrown up coral shingle, both old and recent, which builds up short reaches of beaches separated by wide flats through which the sea rushes at high water, or merely covers the flats at low tide; while on the lagoon side of the wide reef flats a similar process is going on, throwing up finer sand among the beach-rock bars and along their sides, and thus building up, little by little, at first small sand bars, then larger bars, or islets, at right angles to the shore-line, and as they become larger by accretions from both sides, they finally form an island from 1000 to 1200 feet long, according to the width of the reef flat, extending from the lagoon edge of the flat to the sea face of the atoll. The sand bars, little by little, become covered with vegetation, and at some stages of tide appear like islands and islets situated a considerable distance within the lagoon. Whenever the material supplied both from the lagoon side and from the sea face is very abundant, the land ring becomes more or less solid, the islets become consolidated into islands, separated by narrow or wider cuts, until finally they form the larger islands which seem at first glance to form continuous land along the rim of the lagoon, but which are often seen to be separated according to local conditions by narrow cuts, which finally allow no water to pass through and merely indicate the former separation of the various parts of the land.

In the lagoons of atolls of such great length as some of these of the Paumotus, like Rairoa, Fakarava, Makemo and Hao, which are between 30 and 40 miles long, and others of less dimensions, considerable sea rises under the prevailing trades. The sea and wind generally follow the trend of the shores, both in the lagoon and along the sea face, so that the bars of beach rock act like buttresses and collect material at their inner and outer extremities, forming the sand bars and islets which eventually become the land rim of the lagoon. When the material is not from local causes very abundant, or is washed out over the flats, there are fewer islands, and often these are but mere islets or bars for long reaches of the shore, forming the characteristic weather faces of many of the lagoons.

Many of the lagoons are filled with shoals or ledges awash or a few feet above the sea-level. These shoals are parts of the old ledge which have not as yet been eroded, and the disintegration of which has gone far to supply material for the land of the outer rims of the atolls. In Fakarava there were no less than 36 islands and islets and ledges, parts of a former great flat, now broken up, existing parallel to the outer reef flat about four miles in the lagoon. Similar reef flats exist in Tahanea, where they form a secondary lagoon with two to three fathoms of water, extending nearly the whole length of the western face of the atoll. There are several large islands on this flat, and at high water they would appear as the islands and islets of Fakarava do, as disconnected and planted in the lagoon itself. A secondary lagoon also exists in Ravahere and Anaa; in both these atolls the reef flat extends across one extremity of the lagoon and does not run parallel to the longer shore-line of the atoll.

The lagoons of these atolls have a general depth of 13 to 20 fathoms. In some cases they are, as is stated, somewhat deeper (but there are no measurements), the greater depths being 30 fathoms or more, being due to orogenic conditions. Some of the atolls are quite shallow, as at Matahiva as well as Pinaki, where the lagoon is not more than two to three fathoms, and Takume, where it is from five to six fathoms deep. Some of the smaller islets we visited, among which are Tekei, Aki-Aki and Nukutavake, have no lagoons. The former has a shallow sink in which fresh water collects, but the rim is only very slightly higher than the interior. The last two islets are apparently depressed in the center, three to four feet below the outer bank of sand which forms the rim (about 10 to 12 feet high) of the basin of the island. I was at first inclined to look upon these islands as examples of islands which had been cut down to the level of the sea and subsequently been built up by beach rock and sand in the manner described above. The existence of extensive sand dunes on two sides of the island at Pinaki, and of a large dune (estimated to be 35 feet high) on the south shore of Nukutavake, seems to indicate the possibility of there having been a shallow lagoon occupying the center of Aki-Aki and of Nukutavake, and that these lagoons were gradually filled by the sand dunes, much as Pinaki is filling now.

At Pinaki (Whitsunday Island), there is no doubt but that the lagoon is rapidly filling from the sand blown in by the dunes. They are from 12 to 15 feet high and are forcing their way in towards the lagoon, killing the pandanus and whatever vegetation there is growing on the land rim of the lagoon. The dunes have probably filled also a second entrance to the lagoon, indicated now only by a somewhat lower level of the land rim. Mr. Moore and Mr. Townsend, who went ashore at Pinaki, report that the lagoon is not more than three fathoms deep; they could wade over the greater part of it. Mr. Alexander counted no less than 116 islets in this small lagoon —less than a mile in diameter—islets formed of masses of dead Tridacna shells thrown up on ledge rock, on the slopes of which grew madrepores. The bottom of the lagoon is covered by Tridacna and masses of a species of Arca live near the edge, the intervening spaces being filled with nullipores. The entrance to the lagoon is perhaps 150 feet wide, and, there is a cut through the beach rock covering the old ledge, giving access to the sea into the lagoon at certain stages of the tide. The water in the lagoon is quite warm.

At Pinaki, as at other atolls and islets to the eastward, there are fewer cocoanuts than on the westward atolls, and the vegetation consists in great part of pandanus and puteau trees and the usual coral reef vegetation of the Paumotus and Fijis.

The only atoll we have seen, the lagoon of which is entirely shut off from the sea, is Niau. In this case the old ledge forming the rim of the land, which surrounds the nearly circular lagoon, is about a third of a mile in width, and sufficiently high, 15 to 20 feet, to prevent any sea from having access to it except in case of a cyclone, as that of 1878, when the sea washed into the lagoon. The lagoon is shallow, of an average depth of about three fathoms, the deeper parts perhaps five. The water is brackish, of a density of 1.0216 at 28 degrees C. There are no corals living in it, but a species of mullet is found, as well as many marine shells, which, like those in the lagoons of San Salvador, in the Bahamas, are of diminutive size compared to their representatives living outside. The floor of the lagoon is covered with algæ. The lagoon has probably a slight connection with the sea, the water percolating through the limestone ring separating it from the outer reef flat. It is very difficult in this case to decide whether this lagoon has been gradually filled up after elevation or whether it is merely a sink on a more or less uneven limestone surface.

Dana and the other writers on coral reefs mention a great number of lagoons as being absolutely shut off from the sea. I take it these statements are due to their descriptions being taken from charts, many of which (as in the case of the Paumotus) are very defective. For nothing is easier than to pass at a short distance by the wide and narrow cuts which give in so many places the freest access to the sea to the interior of the lagoons, and described as closed because they have no boat passages. I could mention as instances of such lagoons those of the atolls of Takume, Hikueru, Anaa, etc., which may be said to be closed, yet into which a huge volume of water is poured at every tide over low parts of the encircling reef flats.

The character of the coral reefs of the Paumotus is very different from that of other coral reef regions I have seen. Nowhere have I seen such a small number of genera, so many small species, and such stunted development of the corals. None of the great heads of the genera so characteristic of the West Indian regions, or of the great barrier reef of Australia, are to be seen; with the exception of a couple of species of alcyonaria they are absent, so far as our experience shows, and there are but few sponges and gorgonians to be found among the corals. The bathymetrical limit of the reef-building corals seems to be about 20 to 22 fathoms, but nowhere have I seen such extraordinary development of incrusting nullipores as on the sea edge of the shore platforms of some of the Paumotu atolls, where they build up to a height often four feet to form the outer edge of the secondary barrier reef so frequently seen along the reef faces of the Paumotus.

On the 4th of November we were well on our way to Mehitia, the easternmost of the Society Islands, the account of which will be included in my next letter giving the results of our examination of the Society Islands.

We have taken a large number of photographs to illustrate the structure and mode of formation of the Paumotu atolls. Mr. Mayer has devoted much time to the drawing of the medusæ collected.

Judging from the temperature taken at various points, 40° F. seems to be found quite generally at about 500 fathoms depth.

We made a number of surface hauls, as well as intermediate hauls, with the townets, but obtained very little animal life. The poverty of the surface pelagic life, and down to 300 fathoms, is remarkable. I do not think I have ever sailed over so extensive an area as that of the Paumotus and observed so little surface life; on calm days, under the most favorable conditions, nothing could be seen with the naked eye, and at night there was little or no phosphorescence. Inside the lagoons our hauls were equally barren.

The same paucity of animal life seemed to extend to the deep-water fauna. All the hauls we made off the islands, in from 600 to 1000 fathoms, usually the most productive area of a sea slope, brought nothing, or so little that we came to grudge the time spent in trawling on the bottom, as well as towing on the surface or near it, a great contrast to the conditions of the Atlantic in similar latitudes, and very different from our anticipations. For these reasons no attempt has thus far been made to make a trial of the deep-sea pump while in such unproductive areas, and unfortunately while we were in the region of the equatorial current the weather conditions were not suited for a trial of the apparatus.

We expect now to coal and refit, and to leave for Suva via Tonga on the 15th of this month. A. Agassiz.

THE TWELFTH ANNUAL MEETING OF THE GEOLOGICAL SOCIETY OF AMERICA.

I.

The Geological Society of America convened at 10 a. m., Wednesday, December 27th, in the large lecture room of Columbia University, Washington, D. C. President B. K. Emerson called the meeting to order and Dr. G. K. Gilbert delivered an address of welcome, to which the President responded. The following officers were then declared elected for the ensuing year:

President: George M. Dawson, Ottawa, Ont.; *First Vice-President:* Charles D. Walcott, Washington, D. C.; *Second Vice-President:* N. H. Winchell, Minneapolis, Minn.; *Secretary:* H. L. Fairchild, Rochester, N. Y.; *Treasurer:* I. C. White, Morgantown, W. Va.; *Editor:* J. Stanley-Brown, Washington, D. C.; *Librarian:* H. P. Cushing, Cleveland, O.; *Councillors:* W. B. Clark, Baltimore, Md., and A. C. Lawson, Berkeley, Calif.

The following new Fellows were also announced as having received election:

Irving Prescott Bishop, 109 Norwood Avenue, Buffalo, N. Y., Professor of Natural Science, State Normal and Training School; Emilo Böse, Ph.D. (University of Munich, 1893), Calle del Paseo Nuevo No. 2, Mexico, D. F., Geologist of the Instituto Geologico de Mexico; Arthur Starr Eakle, B.S. (Cornell, 1892), Ph.D. (Munich, 1896), University Museum, Cambridge, Mass., Instructor in Mineralogy and Petrography, Harvard University; August Frederick Foerste, A.B. (Denison, 1887), A.M., Ph.D. (Harvard, 1888, 1890); John Flesher Newsom, A.B. (University, Indiana, 1891), A.M. (Stanford, 1892), Stanford University, Calif., Associate Professor of Metallurgy and Mining, Stanford University; Samuel Lewis Penfield, Ph.B., M.A. (Yale, 1877, 1896), New Haven, Conn., Professor of Mineralogy, Sheffield Scientific School of Yale University; Charles Henry Richardson, A.B., A.M., Ph.D. (Dartmouth, 1892, 1895, 1898), Hanover, N. H., Instructor in Chemistry and Mineralogy, Dartmouth College; Arthur Brown Willmott, B.A., B.Sc. (Victoria University, Toronto, 1887), M.A. (Harvard, 1891), Toronto, Canada, Professor of Geology and Chemistry, McMaster University.

During the year the Society has lost by death four of its most distinguished Fellows, of whom two, Sir J. William Dawson and Edward Orton, have been presidents. The others were O. C. Marsh and Oliver Marcy. Memorials were read of all but Professor Marsh, whose biographer, Professor C. E. Beecher, was absent, and had