THE CRUISE OF THE CHALLENGER.

(SECOND LECTURE.)

Delivered in the Hulme Town Hall, Manchester, December 18th, 1877.

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TEMPERATURE OF THE OCEAN WATERS.

IN my former lecture I told you something about the origin and object of the cruise of the Challenger. Then I briefly described to you the instruments and methods of observation employed on board in deep-sea investigations. Afterwards we followed the course which the Challenger took on her way around the world. Then we considered some of the results of the observations on the depth of the ocean, and I concluded by pointing out the basin-like character of the great oceanic areas.

To-night I will, in the first place, speak of the temperature of ocean waters. Our observations show that by far the greater part of the water which fills these great depressions on the surface of our globe has a rather low temperature—that is to say, a temperature below 40° Fahrenheit. Except among the icebergs at the Antarctic circle the water is warmest at the surface; from the surface it cools rapidly for the first few hundred fathoms; then very slowly down to the bottom, or down to a point from which it remains the same till the bottom is reached. Generally throughout the temperate parts of the North Atlantic we descend a mile or more before we reach a temperature of 40°. But in the tropical and south temperate regions of the Atlantic, and throughout the tropical and temperate parts of the Pacific, we only require to descend half a mile, or a little more, when we get a temperature of 40°. As we approach the polar regions the temperature of 40° is met with at the surface. Observe these diagrams, which illustrate the thermal stratification of the waters in portions of the Atlantic. Here we have a section from the equator to the island of Tristan along the median submarine ridge, and showing the island of Ascension in section. Notice how thin this film of heated surface water is when compared with the vast thickness of cold water, under 40°, underneath. This dark blue spot shows where the water is nearly at the freezing point of fresh water. Quite under the equator then we got ice-cold water (32·7). The mud brought up in the dredge under the line was so cold that the hand could not be held in it for any time with comfort. I have seen bottles of beer and champagne placed in this mud for a time with much advantage.

To return to our diagram, you see how the lines of temperature about 40° approach the surface as we go south to Tristan; and had the section been continued into the Southern Ocean they would eventually have run out on the surface. In this diagram, again, we have a section in the western portion of the Atlantic, from the West Indies to Halifax, in Nova Scotia, showing Bermuda in section. All this blue colour represents water under a temperature of 40°. It will be noticed how this cold water comes to the surface as we approach the North American continent. These little red patches on the surface show what is called the delta of the Gulf Stream. The stream has, at this point, commenced to break up and spread over the surface of the North Atlantic. Where we crossed it on our way towards New York it was still an unbroken stream of hot water. The Gulf Stream looks very insignificant when compared with the vast body of cold water underneath. Yet it carries a great quantity of heat into the temperate regions of the North Atlantic, and is probably the chief source of a broad band of heated water which we find here represented by the yellow colour. Down to a depth of between 300 and 400 fathoms we have water with a temperature of over 60° Fahrenheit. This is the only region where we find in the ocean such warm water at so great a depth. Above the line which is marked out by a temperature of 40° (and which I have said is usually in tropical and temperate regions, a little more than half a mile below the surface) the water is greatly affected by the direct heat of the sun, and by the currents produced by the prevailing winds of the globe. You might expect that the heated water would accumulate about the equator, but this is prevented by its removal, so soon as formed, in the currents produced by the trade winds, and by the rapid abstraction of heat in the form of water vapour.

Let us now look at the cold water, that under a temperature of 40°. I think it is now admitted by all that this water comes from the Antarctic Ocean, and that it flows slowly northward. In the Pacific it cannot come from the Arctic for we have only a narrow and shallow strait connecting the two oceans. The Atlantic has a wider and freer communication with the Arctic, but the currents which flow south from it are relatively very insignificant and cannot sensibly affect the general temperature of the Atlantic. I have mentioned that the temperature sometimes decreases from the surface down to the bottom, and sometimes that it decreases down to a certain point, from which it remains the same to the bottom. You will understand this by reference to the diagram. Suppose the water to be flowing north in the direction of the arrows. In its course it meets with a barrier—the lower and colder water is stopped, it cannot get further north, and the basin beyond is filled with water of the same temperature as that at the top of the ridge or barrier.

I mentioned in my last lecture that the low submarine ridges which we find throughout the ocean basins had an important influence on the distribution of temperature at the bottom of the sea. Now you may see how this is. The cold water which flows from the Antarctic along the eastern coast of South America, where there is free communication with the south, has at the bottom a temperature of 31°, *i.e.*, below the freezing point of fresh water. In these basins, to the north and east of the Atlantic, we have at the bottom, and from a depth of about 2,000 fathoms down to the bottom, a temperature of only 35°; and the reason is because these basins are cut off from the Antarctic Sea by ridges, whose tops are about 2,000 fathoms from the surface of the waves; and hence these basins are filled with water having a temperature the same as that found at the same level as the lowest point of these ridges. In the same way the Coral Sea is cut off from the general circulation of the Pacific, and is filled with water of a uniform temperature below 1,400 fathoms. The inclosed seas—as the Mediterranean, the Sulu, the Banda, the Celebes, and China Seas—have their temperatures affected in a similar manner. The minimum temperature in these seas is met with at 900, 700, or 500 fathoms below the surface; and the depth at which this minimum temperature is found, points out the depth of the lowest point of the ridges which separates the waters of these inclosed seas from the waters of the great ocean basins.

Many theories have been advanced to account for the flow of the cold Antarctic water up into the deeper parts of the Atlantic and Pacific. The three most important may be mentioned without discussing them. First, we have the precipitation theory advocated by Sir Wyville Thomson. Sir Wyville thinks the circulation is kept up by the excess of evaporation over precipitation in the Northern Hemisphere, and excess of precipitation over evaporation in the Southern Hemisphere—part of the circulation taking place, in short, through the atmosphere. The second may be called the gravitation theory, advocated by Dr. Carpenter, who thinks that the greater pressure of the column of cold water in the polar regions keeps up the general circulation. Thirdly, the wind theory which is advocated by Dr. Croll, who thinks the flow of cold water to the north is but a part of the general ocean circulation, originated and kept up by the action of the prevailing winds of the globe.

SPECIFIC GRAVITY.

The specific gravity of the ocean, arising from its saltness, was found to be greatest where we have winds constantly blowing over the surface, as, for instance, in the trade wind regions of the North and South Atlantics. The Pacific—especially the Western Pacific—has a relatively low specific gravity. The specific gravity becomes less as we approach coasts where rivers enter the sea and the winds are variable, and as we approach either pole, where much rain falls and where snow and ice are continually melting. In this equatorial region of the Atlantic we have also a band of low specific gravity. This arises from the large quantity of rain which falls in this region of calms between the north and south trade winds, and also from the presence of shore water from the coast of Africa, for this is also the region of the equatorial current.

Our chemist, Mr. Buchanan, has examined the atmosphere or gases dissolved in several specimens of sea water from different depths, with reference chiefly to the amount of oxygen contained in them. He finds the oxygen greatest at the surface—greater at the surface than at the bottom ; from the surface, however, it was found to diminish down to the depth of about 1,800 feet, from which point it gradually increases again. At the bottom the amount of oxygen is greatest at the Antarctic regions, and diminishes towards the north. It is least over red clays, and is more abundant over blue clays than over globigerina oozes. That layer of water about 1,800 feet below the surface which contains the least oxygen, is most probably the water, which, during circulation, has been the longest time removed from contact with the atmosphere. The abundance of vegetable life in the surface waters may also account for the relative abundance of oxygen in the layers above 1,800 feet.

Carbonic acid exists in considerable quantity in ocean waters, and is apparently more abundant in the deep than in the surface waters.

ANIMAL AND VEGETABLE LIFE IN THE SURFACE AND DEEP WATERS OF THE OCEAN.

Everywhere throughout the surface waters of the ocean we have found plant life distributed. We have in some places, as you know, large quantities of gulf weed. Minute algæ, called oscillatoriæ, are generally present in the warmer regions, and sometimes so abundant as to discolour the sea. Diatoms are universally distributed, abounding in those places where the specific gravity of the water is low. In the Antarctic regions we got the tow-nets literally filled with diatoms. Then we have what I regard as calcareous algæ, with the long names of coccospheres and rhabdospheres. Here we have a rhabdosphere represented. These occur in vast numbers at times, where the specific gravity of the water is high. These minute plants are primarily the food of all pelagic and deep-sea animals. They are apparently confined to the surface layers of the ocean. We found no living plants in the deep waters of the ocean. This brings me to speak of the organisms here represented, to which I have given the name of Pyrocystis, that is, fire-bags, because in the open sea, far from land, these organisms are the chief cause of the grand phosphorescent displays sometimes witnessed. There are two forms—the one globular, the other spindle-shaped. The globular one is about the size of a pin's head. They have a very thin covering of silica. We cannot destroy this siliceous covering even by boiling in strong nitric acid. Within the siliceous coat we have a yellowish green endochrome, which is sometimes closely applied to the inner surface of the siliceous sphere—sometimes retracted from it, as in this figure—and sometimes we find it dividing into two. We have a rather large nucleus which colours quickly in a carmine solution, and it is from this nucleus that the phosphorescent light is emitted. From its similar size, globular form, and from its being phosphorescent, this organism has doubtless often been taken for noctiluca. It is, however, quite distinct—quite as distinct as this fusiform variety, which does not resemble noctiluca in form, and is also highly phosphorescent. Noctiluca, which is here figured, is an animal with colourless protoplasm, which may have a few oil globules scattered through it, and is inclosed in a membraneous sac. We have in this position a mouth. The animal swallows diatoms and the like, and then ejects them through any portion of its body. Pyrocystis is a plant. It never takes foreign bodies within its substance. Noctiluca is an animal. They differ also very markedly in their distribution. Noctiluca was met with abundantly in harbours and water of low specific gravity, about the shores of continents, but never in the open sea or about oceanic islands. Pyrocystis was found, on the other hand, in countless numbers in the open sea, far from land, and only sparingly in harbours or where the water of the ocean is mixed with that of rivers. The siliceous coat of pyrocistis gives, in reflected light, the iridescent display so characteristic of thin films—as the soap-bubble. From their close resemblance to the large cylindrical diatoms of the open sea—as *coscinodiscus rex*—from the division of the endochrome, and from having noticed the siliceous spheres separating into hemispheres, I regard these organisms as diatoms.

Many other organisms give out phosphorescent light—as pyrosoma, medusæ, the eyes of some larval crustaceans, copepods—and many fish have lines of phosphorescent dots about their bodies. The majority of these animals seem to give out phosphorescent light only when disturbed or irritated—in some it appears to be emitted at will.

All over the surface of the ocean we find great numbers of minute and very beautiful animals, which secrete silica from the sea water to form their skeletons. Two of these creatures are here represented. They, like the diatoms, abound in those areas where we have a relatively low specific gravity—as in the Antarctic and Middle and West Pacific Oceans. They are called radiolaria, and during the cruise we discovered very many new forms, especially large hollow-spined radiolaria. Professor Haeckel tells me that the whole group will require to be rearranged in consequence of these new discoveries. Professor Haeckel has also examined a little group of rhizopods, which we found by sinking tow-nets into deep water, and to which I gave the provisional name of Challengeridæ. He thinks they must be referred to the radiolaria, and will form the highest and most differentiated family of the group. Two of the forms are here shown. They have generally purse-shaped siliceous shells, with one or more openings, through which the sarcode flows. The shells are frequently highly ornamented with pit-like markings. They have a central capsule which colours in a carmine solution, and many brown-coloured cellæform bodies, probably representing the bright orange-coloured bodies of the surface radiolaria. These bursiform varieties graduate by a series of forms into the hollow-spined radiolaria.

We have again many animals in the surface and sub-surface waters of the ocean which secrete carbonate of lime for their shells and skeletons. Chief among these are the foraminifera. Before the Challenger Expedition it was generally believed by naturalists that the foraminifera, which make up the bulk of the carbonate of lime deposits at the bottom of the ocean, lived at the bottom. We have, however, found these rhizopods living all over the surface of the sea, and in the warmer waters of the tropics and North Atlantic they were taken in countless numbers. I think we have found over twenty species of pelagic foraminifera. Two cf the forms are here represented as we find them on the surface. The globigerinæ have long spines. The sarcode flows from the inside of the shells, and is thrown out in bubble-like expansions between the spines, as here shown. In the globigerinæ and orbulinæ we have small yellow cellæform bodies like those in radiolaria, but smaller, and throughout the sarcode there are many nuclei which colour in carmine solution.

In the warmer waters we have also many pelagic molluscs with delicate shells, as the pteropods, or sea butterflies, of which there are very many species, two of them here shown. And again, atlantas, carinarias, and other heteropods, with equally delicate shells. These molluscs are present in all regions, but the shelled varieties abound in the tropical and sub-tropical regions. There are no barren regions in the ocean, as the older naturalists supposed. Everywhere we found life in great abundance and variety; its kind and amount being determined in any locality by the physical conditions of the ocean—temperature, and saltness, and winds having great influence. Now we see great whales and schools of porpoises and dolphins. Now fishes, great and small; fishes with silvery scales, or ornamented with brilliant phosphorescent spots. Cuttle-fish are everywhere. Velellas, porpitas, ianthinas, carinarias, and Portuguese men-of-war float on the waves, and spread their tiny sails to the wind. The tow-nets bring up myriads of crustaceans and molluscs, annelids, the larvæ of echinoderms, siphonophora, medusæ, the foraminifera, and radiolaria, in all their living glory and matchless beauty, and other creatures, all too numerous to mention. Minute they may be, yet most magnificent "treasures which the vulgar in their scorn reject."

It is impossible to speak without some enthusiasm of the surface life of the ocean, for some of my pleasantest recollections of the Challenger are the hours spent examining these living beauties with the microscope, or with a water glass gazing down at them as they sported about in the open sea. Then at night, when the sea was calm and all afire, like the "Ancient Mariner"—

"Beyond the shadow of the ship
I watched the water snakes ;
They moved in tracks of shining white,
And when they reared the elfish light
Fell off in hoary flakes.

"Within the shadow of the ship
I watched their rich attire ;
Blue, glossy green, and velvet black,
They coiled and swam, and every track
Was a flash of golden fire.

"Oh, happy living things ! No tongue
Their beauty might declare.
A spring of love gushed from my heart,
And I blessed them unaware."

ANIMALS ON THE FLOOR OF THE OCEAN.

Our trawlings and dredgings established the fact that animal life exists at all depths on the floor of the ocean. All the marine invertebrate types have been obtained, as well as fishes, at depths greater than three miles. What are usually called plants do not exist at great depths in the ocean. About 150 fathoms is probably the greatest depth at which they occur. Arenaceous foraminifera, and some few calcareous forms, live all over the ocean bed. They are however much more numerous in shallow water. Siliceous sponges, such as this Euplectella (Venus's flower-basket) and the glass rope sponge, are highly characteristic deep-sea animals and extend all over the bottom of the sea. Hydrozoa and polyzoa are represented at all depths. The stem of one hydrozoan was over two yards in length, and came from a depth of about 3½ miles. A few corals extend to great depths. The pennatulidæ are represented by the umbellularia which were found in some of the deepest hauls. The echinodermata, are the most abundant deep-sea animals, as crinoids or lily stars, brittle stars, sea-eggs, holothurids or slugs. Some of these forms were supposed to be nearly extinct when these deep-sea investigations were commenced, but several which closely resemble fossil species were frequently taken. Brachiopods and annelids occur at all depths. Sea spiders, or pycnogonida, were frequently taken in deep water, some specimens being two feet across. Crustacea were frequently captured in deep water. Barnacles occur attached to pumice-stones and manganese nodules in the deepest water. Schizopoda and shrimps were often taken, some of the former being blind. Crabs appear to be confined to comparatively shallow water, and were never taken in the deep hauls. We have no large and beautiful shells in the deep sea—with perhaps one exception all the specimens taken were small and insignificant. Of fishes, we have taken many curious, new, and highly interesting forms. Some come from great depths—this small lophius-like fish from a depth of nearly three miles. The anterior dorsal spine is transformed into a long filament arching over the head and mouth, armed with horrid teeth. At the extremity of the filament there is a brilliant phosphorescent spot. We may suppose that this little black monster hangs out his phosphorescent star, then swallows all who come to admire. Here we have a salmon-like fish with the upper rays of the pectoral fins elongated and transformed, and capable of being erected so as to resemble gorgonias, crinoids, and umbellularias. We may suppose that this wily creature places himself among polyps, and, erecting his rays, deceives his prey. Here, again, we have a scopellid-like fish with very remarkable eyes—the most remarkable eyes in the whole vertebrate series of animals. They are situated on the upper surface of the head, and look like two white patches—in size and shape like one's finger nails. In section, we have at the surface a hard, transparent, glassy membrane, which probably represents the cornea. Then—subjacent to the membrane—we have an open space or cavity, which in the living state was filled with a fluid, which may represent the aqueous humour, but we have no lens or vitreous humour. Then we have the retina spread out over the floor of this cavity with the rods presented to the light and arranged in hexagonal bundles. Subjacent to this is the pigmented choroid, and, deepest of all, the sclerotic. This will probably form a new family of fishes. It seems closely allied to the scopellids. I gave the fish in my notes the name of *Lychnoculus mirabilis*—wonderful lamp eye. It is possible that this wonderful eye may be phosphorescent at the will of the animal, and that the creature may frighten its enemies, or allure its victims by a flood of phosphorescent light. Some ophidiid fishes from deep water were practically blind, the eye being represented by a small black dot deeply imbedded in the head.

Animal life appears to be much more abundant, both in number and variety, along the flanks of the great continents than at similar depths far out in the great ocean basins. All the groups of deep-sea animals were found most abundantly at depths between three-quarters of a mile and a mile—at greater depths they are more sparingly distributed. The deep-sea animals resemble more closely those found in high northern and southern latitudes than they do the shallow water animals of the tropics. This we would expect from the similarity of the high latitudes in temperature and light to those prevalent in the deep sea. The deep-sea animals also resemble more closely the fossil forms of tertiary and secondary formations than do shallow water animals of the present day. A possible explanation of this may be that those secondary and tertiary forms which migrated to the deep sea—into these areas where the conditions have been the same for ages—have been exposed to less competition, fewer vicissitudes, and hence have undergone less change than shore forms. There would appear to be considerable evidence for supposing that migrations have taken place from the shallow waters of the continents into the deep waters of the ocean basins, and that such migrations have been going on for a vast time. The genus serolis is abundant in the shallow waters of the Antarctic Sea, and extends far north in the deep waters of the Atlantic. The higher crustaceans *(Brachyura)* appear to belong to the northern continental masses, and to have been able to migrate only to a small extent to the south, as they are poorly represented over the southern ocean. If the great continents are of vast antiquity, and such migrations have taken place, then we would expect the animals far from land and out in the deep sea to be more like fossil forms than those found near shore and in shallow water. The food of the animals which live at the bottom of the sea consists to a very great extent of the little animal and vegetable matter remaining in the shells, and exuviæ which have fallen from the surface to the bottom. The great majority of these deep-sea animals live by eating the mud, and these animals are more abundant on the organic oozes than on the red clays far from land. While many deep-sea animals are blind, others have well developed eyes. Very many deep-sea animals are phosphorescent.

OCEANIC DEPOSITS.

Let us now consider of what the floor of the ocean itself is made up.

I have placed on the wall to the left of the platform two lists—

one with the names which we give to ocean deposits, and another pointing out the sources of the materials of which these deposits are built up.*

Rivers carry away from the land down into the sea substances in suspension and in solution. The former are deposited about the shores. Some of the latter are (as silica and carbonate of lime) secreted by plants and animals, and their remains make up a large part of ocean deposits.

Shore Deposits are principally made up of the detritus which is carried down to the ocean by rivers and worn away from coasts by the action of waves. All this material would appear to be deposited within one or two hundred miles of the shore. Where great rivers enter the sea, and where we have strong ocean currents, we may have some of the finest material carried to greater distances, but its amount can never be great. In those seas where we have floating ice this land *débris* is carried to greater distances. For instance, we found such material in the North Atlantic as far south as the Azores, and in the South Pacific as far north as the 40th parallel. These deposits, which are now forming along the shores of the continents and great islands, for about 200 miles out to sea, resemble in every respect the sedimentary rocks of geology, and they will doubtless form the chalks, the greensands, the shales, and conglomerates of the future. Such deposits are represented by the blue and green colours on this map.

When we pass beyond 200 miles from the shore, and out into the open sea, we find a different state of things. In the temperate

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* OCEANIC DEPOSITS.

1. SHORE DEPOSITS—(*a*) Blue muds; (*b*) Green muds; (*c*) Yellow muds, about the shores of continents—(*d*) Coral muds; (*e*) Grey muds and sands, about oceanic islands.
2. RED AND CHOCOLATE CLAYS, in deep water far from land.
3. PTEROPOD OOZE } calcareous deposits in deep water.
4. GLOBIGERINA OOZE }
5. DIATOM OOZE } siliceous deposits in deep water.
6. RADIOLARIAN OOZE }

ORIGIN OF DEPOSITS.

Inorganic Elements.—River and coast detritus; Detritus from floating ice, Dust from deserts; Dust from volcanoes—sub-aqueous and sub-aerial; Cosmic dust; Pumice-stone; Inorganic residue of organisms.

CHEMICAL DEPOSITS.

Organic Elements.—Foraminifera; Calcareous algæ—coccospheres and rhabdospheres; Pelagic molluscs; Diatoms; Radiolaria; Challengeridæ; Shark's teeth; Mammal bones.

and tropical regions, and in depths of less than two or three miles, we find that the deposits are usually made up chiefly of the shells of foraminifera and molluscs, and the remains of calcareous algæ. These foraminifera, molluscs, and algæ, lived on the surface of the sea, and it is their dead remains which we find at the bottom. When the foraminifera predominate in the deposit we call it a *globigerina ooze*, and when the pteropods, a *pteropod ooze*. The light-coloured or yellow patches on this map show the areas where we found these deposits, formed chiefly of dead carbonate of lime shells. In the Antarctic Ocean we found the deposit almost wholly made up of the frustules of diatoms, which had lived on the surface, and after death had fallen to the bottom. This is a specimen of the deposit, and its position is represented on the map by this orange patch—*a diatom ooze*. In the Middle and Western Pacifics we have an area, as I have already pointed out, where the specific gravity of the water is low. And here, also, we find organisms abound which secrete silica for their shells and skeletons—organisms with beautiful forms, and called radiolaria. In these regions some of the deposits are largely made up of the remains of these creatures, and we call these *radiolarian ooze*.

By far the most abundant oceanic deposit is red or chocolate-coloured clay. Such deposits are found at depths greater than 2½ miles and far from land. The areas where we met with such deposits are on this map coloured red. The origin of this deposit is curious and important. I have told you that all matters carried by rivers into the ocean, in suspension, are deposited within 200 miles of the land. There is, however, one important exception.

Volcanoes during eruption throw out liquid lava. Some of this, cooling rapidly in the air, forms pumice-stone, which has a very areolar structure, and, in consequence, is so light that it will float on water. In some volcanic regions there are vast deposits of pumice. Rivers cutting their way through such deposits bear great quantities of pumice-stone out to the ocean. Here in the open sea we found it floating about—we used to catch it in our tow-nets. After floating about for a time these stones become water-logged and sink to the bottom. Our dredge used to bring up great numbers of them from the bottom, and especially from the red clay areas. Here is one water-worn piece which came from a depth of over three miles in the North Pacific, and you see that now, when dried, it will still float on water. Now, this pumice-stone is the source from which the clay of ocean deposits, far from the land, is derived. The carbonic acid of ocean water acts on the feldspar of these stones, and they are decomposed, lime and magnesia are removed, water is taken up, and a hydrated silicate of alumina or clay is the result. We find in these clays crystals of sanadin, quartz, augite, and other crystals—the same crystals, however, which we find in the floating pumice-stones.

But you will ask what becomes of the calcareous shells which I have told you live on the surface and fall to the bottom after the death of the organisms. Well, these shells are removed in the greater depths of the ocean by the action of the carbonic acid in the sea water—they are converted into a bicarbonate which remains in solution. Where the carbonate of lime organisms are very abundant on the surface, we find that the calcareous deposits occur at much greater depths than where they are relatively less abundant. This is another beautiful illustration of the relation existing between the condition of things at the surface and at the bottom of the sea. The shells of the pelagic molluscs are removed first from the deposits with increasing depth.

In areas of great depth far from land we have, then, few things falling to the bottom. These are pumice-stones—and the result of their decomposition *clay*—volcanic ashes, and dust from deserts carried by the winds. In some regions of the West Pacific we have siliceous remains in the deposits at great depths, after the carbonate of lime is removed. We have also in some red clay areas, far from land, great numbers of sharks' teeth, ear-bones of whales, and other bones. In this region of the South Pacific, which is farthest from land that we can get in the world, we used to bring up sometimes, in one dredge, over 600 sharks' teeth, or fragments, some of them of gigantic size; 100 ear-bones of whales, and 50 fragments of other bones. These sharks' teeth belong to species of carcharodon, oxyrhina, and lamna. All the vascular portions of the teeth are removed, only the hard, compact dentine remains. These are fossil teeth the same as we find in tertiary deposits. Our largest specimen of carcharodon is a little larger than any fossil or recent shark's tooth to be found in our museums. The ear-bones are those of ziphius, balænoptera, balæna, orca, and delphinus. The other bones are, as this one, the beak of ziphius, and other bones of whales. In these same areas, which are areas of exceedingly slowly accumulating deposits, other chemical changes take place. Another of the products of the decomposition and disintegration of the loose volcanic materials at the bottom is the peroxide of manganese. This is deposited in concretionary form around the sharks' teeth, ear-bones, and other substances at the bottom. Thus we get nodules such as these of a black brown colour, containing 30 or 40 per cent, it may be, of the peroxide of manganese. In their formation around a nucleus the clay at the bottom has been incorporated in the nodule, and when we remove the manganese we get a clayey skeleton—such as I have here.

There is still another curious point about these deposits far from land which I must mention. In the clays and in the nodules from these regions we find small spherules of native iron, and nickel, and other magnetic spherules which appear to have fallen from the interstellar spaces—cosmic dust, in short. I often noticed these spherules while working at these clays during the cruise. I got my first hint of their true nature, however, from reading a note of Prof. Roscoe's, on cosmic dust, in the *Arctic Manual.* I afterwards extracted the particles from the clay with a magnet. The metallic particles can be hammered out in a mortar, and can be seen with the naked eye.

This diagram, which might represent a section from the coast of South America, out into the Pacific for, say, 500 miles, may render what I have been saying more apparent. Near shore we have great accumulations of river and coast detritus. Further from land, in depths of from one to two miles, we have calcareous deposits chiefly made up of dead surface shells. Still further away from the land, and in depths of three or four miles, all the carbonates are removed from the bottom, no coast detritus reaches the spot, and we have falling to the bottom dust or ashes carried by the wind, remains of sharks, of whales—that is, only the dense bones and teeth of these, and pumice stones. Here also we get the little spherules of native iron or cosmic dust; and the reason of this seems to be that here they are not covered up by deposit or washed away. Here occur also the slow chemical changes which result in the deposition of manganese. The same may be said of the shark's teeth and ear bones, and pumice-stones as of the cosmic dust. These occur, doubtless, all over the bed of the ocean; but we get them abundantly in our dredgings on the red clay areas simply because here they are not masked or covered up by coast detritus, or by great accumulations of remains of surface organisms.

This cosmic dust—these remains of sharks and whales—then, would seem to be a measure of the rate of deposition, and where we find them we may conclude that the rate is very slow, and where they occur in the greatest abundance that the rate is reduced to minimum. Where the shark's teeth and ear bones are so abundant, it is probable that a deposit of a few inches only has taken place since tertiary times.

There do not appear to be any equivalents of the deposits now forming in the deep sea far from land in the geological series of rocks. The white chalk is essentially different from a globigerina ooze. I believe that our observations, viewed as a whole, go to support the view that these ocean basins are of vast antiquity; and that, as I said in my former lecture, the ocean basins have ever been ocean basins, and on the whole have been areas of subsidence. On the other hand, the continental areas appear to have ever been the areas on which continents have existed, and these have, on the whole, been areas of upheaval.

BATHYBIUS.

It has been supposed that the floor of the ocean was covered by a slimy creature, or plasma, of indefinite extent. It was called Bathybius, and its existence had the sanction of the first naturalists. We could not detect anything of the kind at the bottom of the sea. I believe, however, that we have shown what it is that was described as Bathybius. If you take an ounce of pure sea water, and add to it two ounces of pure strong spirit of wine, you will get an abundant flocculent precipitate of sulphate of lime. After a short time this becomes crystalline. If, however, you add, say, four ounces of spirit to one of sea water, this flocculent precipitate does not pass to the crystalline state, it remains in a flocculent gelatinous-like condition. Here, for instance, is a bottle, whose contents have been as you see them for over two years. This is Bathybius. It is the amorphous sulphate of lime thrown down from the sea water by the spirit of wine. The mistake happened thus: When the first soundings were being made in the North Atlantic, the naturalists instructed the officers in charge to put any mud or ooze that came up at once into a bottle, and to fill the bottle up with strong spirit, and as there is always a good deal of sea water mixed up with this mud or ooze, the spirit precipitated the sulphate of lime. This, from the abundance of spirit, remained in the gelatinous condition, and gave portions of the mud a mobile gelatinous-like appearance—such as you see in this bottle. When the naturalists at home examined this mud they found that it contained some organic matter, they noticed its jelly-like condition, and they found that portions of it (the gelatinous sulphate of lime) coloured in a peculiar manner in carmine solution—much the same as some animal substances colour. Their conclusion was natural. They said this was protoplasm—a low form of animal life of indefinite extent, living at the bottom of the sea. I have said that we could not detect any trace of such a creature in or on the mud from the sea bottom. As the result of a great deal of work and observation I came to the conclusion that the appearances described were due to an amorphous precipitate thrown down from sea water on the addition of spirit. I invited the assistance of our chemist, Mr. Buchanan, who made a careful analysis of this precipitate, and he assures us it is all sulphate of lime. Observe then that the original describers were led astray by the excessive precautions they took to ascertain the true state of matters at the sea bottom. Their conclusion was based on careful and pains-taking observation, and it is no credit to us that with our superior advantages we should have pointed out the error. Some of our German friends, I notice, still cling to Bathybius; but I believe Bathybius will soon disappear from German text-books, as it has from those of this country.

I have endeavoured, ladies and gentlemen, to give you some account of the cruise of the Challenger—of what she was sent to do, how she did it, and what results may be expected to flow from her observations. Any one of the subjects on which I have touched would have sufficed for a single lecture. When the ship was paid off last year the expedition may be said to have ended in so far as it was a naval undertaking, and it was a great success. The navy here accomplished a great work. A flood of light has been thrown on a vast region of the earth's surface about which before all was doubt, guess-work, and ignorance. We civilians will not soon forget the courtesy of the naval officers or the cheerful assistance of the British blue jackets. The Challenger has not robbed the ocean of all her secrets, but she has made captures for almost every branch of science. She has drawn a line of observations around the world, and through the deep sea, from which all future investigations must take their start.