ART. XXXII.—*On the Sea-bottom Deposits observed during the Cruise of the Challenger in a report to Prof. Wyville Thomson;* by JOHN MURRAY, Esq., naturalist of the expedition.*

THE kinds of deposits obtained in soundings by the Challenger, may for the present be classed under the following heads:—

1. *Shore-deposits.*
   (*a*) Blue and green muds.—Met with near the shores of most of the great continents and islands.
   (*b*) Gray muds and sands.—Met with chiefly near oceanic islands of volcanic origin.
   (*c*) Red mud.—Met with on the eastern coast of South America.
   (*d*) Coral-mud.—Met with near coral reefs.
2. *Globigerina-ooze.*—An abundant oceanic deposit not met with south of latitude 50° S.
3. *Radiolarian ooze.*—An oceanic deposit met with only in the Western and Middle Pacific.
4. *Diatomaceous ooze.*—An oceanic deposit met with only south of 50° S. latitude.
5. *Red and Gray Clays.*—The most abundant oceanic deposit.

The above names have been selected as indicating those elements which give the predominating character of the deposit. As a rule, when the débris of continents or islands, the dead shells of Foraminifera, the exuviæ of Radiolarians, etc., the frustules of Diatoms, or red or gray clayey matter—when any of these have appeared to make up considerably more than one half of the specimen under examination, it has been called a shore-deposit, a Globigerina, Radiolarian, or Diatom ooze, or red or gray clay.

Sometimes it has been doubtful whether a specimen should be placed under one of the above heads or another, on account of the nearly equal ratio of constituents, or where one deposit overlies another of a different kind. In these cases the specimen has been placed under that head with which, on a general view, it has seemed to have most in common, or to which the surface-layer belonged, and a detailed description has been added in the list.

A sixth kind of deposit or formation might have been added, to embrace those bottoms in which a great quantity of the *peroxide of manganese* occurs. This substance, in the form of

* From the Proceedings of the Royal Society, vol. xxiv, No. 170. The general remarks here cited are preceded in the Report by detailed descriptions of each of the soundings in the course of the expedition. These notes and conclusions are from a preliminary report, which is soon to be followed, now that the expedition has returned, with a fuller statement.—EDS.

nodules or concretions, of incrustations or in grains, has been found in nearly all sea-deposits and at all depths in more or less abundance. However, for the present it has been considered best to treat of its occurrence separately, at the same time pointing out those regions where we have found it in greatest abundance.

A few remarks may now be made upon each of the kinds of deposits indicated.

1. *Shore-deposits.*—It has been found that the deposits taking place near continents and islands have received their chief characteristic from the presence of the débris of adjacent lands. In some cases these deposits extend more than 150 miles from the coast. Several varieties can be recognized among these shore-deposits.

(*a*) *Blue and Green Muds.*—In the great majority of cases the deposits near continents and large islands, containing the older and crystalline rocks, have been of a blue or green color; the only exception appears to be the east coast of South America, where we have a red mud, to be presently referred to.

In from 100 to 700 fathoms these deposits are often of a green color, due to the presence of a green amorphous clayey matter, and dark and pale green glauconite particles. Beyond 700 fathoms they are usually of a blue or dark slate-color, having a thin upper layer of a red or brown. This red layer is a soft ooze, whilst the blue mud or clay beneath is very compact and tenacious. Much amorphous clayey matter and fine particles of mica, quartz, and other minerals are found in all these deposits, the mineral particles increasing in size as we approach the land.

Down to 1500 fathoms, we have generally found that Pteropod, larval Gasteropod, and Lamellibranch shells were tolerably abundant, and that there were many of the shore forms of Foraminifera, as Textularias, Rotularias, Nodosarias, Uvigerinas, Lagenas, etc. Pelagic Foraminifera occur throughout the deposit, but not in such abundance as in a true ocean-deposit. The frustules of Diatoms and their broken parts are numerous. Manganese grains are found in many of the bottoms, usually in the deeper soundings. We have also found imbedded in these muds pieces of wood, fruits, portions of fruits, and leaves of trees. Large pieces of rock, as pumice and granite, and rounded pebbles also occur. Our soundings near the southern ice-barrier were muds of a blue color, containing many granitic and other pebbles and blocks, mostly rounded, and many Diatoms, and resembled in most respects the deposits we found off the east coast of North America, Halifax to New York.

Beyond 1500 or 1700 fathoms, Pteropod and Heteropod shells are usually not found, and in 3000 fathoms hardly a Foraminiferous or other carbonate-of-lime organism remains.

Siliceous organisms occur at all depths, but at times their remains would seem to be completely removed.

These green and blue muds have been found to prevail in all the enclosed seas we have visited, as Arafura, Banda, Celebes, and China seas, Inland Sea of Japan; and in all these the carbonate-of-lime organisms would appear to be removed from the bottoms in depths less by some 400 or 500 fathoms than on open coasts.

In the green muds from 50 to 700 fathoms we have found those beautiful casts of Foraminifera, Pteropods, *Echini*-spines, and other carbonate-of-lime organisms, frequently in great numbers. These are of a dark green, pale green, and dirty white color. In all cases where these green internal casts occur we have many glauconite grains in the bottom. Beyond 700 fathoms these casts seldom occur, and when they do they are very sparingly distributed; and the same may be said of the glauconite grains which accompany them. River-muds, in which Pteropods, Radiolaria, and pelagic Foraminifera are usually wanting, are included in these deposits.

The following are the localities in which we have found the blue muds (an asterisk before the locality indicates that glauconite casts and grains have been found there):

* Off coast of Portugal; off Virgin Islands (?); * off coast of North America, Halifax to New York; off Guinea, coast of Africa; * off Cape of Good Hope; off Antarctic ice-barrier; * off Australia; * off New Zealand; * off New Guinea and Phillipines, and throughout the seas of the East-Indian archipelago; * off Japan; off east coast of South America.

The following are the depths of the soundings which have been placed under this head:—

Blue Muds.

fms.	fms.	fms.	fms.	fms.	fms.	fms.
1125	600	2020	1300	40	2100	2000
1290	3875	1750	2200	32	700	1075
1475	2425	2500	400	1100	90	2250
1380	1700	2325	150	700	150	20
1800	1240	1250	140	2800	375	2675
1000	1350	1675	75	1425	2225	1875
525	1340	1800	39	2550	2050	2225
900	1250					

Green Muds.

fms.	fms.	fms.	fms.	fms.	fms.	fms.
470	100	120	400	580	705	245
560	150	650	10	129	185	565
80	2200	950	70	255	37	775
75	290	1200	800	100	152	

(*b*) *Gray Muds and Sands.*—Near volcanic islands we have found that the deposits have a distinctive character, from the presence of the débris of volcanic rocks. The presence of pieces of pumice, scoria, etc., prevents this deposit having that clayey character so characteristic of the blue mud. The color is generally gray, but occasionally is a black sand or a more or less slate-colored mud. In some places the shells of oceanic organisms make up a large part of these muds.

Down to about fifteen hundred fathoms we have Pteropod, Heteropod, and surface Gasteropod shells, and the shore forms of Foraminifera are common. Deeper than 1500 fathoms, Pteropod shells are rare or entirely removed. Pelagic Foraminifera are found at all depths; but occasionally they and the siliceous organisms are quite absent at a depth of little over 2000 fathoms, and then we have a clay or mud with many small particles of pumice, scoria, etc. Manganese appears to be intimately associated with some of these bottoms, especially where the débris of augitic lavas are present, as at Sandwich Islands, Canaries, and elsewhere. Off the Desertas, in 670 fathoms, all the dead shells, pieces of Polyzoa, etc. had a slight coating of this substance, and we have had indications of the same thing in even less depths. In 1100 fathoms off the Canaries some pieces of shell had rather a thick coating; and in 1575 fathoms, not far from this place, the dredge brought up a great quantity of a Gorgonoid axis deeply imbedded in or coated with this black oxide of manganese.

In some localities this deposit extends to a great distance from the islands, as at Hawaii, 200 miles or more.

The following are the depths of the soundings which we have classed as

Gray Mud.

fms.	fms.	fms.	fms.	fms.	fms.	fms.
670	7	1000	260	20 to 100	2150	2650
1150	640	1125	360	75	2600	1525
930	1750	1070	1100	520	1050	420
1500	620	1000	50	630	500	590
278	1890	1675 (?)	150	600	2050	620
630	1525	465	600	1200	2875	680
560	450	675				

Occasionally a few casts of the Foraminifera have been observed of a red color. These were usually very rough, and had not the delicate hues of the green glauconite casts. One very remarkable exception occurs:—off the Crozets there were (in 600 fathoms) many beautiful casts of the carbonate-of-lime organisms of a pale straw-color. None of the glauconite grains were noticed in the same sounding or locality.

(*c*) *Red Mud.*—It has already been stated that the deposit

along the east coast of South America, from Cape San Roque to Bahia, differed from the deposits found along the shores of other continents and large islands in being of a red color. There can be little doubt but that this red color is due to the presence of the ochreous matter carried into the Atlantic by the South American rivers. There are reasons for thinking that the red color of some of the deep-sea clays in this region of the Atlantic may have a like origin.

The soundings near the shore and in shallow water have a deeper red color and contain larger mineral particles and fewer organic remains than those farther from land and in deeper water. The mineral particles are chiefly quartz and mica.

In all these soundings there are many pelagic and other Foraminifera, Heteropod, Pteropod, larval Gasteropod, and Lamellibranch shells, Coccoliths, and Rhabdoliths. Siliceous organic remains, as of Diatoms and Radiolaria, are almost quite absent in these bottoms. In some of the shallower depths a few red-colored casts of Foraminifera were observed; but these were rare, rough, and more or less imperfect.

The following are the depths of the soundings along this coast:—

fms.	fms.	fms.	fms.	fms.
1375	1650	32	1600	1015
500	675	400	1200	1275
2050	120	1715	700	2150

(*d*) *Coral-Mud.*—This is a deposit found in the neighborhood of coral reefs. It is characterized by a large quantity of amorphous calcareous matter, by the débris of coral reefs, by many large calcareous forms of Foraminifera, and by broken pieces of Polyzoa, etc. All the deposits about Bermuda are of this nature, extending from the edge of the reef down to a depth of 2500 fathoms. At 1000 fathoms the mud assumes a rose tinge; this deepens into a red color with greater depth, and the accompanying decrease of carbonate of lime and increase of clayey matter, until the coral-mud merges into the red and gray clays of the surrounding ocean. About Bermuda very few mineral particles were found. In some of the soundings to the S. W. of the island there were some small pieces of a green rock like those at St. Paul's Rocks, and probably serpentine. One or two pieces of quartz, or sanidin, a piece of mica, and a small piece of pumice (?) were also noticed. Dissolving away carbonate of lime in some of the shallower soundings only a trace of clayey matter remained with a perceptible rose tinge. No casts of the Foraminifera were noticed about Bermuda.

At the Virgin Islands, at Tongatabu, at Fiji Islands, at Cape York, Admiralty Islands, Honolulu, and Tahiti we also met with coral-muds. Except at Cape York, these muds appeared

to exist as a narrow band around the land, and had usually a considerable admixture of clayey matter and mineral particles. Where there was much clayey matter we found usually a few rough red casts of the Foraminifera.

The following is a list of the depths of the soundings included under coral-muds :—

At Bermuda.			At other places.		
fms.	fms.	fms.	fms.	fms.	fms.
2250	2100	1250	460	140	25
1820	1950	1575	390	210	100
950	2650	1500	625	610	40
430	1325	200	18	70	90
1375	1075	37	240	25	100
2450			315	16	
			255		

2. *Globigerina-ooze*.—After the deep-sea clays, this is the most abundant deep-sea deposit. It has occurred at all depths from 250 to 2900 fathoms. The *Globigerinæ*, which give at once the name and chief characteristic to this deposit, are really found all over the bottom of the ocean. Even in our deepest clays, if the surface-layers be selected and all the amorphous matter be washed away, one or two shells of some variety of pelagic Foraminifera can usually be detected. By pursuing this method I have failed only on one or two occasions. They appear to be quite absent in the Arafura Sea. It is, however, when they occur in vast numbers that they form the deposit known by this name; at least such is the sense in which it is here used. We did not find a Globigerina-ooze in any of the enclosed seas, in the Southern Ocean south of lat. 50° S., nor in the North Pacific north of latitude 10° N.

In the Southern Ocean only one small species of *Globigerina* was found in the surface-waters; but in the North Pacific many varieties of pelagic Foraminifera abound near the surface of the ocean. In other parts of the preceding oceans, and in the other oceans we have visited, it occurs in irregular patches, being always present in the open ocean when we have depths of less than 1800 fathoms. Its presence or absence at depths beyond 1800 fathoms is, however, determined by conditions at present unknown. A number of varieties occur both as to color and composition. Some specimens are nearly pure white, others have a rose-color, and others are red or dark brown. The red and brown color arises from the presence of the oxides of iron and manganese. In the white varieties the sediment, after dissolving away the carbonate of lime, is in some specimens abundant, in others not abundant, and is either of a red or slate-blue color. We find the former color to prevail in those soundings

far from continents and large islands, and the sediment is not abundant except where pumice or scoria is present. The latter, or slate-blue color, is found in those soundings more or less near continents and large islands; and it is suspected that this sediment has its source chiefly from the disintegration of these adjacent lands.

Mica, quartz, pumice, scoria, and other mineral products are met with; but in those soundings farthest from land a little piece of pumice or scoria may be the only trace of mineral particles.

In some specimens there are very many remains of organisms with siliceous shells, as Radiolaria, Diatoms and Challengerias; but in others these remains are almost entirely wanting. In three soundings in mid-Atlantic, between the Canary and Virgin Islands, and in several soundings in the South Pacific, manganese in the form of grains and nodular concretions is very abundant. As a rule, however, this substance occurs rather sparingly in Globigerina-ooze. In some instances we get little nodules of these bottoms, the shells as it were being run together by a siliceous cement. Many small pieces of cherty-like mineral also occur, which are angular and soft, and do not look as if they had been transported. Manganese nodules occurring in the Globigerina-ooze have often a nucleus of a yellow and green color, in which Globigerina-shells can be seen; but their carbonate of lime has been entirely removed, and replaced by a silicate. There are reasons for thinking that these indications of flint (?) occur only in those samples where the siliceous shells of Radiolaria, Diatoms, etc., are wanting, and do not occur where these organisms are present. A reëxamination of all the bottoms must be made before this statement can be definitely affirmed. Casts of Foraminifera occur very sparingly in Globigerina-ooze; in the purest samples not at all. In those with an admixture of clayey matter we have frequently one or two partial casts of a very rough character. In two soundings, Nos. 211 and 301, in the Pacific, we found the Foraminifera not only filled, but also coated, with a red substance, so that we had both an internal and an external cast, the two being connected by little rods representing the foramina of the shell. In these soundings there was much clayey matter and disintegrating pumice and scoria.

In a few soundings in the Pacific, as No. 304, we have had a Globigerina-ooze on the surface of the bottom, and a foot beneath a nearly pure red or brown clay. Again, as in Nos. 268 and 307, we have the reverse arrangement, a clay occupying the surface, and the deeper layers having many *Globigerinæ*. In all these cases the surface-layer has been normal with the

other soundings in the same region as to depth. In the first case we might bring in elevation to account for the Globigerina-ooze overlying the red clay, or we might suppose that chemical changes are going on in the deeper layers which remove the carbonate of lime. In the second case we may account for a red clay overlying a deposit with many *Globigerinæ* in it by supposing a depression of the bottom after the latter had been laid down; or we may believe that agencies are now removing carbonate of lime from the surface-layer, and that these were not active in some past time.

This deposit occurs, in one sounding, in the Pacific at a depth of 2925 fathoms in mid-ocean. In the eastern part of the Atlantic it occurs also at great depths.

The following is a list of the depths at which we have found a Globigerina-ooze :—

Atlantic Ocean.

fms.	fms.	fms.	fms.	fms.	fms.
1090	1900	2200	1350	1425	2275
1525	1950	1675	900	1650	2475
2250	2325	1675	2025	2300	2200
2225	1420	1240	2660	2300	2150
1945	2575	1000	2675	2400	2275
1975	2450	2500	2400	2400	2050
1150	2475	2275	1500	2075	1900
2300	2175	1850	1900	780	2025
2025					

Southern Ocean.

fms.	fms.	fms.	fms.	fms.	fms.
1900	1570	1375	1600	1800	2150

Pacific Ocean.

1974	1350	1675	2925	1915	1500
1100	1450	2000	2425	1600	1825
275	1700	1100	1940	2025	1775
400	1400	1850	2075		

3. *Radiolarian Ooze.*—Organisms with the siliceous skeletons abound in the surface-waters, and apparently also in the deepest waters, of all the oceans and seas we have visited.* The skeletons of these organisms are found in all, or almost all, the sea-bottoms. Even in those cases where at first sight they would seem to be quite absent, a more careful examination (by dissolving away a large quantity of carbonate of lime where this exists, and examining the sediment by careful washing in the case of clays, etc.) will usually reveal a Radiolarian skeleton, a Diatom frustule, or broken portions of these.

* They are, however, much more numerous in the Pacific than in the Atlantic, especially in the equatorial waters.

It is, however, only in some limited areas that these exuviæ rise into such prominence as to be characteristic of the deposit taking place. Such is the case in the Antarctic, where we have a Diatom-ooze, and in the Western and Middle Pacific, where we have the above deposit.

Our deepest sounding (4475 fathoms or 4575) was a Radiolarian ooze; with the exception of a little amorphous matter, manganese particles, a few yellow cherty-like particles, and some pumice pieces, this bottom was entirely composed of the exuviæ of organisms with siliceous skeletons—as Radiolaria, one or two Diatoms, and some organisms which seem to be undescribed (Challengerias), but which are numerous in the deeper waters of the Pacific.

A section of about three inches came up. The upper two were of a red color, due to the presence of much manganese; the lower one was of a pale straw-color, and contained relatively few manganese grains.

In our trip from the Sandwich Islands to the Society Islands we again met with Radiolarian ooze. Between 7° and 12° north of the equator we came on a patch represented by four soundings, some of these containing not a single *Globigerina;* then just on the equator, in two soundings, one at a depth of 2925 fathoms, we got a Globigerina-ooze containing a good many Radiolaria. Between 2° and 10° south we again had a patch of Radiolarian ooze represented by three soundings, and containing only a few pelagic Foraminifera or their broken parts. The occurrence of this patch of Globigerina-ooze in the position indicated, and the comparative or total absence of the Globigerina-shells in the deposits a little to the north and south of it, is sufficiently curious and significant. It will be well to note that, in the Globigerina-patch, manganese and other mineral particles are much less abundant than in the adjacent Radiolarian. Note also the presence of the south equatorial current and the dip of some isotherms over the Globigerina-patch. One or two soundings to the east of Japan might have been classed under this head; but in them the siliceous remains do not make up over one third of the sample in bulk. Generally it may be said that in the Western and Middle Pacific the siliceous remains of Radiolaria and Diatoms are abundant in the deposits, whereas in the South Pacific and Atlantic they are much less so, or absent in the bottoms.

The following are the depths of the soundings placed under the head of Radiolarian ooze:—

fms.	fms.	fms.	fms.
4575	2700	2250	2350
4475	2900	2600	2750
2750			

4. *Diatomaceous Ooze.*—South of the latitude of the Crozets, on our southern trip, we found Diatoms abundant, both in the surface waters and in the bottom.

About the Crozets, Kerguelen, M'Donald's Islands, and close to the ice-barrier, the frustules of these organisms were very abundant in the soundings, but were masked by much land-débris. Between the parallels of 53° and 63° S., i. e., between the north edge of the ice and the latitude of M'Donald's Islands, we got in three soundings a pale straw-colored deposit, composed principally of the frustules of Diatoms and their broken-down parts. In addition, they contained a good many Radiolarian remains, a few specimens of one small species of *Globigerina*, a few particles of mica, quartz, and granitic pebbles, also a little amorphous blue clayey matter. No manganese particles were noticed. The one of these soundings which is nearest to the ice contains much amorphous clayey matter and larger mineral particles than the other two. When dried this deposit is of a white color, and is very light.

The depths of the soundings referred to above are 1260, 1975, and 1950 fathoms.

5. *Red and Gray Clays.*—By far the most abundant oceanic deposits are the deep-sea clays. These are of a gray, red, or dark chocolate-color, and are found at depths greater than 2000 fathoms. The red and chocolate-colors of many of these clays are due to the presence of oxide of iron in the first and oxide of manganese in the latter instance. Most of them contain some carbonate of lime in the form of Globigerina shells; in one or two instances, however, I have not been able to find a single shell, nor has acid caused the least bubble of effervescence. The remains of siliceous organisms occur also in great numbers in the clays of some regions—so much so that, as I have stated, some of those soundings in the Northwest Pacific which have been classed as clays might have been called Radiolarian ooze. In most places, however, they are nearly or quite absent. These clays are not amorphous in the true sense of the word—not amorphous in the sense in which a chemical precipitate is amorphous. They all contain small white and other colored mineral particles in great abundance—exceedingly small particles, so as to be recognized only under the high powers of the microscope. They contain amorphous matter, it is true; but it is doubtful if this ever makes up so much as a half of any sample in bulk. They also contain larger mineral particles, as quartz, mica, pumice, scoria, peroxide of manganese, and other mineral particles. Quartz and mica particles appear to be present only in some localities, as the North Atlantic and elsewhere. Peroxide of manganese is perhaps always present in the form of grains or nodules, sparingly distributed in some

regions, in others making up nearly a half of the deposit or formation.

Pumice (the common feldspathic or the highly vesicular augitic variety) and scoria appear to be universally distributed over the bottom of the ocean, and to be abundant in most of the deep-sea clays and present in them all. In those clays farthest from continents and islands, sharks' teeth, ear-bones of whales, other bones of whales, and bones of turtles (?) are very frequently found, all these having usually a more or less thick coating of peroxide of manganese. The following are the depths at which we have found these red and gray clays:—

Atlantic.

fms.	fms.	fms.	fms.	fms.	fms.	fms.
2740	2575	3025	2475	2650	2875	2700
2950	2435	2800	2600	2500	2750	2350
2750	2385	2960	2850	2360	2750	2275
2800	2675	2850	2675	2575	2700	2550
3150	3000	2700	2800	2850	2750	2650
2720	2975	2600	2650			

Southern and Pacific Oceans.

fms.	fms.	fms.	fms.	fms.	fms.	fms.
2600	2275	2500	2900	2740	3000	2250
2600	2550	2425	2775	3125	2900	2335
2600	2650	3900	2050	2025	2610	2270
2900	2450	3600	2530	2850	2350	2400
2650	2325	2900	2900	2950	2325	2600
2325	2300	2300	2300	2875	2385	2550
2450	2475	2575	2350	2775	2450	2300
2440	2450	2800	2900	2225	2375	

6. *The Manganese in Deposits.*—The peroxide of manganese, in the form of minute grains, concretions, nodules, aggregations, or incrustations, occurs widely distributed in ocean-deposits. It has been met with most frequently in the deep-sea clays; indeed it seems to be present in all of them, sparingly in some localities, abundantly in others.

It is, however, not confined to these clays; it has been found in most of the other deposits and at all depths greater than 500 fathoms. In the Globigerina- and Radiolarian-ooze and in the clays it usually assumes the forms of minute grains, pellets and nodules. In those bottoms to which it gives a chocolate color, the higher powers of the microscope show small, round, red-brown grains of manganese, often with a dark spot in the center.

The nodules vary from little pellets to masses of a large size and of several pounds in weight. In some regions everything at the bottom, even the bottom itself, would appear to be overlaid by and impregnated with this substance. In the foregoing list, as at No. 318 and elsewhere, some of the nodules have

been described with a little detail. The varieties which are most commonly procured may be here mentioned:

(*a.*) Nodules of a black-brown color throughout, the manganese being laid down in concentric layers, which are evident from their enclosing lines of red clay.

(*b.*) Nodules having a nucleus of pumice which is surrounded by concentric layers, the original nucleus being often very deeply impregnated by spider-like ramifications of the manganese, or nearly the whole pumice may be replaced by manganese. When pieces of bone have formed the nucleus we have much the same state of things. The compact bone of the tympanics of cetaceans does not, however, appear to alter so rapidly as other bone; and hence it may be that we get ear-bones in such great numbers.

Sharks' teeth of all sizes (one was four inches across the base) are frequent, and are sometimes surrounded by concentric layers of nearly an inch in thickness. A siliceous sponge (*Farrea*) was found imbedded in two inches.

A mass of red clay may occupy the center of the nodule. The nucleus is occasionally a mottled yellow-and-green substance, with agate bands in some parts, and *Globigerina*, the carbonate of lime being replaced by silicate in these last. This nucleus can be cut with a knife, like new cheese, or it is hard and brittle, breaking with a conchoidal fracture.

Large flat aggregations occur which seem to have been formed on hardened flat portions of the bottom.

The Globigerina-shells and Radiolaria are at times covered by small specks of the manganese; and in the former these are deposited in the substance of the shell.

In several soundings and dredgings to the southwest of the Canaries we got very many large pieces of a branching Gorgonoid which were deeply coated and impregnated with manganese. This was in a depth of from 1100 to 1575 fathoms.

In 670 fathoms, off the Desertas, the dead shells, pieces of coral, Polyzoa, etc., were all coated with a thin film of the peroxide of manganese; and we have had indications of the same thing in still shallower water.

In some of the Radiolarian oozes, and in other deposits, we have found the manganese more abundant in the upper layers than in the lower, and *vice versâ*.

The following are the localities where we have met the manganese in greatest quantities:

Off the Canary Islands; Mid-Atlantic, between Canary and Virgin Islands; southwest of Australia; north and south of the Sandwich Islands; north of Tahiti; generally in the South Pacific in our course between Tahiti and Valparaiso.

Further observations may show that manganese abounds in those places where we have much of the débris of augitic lavas.

7. *Abyssal Rhizopods, Bathybius.*—The manganese nodules, sharks' teeth, etc., which we got in our deepest trawlings have very frequently small branching tubes, composed of clay and sandy particles, running over their surfaces. These belong to a Rhizopodal organism. The sarcode which fills these tubes contains many large brown pigment-cells, and small bioplasts are collected in clumps at distances along the length of the tube, or are scattered throughout it.

Tubes of a similar nature, but composed of pieces of *Globigerina*, Radiolaria, etc., would appear to be rather abundant on some of the oozes, and to run irregularly over the bottom.

In the clays we always get some arenaceous forms of Foraminifera when there has been a successful haul with the trawl. Their shells are made up of pieces of manganese, clay, and small mineral particles, and they contain the same kind of sarcodic substance as the tubes above referred to.

An attached calcareous form (c. f. *Carpenteria*) has been found in rather deep water, and Biloculinas, Nodosarias, Triloculinas, and other forms have been frequently procured alive. These last have orange-colored pigment-cells, in which respect they resemble surface Rhizopods. A living specimen of *Orbulina* or *Globigerina* undoubtedly from the bottom has not yet been met with.

In the early part of the cruise many attempts were made by all of the naturalists to detect the presence of free protoplasm in or on the bottoms from our soundings and dredgings, but with no definite result. It was undoubted, however, that some specimens of the sea-bottom preserved in spirit assumed a very mobile or jelly-like aspect, and also that flocculent matter was often present.

Mr. Buchanan determined that the flocculent matter was simply the amorphous sulphate of lime precipitated by spirit from the sea-water.* Subsequently a number of experiments were made upon the behavior of this amorphous precipitate when precipitated with different quantities of spirit and when treated with coloring solutions. The precipitate was also examined alone and mixed up with some of the ooze. The ooze was examined at the same time, and in the same manner, but without having been treated with spirit. The results were briefly these:

(*a.*) When sea-water is treated with twice its volume of spirit or less, nearly the whole of the amorphous precipitate assumes the crystalline form in a short time.

* See a paragraph from Mr. Buchanan's report on the following page.

(*b.*) When treated with a great excess of spirit the precipitate remains amorphous, and assumes a gelatinous aspect.

(*c.*) This gelatinous-like sulphate of lime colors with the carmine and iodine solutions, and when mixed with the ooze has, under the microscope, the appearances so minutely described by Häckel.

(*d.*) The ooze washed with distilled water, or taken just as it comes up, and treated in the same manner with coloring-solution, does not show these appearances. The jelly-like aspect and the matter colored with carmine can always be removed from the spirit-preserved specimens of the ooze by treating with distilled water.

(*e.*) In all cases the jelly-like or mobile aspect of the oozes is found to be due to the presence of the flocculent precipitate from the sea-water associated with the ooze.

(*f.*) No free albuminous matter could be detected.

When it is remembered that the original describers worked with spirit-preserved specimens of the bottom, the inference seems fair that *Bathybius* and the amorphous sulphate of lime are identical, and that in placing it among living things, the describers have committed an error.*

* Mr. J. Y. Buchanan, chemist and physicist to the Expedition, makes the following remarks on *Bathybius* in his Report, p. 605 of the Proc. Roy. Soc., vol. xxiv. Read March 16. In connection with carbonic acid I may mention that I have frequently tested waters, and especially bottom-waters, for organic matter. None of the methods in use for determining this substance in drinking-water giving satisfaction when applied to sea-water, I had to content myself with endeavoring to detect its presence. If the jelly-like organism which had been seen by some eminent naturalists in specimens of ocean-bottom and called *Bathybius* really formed, as was believed, an all-pervading organic covering of the sea-bottom, it could hardly fail to show itself when the bottom-water was evaporated to dryness and the residue heated. In the numerous samples of bottom-water which I have so examined, there never was sufficient organic matter to give more than a just perceptible grayish tinge to the residue, without any other signs of carbonization or burning. Meantime my colleague, Mr. Murray, who had been working according to the directions given by the discoverers of *Bathybius*, had actually observed a substance like "coagulated mucus," which answered in every particular, except the want of motion, to the description of the organism; and he found it in such quantity that, if it were really of the supposed organic nature, it must necessarily render the bottom-water so rich in organic matter that its presence would be abundantly evident when the water was treated as above described. There remained, then, but one conclusion, namely, that the body which Mr. Murray had observed was not an organic body at all; and on examining it and its mode of preparation I determined it to be sulphate of lime, which had been eliminated from the sea-water always present in the mud, as an amorphous precipitate, on the addition of spirit of wine. The substance when analyzed consisted of sulphuric acid and lime; and when dissolved in water and the solution allowed to evaporate, it crystallized in the well-known form of gypsum, the crystals being all alike, and there being no amorphous matter among them.

These observations were made chiefly on the voyage from Hong Kong to Yokohama in the first quarter of the year 1875; and it subsequently occurred to me that an approximate determination of the organic substance in sea-water might be effected in the following way: Supposing the amount of carbonic acid in the water to be known, let a little permanganate of potash be added to a sample of it,

8. *Origin of Deep-Sea Clays. Relative rate of Deposition of Deposits. Conclusion.*—The very wide distribution of pumice, vesicular lava, or light scoriæ has been already alluded to. Some of the bottoms which have been classed under the head of clays, as 2900 fathoms south of Tongatabu, are largely made up of pumice in a fine state of division. Pumice or vesicular lavas have, in short, been found in all the kinds of deposits, most abundantly in the vicinity of volcanic islands and in the deep-sea clays. It appears to be universally present, and its disintegration is most probably the chief source of the clayey matter found in oceanic deposits. North of the Sandwich Islands we for several days got small pieces of pumice floating on the surface, most of the pieces being covered with a fungoid growth. In this connection it may be well to remember that Mr. Bates states somewhere that he found pumice rather common, floating on the surface of the Amazons, over a thousand miles from the nearest volcanic region. Many instances are given by Sir Charles Lyell of volcanic ashes having been transported to great distances by the wind.

At Honolulu Mr. Green informed me that *Pele's hair* had been picked up in his garden there after an irruption of Kilauea in Hawaii, a distance of about 180 miles from the crater. If there be an ash after the carbonate of lime is removed by carbonic acid or other agent, this will be another source of the clay.

Mr. Buchanan has determined in the clays the presence of copper, cobalt, and nickel, in addition to iron and manganese. Remembering this, one is tempted to suggest the presence of meteoric or cosmic dust in these deposits.

When we have had a good haul from a red-clay bottom, when the bag comes up full of nodules, tympanic bones, and sharks' teeth, we cannot resist the idea that we are dealing with things of a vast antiquity, and that we have evidences of a very slowly accumulating deposit. When there has been no reason to suppose that the trawl has sunk more than one or two inches in the clay, we have had in the bag over a hundred sharks' teeth and between thirty and forty ear-bones of cetaceans; some of these have been imbedded in over an inch of the manganese, arranged in concentric layers, while others have had just a trace of manganese on them, or none at all. We have every reason to suppose that the aggregation of the manganese around these relics is a very slow process, and that

and let the carbonic acid be determined in the usual way by boiling the solution. If the water contained any easily oxidizable carbon compound, we should obtain more carbonic acid in the second than in the first determination, and the difference would correspond approximately to the amount of organic carbon present. In several waters which I have treated according to this principle, I have found from two to five milligrams of carbon per liter.

consequently the occurrence of these deeply imbedded and recent teeth and tympanics in the same surface-layers argues strongly in favor of an exceedingly slow rate of deposition. These vertebrate remains are most abundant where the manganese abounds, but occur also in the red and gray clays, especially in those the farthest from the land, and where we may suppose the rate of deposition to be reduced to a minimum.

In the Globigerina, Radiolarian, and Diatom oozes we have found during the whole cruise only one or two sharks' teeth and perhaps one tympanic bone. In shore-deposits they were even more rare. These facts, taken with others that will at once suggest themselves, go to show, as might be expected, that the shore-deposits accumulate faster than the organic oozes, and these last faster than the deep-sea clay. The organisms in our Radiolarian ooze appear to resemble very closely, and in their relative proportions, those described from the Barbadoes earth. Those described from the Oran deposit in Algeria are very like those in the blue muds taken along the course of the Japan stream. The Globigerina-oozes which we get in shallow water resemble the chalk much more than those in deeper water, say over 1000 fathoms. It is possible that deposits similar to those taking place in deep water, far away from the great continental anticlines, may never have been elevated into dry land.

In conclusion, large quantities of the various bottoms have been stored with a view to future work, and a large amount of material bearing on the subjects treated of in this Preliminary Report have been accumulated. When these come to be carefully examined and compared, with the aid of appliances and conveniences not to be had on board ship, many of the statements herein made may require to be altered and amended, and other facts and relations, more curious and interesting than any hinted at, may be revealed.