X.—Scottish National Antarctic Expedition, 1902–04: Deep-Sea Deposits. By J. H. Harvey Pirie, B.Sc., M.D., Geologist and Surgeon to the Expedition. (With a Map.)

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The material brought home by the *Scotia* and available for examination consists in all of fifty-five samples of deposits from the floor of the ocean. The majority of these consist of true "deep-sea" deposits, *i.e.* material from depths of over 100 fathoms; but, for convenience, the description of a few samples from shallow waters (mostly in the neighbourhood of the S. Orkneys) is also included in this report.

The number of deposits is considerably less than the number of soundings taken by the Expedition, because, for various reasons, a sample of deposit was not obtained in every case where a sounding was taken.

In the majority of the shallow-water soundings taken in the neighbourhood of the Expedition's winter quarters in the S. Orkneys, a simple sounding-lead was used and no effort made to obtain a specimen of the mud from the bottom. In the case of the deep-sea soundings a lead was also used in a few of the earlier soundings taken between the Falkland Islands and the S. Orkneys, and in these cases, although a small amount of material was obtained from the tallow on the bottom of the lead, such samples cannot be regarded as giving a true representation of the nature of the sea-floor, and the material available is too small for a full examination. Sometimes the sounding-tube came up empty; on one occasion at least this was due to the fact that a tube (Buchanan) was used without any rubber valve at the top, so that the plug of mud, which probably had been in the sounding-tube, could easily have been pushed out during the rapid raising of the sounder from the bottom. On several occasions there was evidence from the presence of dents on the tubes that it had gone down on "hard ground"—whether a general rocky bottom or an isolated boulder of rock, it is, of course, impossible to say with certainty in every case; but from the fact that in one or two instances a subsequent trawling from the same situation brought up an abundant supply of soft material, the likelihood would be that in these instances at least the tube had simply happened to light upon one of the boulders which, dropping from melting icebergs, must be scattered fairly thickly over the floor of the Antarctic and sub-Antarctic seas; in no instance did the emptiness of the sounding-tube appear to be due to the bottom material being of so clastic a nature that it had not sufficient cohesion to remain in the tube during the process of hauling up. Another reason for each sounding not furnishing a sample of deposit is to be found in the snapping of the sounding-wire and loss of sounding-tube (and perhaps also water-bottles and thermometers, to say nothing of many fathoms of wire). This, unfortunately, was a not

uncommon occurrence. It did not often happen while sounding in the Weddell Sea, where the ship was usually in "small water"—the swell being broken by the abundant pack ice,—but it occurred only too frequently in the more stormy seas to the north and north-east of that area. So much rough weather was, in fact, encountered that it was often impossible even to attempt a sounding, the rolling of the ship being so great; and even if the lowering of the sounder was accomplished safely, it was no uncommon occurrence for the wire to snap either before winding in could be started or soon after it had commenced its upward journey. On a few occasions the wire snapped through catching on floating ice, but this was a rare accident. From the point of view of deposits the paucity of material from the region between the Falkland Islands, the S. Orkneys, and the S. Sandwich group is most to be deplored, and, though to a somewhat less extent, the comparative infrequence of those obtained along the 10th meridian W. long. between 60° S. lat. and Gough Island.

The sounding-machine used was a Lucas machine, which, being driven by a rope from a special small engine, could reel in at about the rate of 100 fathoms per minute. The sounding-tubes employed were in most instances those devised by BUCHANAN for bringing up a sample of both deposit and bottom-water, the mud tube being 1 inch wide and either 12 inches or 18 inches long, usually the longer tube being employed. Under the systematic description of the samples, if nothing is mentioned as to the sounding-tube employed it is to be understood that a Buchanan tube was used. These tubes were found eminently satisfactory in their working. One practical point in sounding was found by experience to be that kinking and snapping of the sounding-wire could be to a great extent prevented by introducing a 10-fathom length of hemp rope between the lower end of the wire and the sounder.

At the commencement of the voyage from the Falklands southwards an ordinary deep-sea lead was used on a few occasions and also a tube of the Baillie pattern supplied by the Admiralty. The use of the former and the fact that a number of sounding-tubes were lost are responsible for the small number of samples obtained from this locality. In a few of the shallow-water soundings a Lucas "snapper" lead was employed; these naturally tend to bring up pebbles, and if the jaws are not quite closed any mud or clastic material will in all probability be washed out. For the soundings taken while in winter quarters at the S. Orkneys a small Lucas machine mounted on a sledge was used with, in most instances, a simple lead attached so that no bottom material was brought up. The few samples obtained came either from a snapper-lead or a small hand-dredge.

The plugs of mud from the Buchanan sounding-tubes were pushed out entire by a wooden rod or piston accurately fitting the interior of the tubes. In most cases the material was then simply bottled and brought home unaltered for detailed examination. In very few instances was any obvious naked-eye difference to be made out in the appearances presented by the more superficial and by the deeper portions of the plug of deposit, although in a few cases where the specimen was divided into two and the parts

preserved separately subsequent examination did reveal slight differences. The results obtained by Dr PHILIPPI (1) of the German Antarctic Expedition show, however, that considerable differences may exist between the surface layers and deeper portions of the deposit in certain areas and indicate the importance of dividing the plug of deposit into two or more portions for separate examination, and also perhaps of using longer mud tubes on the sounder. Dr PHILIPPI recommends tubes 1 metre long. Tubes longer than this have the disadvantage that they may stick so firmly that when reeling in is commenced the wire is very apt to snap.

Material was also obtained in a number of instances from the trawl. When this was small in amount it had, of course, to be taken simply as it was, possibly partly washed on the way up and not truly representative of the bottom material *in situ*; but where abundant, and if a sample were desired in bulk, the outer portions were discarded and a portion taken from the interior of the mass of mud in the trawl, as this could be regarded as truly typical of the deposit. The whole of the remainder of the material was then emptied into a large zinc cylinder built up of a series of rings, at the bottom of each ring being a sieve of wire mesh, the sizes of the mesh in the various rings being $1\frac{1}{2}$ inches, $\frac{1}{2}$ inch, $\frac{1}{12}$ inch, and $\frac{1}{24}$ inch respectively. In this cylinder the material was well washed with a stream of water from a hose, all clayey matter and particles under $\frac{1}{24}$ inch diameter washed away, and the rock fragments, pebbles, gravel, sand, etc., sorted out according to their size by the different sieves. The material from each of these was preserved separately for further examination.

Whenever a specimen of deep-sea deposit was procured, notes were made at the time of the mode whereby it was obtained and of its amount, colour, consistency, and general physical characters. A rough examination was frequently made on board at the time of obtaining it, but in nearly every instance the detailed examination was made on the return home of the Expedition.

This detailed examination was made after the plan devised by Sir JOHN MURRAY and Professor RENARD, and described by them in the volume of the *Challenger* reports dealing with deep-sea deposits (2). This plan could, of course, only be carried out in its entirety where a sufficient amount of the sample was available. There was amply sufficient in the majority of cases; but where there was not, the quantitative determination, for instance, of calcium carbonate, had to be omitted and only an estimation given of the relative amounts of calcareous organisms and of the other constituent elements of the sample. For a full description of the method the *Challenger* volume on deep-sea deposits may be consulted: the following is a brief description of the routine I followed.

The macroscopic characters, both in the wet and dry condition, were first noted. Then the percentage of calcium carbonate in a dried weighed sample was ascertained by analysis. The residue obtained after removal of the carbonate of lime was then well rubbed, stirred, and shaken with abundance of water, and submitted to a process of fractional decantation. The first decantations carry off that part of the residue

designated "fine washings"; this portion contains amorphous and clayey matter, minute mineral particles mostly under 0·02 mm. in diameter and always less than 0·05 mm., and some of the siliceous organisms. In the next decantations siliceous organisms, if they are present, predominate; but some of the lighter mineral particles, between 0·05 and 0·02 mm. in diameter, will also be found. The heavier minerals, including practically everything over 0·05 mm. in diameter, remained behind after all the lighter material had been decanted off. Each of the decantations was allowed to settle down in a basin and the material was then submitted to microscopic examination. The percentage of the heavier minerals was frequently checked by weighing and comparison with the weight of the original sample; but as some allowance had always to be made for the lighter minerals carried off in the second decantations, the percentage figure given for "minerals" can only be regarded as an estimation—in most cases, however, probably a fairly accurate approximation of the amount over 0·02 mm. in diameter. The figures given for the percentages of siliceous organisms and of "fine washings" are, of course, also only approximate estimates; but as the routine followed in every case was the same, they may safely be taken, if not as absolutely accurate, at least as of fairly accurate comparative value.

Where a sample contained calcareous organisms, a similar rubbing-down process was gone through with a specimen unattacked by acid, so that the foraminifera and other calcareous organisms might be sorted out. All foraminifera picked out from deposits at any stage (and in a number of instances also original samples of deposit for separation) were sent to Mr F. Gordon Pearcey for examination, and I am indebted to him for the identification of those which are referred to in this report. I have also to express my indebtedness to Sir John Murray for instruction in the *Challenger* office in the general methods of examining deep-sea deposits; to Professor James Geikie of the University of Edinburgh, in whose laboratory the examination of the material was carried out; to his assistant, Dr Campbell, for help in identification of minerals and rock specimens; and lastly, to the University of Edinburgh for a grant from the Moray Research Fund for expenses connected with the work.

Material Available for Examination.

Of the fifty-five samples brought home by the *Scotia*, one (No. 1) comes from the tropical portion of the S. Atlantic, namely from the Abrolhos Bank, off the coast of Brazil, and, more especially since it is fragmentary in character, needs no further description than that given in the systematic account of the samples. One (No. 2) is a typical terrigenous mud from the shallow water of Stanley Harbour in the Falkland Islands. One (No. 29) is from a depth of 56 fathoms on the Burdwood Bank, lying to the south of the Falkland Islands. Five samples (Nos. 24*a*, 24*b*, 24*c*, 25*a*, 25*b*) are from depths of under 100 fathoms, in close proximity to the land of the S. Orkney Islands, whilst 2 others (Nos. 22 and 23) are from just over 200 fathoms not

far off these islands. One (No. 34) comes from 161 fathoms off the coast of Coats Land. The remaining forty-four samples are all true deep-sea deposits from the S. Atlantic Ocean and Weddell Sea.

General Description according to Geographical Distribution.

A. *Between the Falkland Islands, S. Orkneys, and the Sandwich Group.*—Nine samples were obtained from this area, which is one of great interest from the point of view of the bottom deposits, owing to the rapid transitions which must occur from one type to another. Unfortunately, for reasons mentioned already, their number is small, and some of them were obtained only in very small quantities, so that exact determinations were not always possible.

On the Burdwood Bank, towards its eastern end, the one specimen obtained (No. 29), taken in conjunction with the character of the material brought up by the trawl, which contained large numbers of foraminifera and other calcareous organisms, but practically no mud, indicates that this point is beyond the edge of the belt of terrigenous muds surrounding the S. American continent, and within the Globigerina ooze zone.

In lat. 56° 54′ S., long. 56° 24′ W., at a depth of 1946 fathoms (No. 28), a Globigerina ooze was obtained, containing 24 per cent. of $CaCO_3$ with characteristic cold water forms of foraminifera—viz., *G. dutertrei* and *G. pachyderma*—dominant, but also most of the foraminifera characteristic of the S. Atlantic Globigerina oozes. The mineral particles in this sample form 40 per cent. of the whole, and are largely volcanic in their origin. Between this point and the S. Orkneys, two samples (Nos. 27 and 26*b*), although marked on the chart as lying within the Diatom ooze band, might more properly be described as volcanic muds or sands, the mineral particles, chiefly of volcanic origin, constituting such a large proportion of their bulk. It is possible that these three samples are the product of submarine volcanic activity in the neighbourhood; but, on the other hand, they are quite within the range of distribution by ice and winds of the active volcanoes and volcanic rocks of the S. Shetlands and W. Antarctica.

The siliceous organisms in No. 26*b* (lat. 59° 23′ S., long. 49° 08′ W., 2180 fathoms) form 15 per cent. of the deposit, but consist as largely of radiolaria as of diatoms. A few miles to the south-east (No. 26*a*, lat. 59° 43′ S., long. 48° 10′ W., 2110 fathoms) the percentage of siliceous organisms (again containing a fair proportion of radiolaria, although relatively less) falls to ten, and the deposit approximates in character to an Antarctic terrigenous deposit (glacial mud). It seems doubtful whether a really typical Diatom ooze is to be obtained in this neighbourhood. Further to the east (samples Nos. 3 and 4 obtained on the *Scotia's* first voyage southward in lat. 58° 22′ S., long. 45° 00′ W., 1698 fathoms, and lat. 59° 32′ S., long. 43° 10′ W., 2307 fathoms) the indications point to the bottom material being more like the classical type of

Diatom oozes, although there is still a very large proportion of mineral particles. The preliminary reports sent home by Dr HEIM (3) of Lieut. FILCHNER'S Expedition show that still further to the east, in the neighbourhood of S. Georgia, the Diatom ooze band extends considerably further to the north than is shown on the *Challenger* map, in that published by myself in the *Scot. Geog. Mag.* in 1905 (4), and in MURRAY and PHILIPPI'S *Valdivia* report (5), and its limits must apparently be extended so as to pass to the north of S. Georgia, but here again radiolaria form a considerable part of the siliceous contents.

Two samples obtained somewhat to the west of the southern end of the Sandwich group were too fragmentary to determine with any exactitude, but appear to be transitional between Diatom oozes and glacial clays.

B. *Weddell Sea.*—All the samples obtained in the Weddell Sea to the south of the 60th parallel consist of material almost entirely of terrigenous origin, and are dealt with at length (p. 677 *et seq.*) under the heading "Terrigenous Deposits, particularly Glacial Muds and Clays."

C. *Between* 60° *S. latitude, Gough Island, and S. Africa.*—Five samples (Nos. 45 to 49) were obtained along the meridian of 10° W. long., between 60° S. latitude, and Gough Island; two between Gough Island and Cape Town.

In this area the northern boundary of the Antarctic glacial clay lies probably a little north of the 60th parallel, and the transition from it to the Diatom ooze band must be a fairly sharp one. Sample No. 44 (from lat. 61° 21′ S., long. 13° 02′ W., 2764 fathoms) is a tough clay approximating in some respect to an abyssal Red clay, although differentiated by containing a large amount of the finest rock flour of terrigenous origin. Not a single diatom, however, could be found in it, whereas in No. 45 (from lat. 56° 58′ S., long. 10° 03′ W., 2518 fathoms) siliceous organisms constitute 55 per cent. of the whole deposit, diatoms forming the greater part of this. This deposit is not, however, a typical Diatom ooze, but is intermediate in type between it and a volcanic sand. It contains 40 per cent. of minerals, mostly of evident volcanic origin. This point is about midway between Bouvet Island and the Sandwich group, both volcanic in nature; but considering the prevalent westerly winds in this region, the latter is the source from which the pieces of pumice and volcanic minerals have in all probability been derived.

In lat. 51° 07′ S., long. 9° 31′ W., 2103 fathoms (No. 46), the sounding-tube came up empty, having been apparently on hard ground, but the trawl brought up a small quantity of a characteristic Diatom ooze of a light straw colour when wet, almost pure white when dry, and of a floury consistence with very little grittiness. The percentage of siliceous organisms is as high as 80, diatoms predominating largely over radiolaria. Mineral particles form only 5 per cent. here, whilst there is 9 per cent. of $CaCO_3$, chiefly foraminifera.

In lat. 48° 06′ S., long. 10° 05′ W., 1742 fathoms, the bottom material (No. 47) is transitional in type between Diatom ooze and Globigerina ooze, containing as it does

55 per cent. of foraminifera (chiefly cold-water forms—*Globigerina inflata*, *G. dutertrei*, and *G. pachyderma*) along with other more Northern types, but also 30 per cent. of siliceous organisms, chiefly diatoms, although radiolaria are fairly abundant. The position of the Diatom ooze band on this meridian must therefore be shown as in my chart, *i.e.* shifted northwards from the position in which it is marked in the *Challenger* map and also in the *Valdivia* report. The trawl in this situation, on the southern extension of the mid-Atlantic rise discovered by the *Scotia*, brought up a considerable quantity of rock fragments, almost all under 2 inches in diameter and mostly angular or sub-angular in shape. A few showed glacial striæ, one black shaley pebble being particularly well rounded and striated. The rocks were of rather greater variety than those obtained in the Weddell Sea, where granitic and gneissic rocks predominate. They included white quartzite (abundant), granite, diorite, greywacke, shale, slate, one piece hard fireclay, and a few volcanic rocks, chiefly scoriaceous, also some compact basalts. Some of the fragments were clean, but the majority had a black manganese staining on their surface.

The sample from lat. 41° 30′ S., long. 9° 55′ W. (No. 49), a little to the south of Gough Island, is a typical Globigerina ooze, containing 71 per cent. $CaCO_3$ with fairly abundant coccoliths and a few rhabdoliths. The foraminifera, however, are all more or less dwarfed forms.

In the two samples of Globigerina ooze obtained between Gough Island and Cape Town (Nos. 50 and 51) the percentage of lime falls to 46 per cent. and 40 per cent. respectively. The mineral particles here only constitute 1 per cent. of the whole deposit, but the fine washings still show a considerable amount of minute mineral particles, although the proportion of true amorphous clay is much larger, in No. 51 being almost sufficient in quantity to term the deposit a transition to Red clay. A typical area of this deposit is known to be not far off, between this point and the Cape of Good Hope.

Systematic Description of Samples.

1. Station 81; December 20, 1902; lat. 18° 24′ S., long. 37° 58′ W., on the Abrolhos Bank; depth 36 fathoms.

Hard Ground.—Nothing came up in the sounding-tube. From the dredge, which was very much torn, and from the attached swabs were picked off a number of calcareous organisms, fragments of coral, lamellibranch shells, bryozoa, and foraminifera.

Foraminifera:—Chief forms: *Globigerina rubra*, *Polytrema miniaceum*, *Amphistegina lesonii*; various others.

2. Station 118; January 26, 1903; Stanley Harbour, Falkland Islands; depth $2\frac{1}{4}$ fathoms.

MUD.—A dark brownish-green earthy mud with some white specks; soft and only slightly coherent when wet. Lighter in colour when dry with numerous small glistening specks of mineral particles and a few small pieces of shells. Slightly gritty. Strong smell of H_2S.

$CaCO_3$ 27 per cent. (Anal.):—Ostracods, echinoid spines and plates, gastropods, lamellibranchs, foraminifera.

Siliceous organisms 5 per cent.:—Sponge spicules, a few diatoms, and plant needles.

Minerals 30 per cent., m. di. 0·08 mm., rounded and angular:—Quartz mainly, a little biotite and hornblende.

Fine washings 38 per cent.:—Brown in colour, amorphous clayey material, minute mineral particles, and fragments of siliceous organisms, especially plant needles ·01 to ·2 mm. in length.

Foraminifera:—Chief forms:

Calcareous.	Arenaceous.
Bulimina elegantissima.	*Proteonina difflugiformis.*
Polystomella striatopunctata.	*Trochammina nitida.*
Polystomella macella.	*Trochammina nana.*

3. Station 140; January 31, 1903; lat. 58° 22′ S., long. 45° 00′ W.; depth 1698 fathoms.

DIATOM OOZE.—Only a very small quantity obtained adherent to the tallow on the bottom of the sounding-lead. Probably partly washed, and not representing the true condition of the bottom. Of a greyish-black colour, very gritty to the touch.

$CaCO_3$:—Nil.

Siliceous organisms 40 per cent.:—Chiefly broken fragments of diatoms: *Rhizosolenia*, *Fragilaria*, *Coscinodiscus*, etc.

Minerals 45 per cent., m. di. 0·13 mm. Some as large as 0·75 mm., rounded and angular:—Quartz, felspar, both monoclinic and triclinic, volcanic glass, palagonite, dark basaltic scoriæ, hornblende, hypersthene, pale green augite.

Fine washings 15 per cent.:—Some amorphous material and minute mineral fragments, largely fragments of diatoms.

4. Station 146; February 1, 1903; lat. 59° 32′ S., long. 43° 10′ W.; depth 2307 fathoms.

DIATOM OOZE.—Deposit adherent to the lower 15 inches of the sounding-lead, and to the tallow on the bottom of it. As in the case of No. 3, the material cannot be taken as truly representative of the ooze *in situ*, as it has almost certainly been washed to some extent in bringing up. Grey in colour while wet; dirty white when dry. Gritty. Slightly coherent.

$CaCO_3$:—Nil.

Siliceous organisms 55 per cent.:—Diatoms: *Coscinodiscus*, *Navicula*, *Rhizosolenia*, *Eucampsia*, *Actinocyclus*, *Fragilaria*, etc.

Minerals 25 per cent., m. di. 0·11 mm., largest 0·63 mm., rounded and angular:—Brown and green volcanic glass, many of the pieces altered into reddish palagonite, and with a dark coating of MnO_2, magnetite, quartz, green fibrous hornblende, felspar, biotite.

Fine washings 20 per cent.:—Fragments of diatoms, small mineral particles, and amorphous matter.

5. Station 183; February 9, 1903; lat. 59° 42′ S., long. 34° 13′ W.; depth 1325 fathoms.

Diatom Ooze.—Only a very small amount scraped off the sounding-lead. Certainly a washed specimen; as examined, it was composed almost entirely of fragments of diatoms and pieces of rust off the sounder.

Diatoms:—Coscinodiscus, *Fragilaria*, etc. A few mineral particles, mostly under 0·05 mm. The only recognisable fragment a piece of pumice; a few granules with a manganese coating.

6. Station 198; February 12, 1903; lat. 59° 49′ S., long. 31° 32′ W.; depth 663 fathoms.

Hard Ground.—Merely a few grains of deposit adherent to the sounding-lead. Fragments of diatoms, none recognisable. A few mineral particles, including quartz, felspar, green and brown hornblende. Some amorphous matter.

7. Station 215; February 15, 1903; lat. 61° 58′ S., long. 26° 03′ W.; depth 2250 fathoms.

Glacial Mud or Clay.—Only obtained in very small amount adhering to the vaseline on the sounder. Greyish-green in colour when wet, dirty white when dry. Microscopically it consists almost entirely of clayey matter, no definite mineral particles being recognisable, although there are a few granules coated with manganese, and some very small reddish fragments, possibly of palagonite. There are also a few fragments of siliceous organisms. The deposit is almost certainly similar in character to No. 8.

8. Station 226; February 17, 1903; lat. 64° 18′ S., long. 23° 09′ W.; depth 2739 fathoms.

Glacial Clay.—Obtained in quantity from the Admiralty sounding-tube. Of a greenish drab colour when wet, pale grey when dry. Upper layers loose and flocculent; lower, a tough clay. Soapy feeling when rubbed between the fingers, with a few gritty

particles. No odour. When dried is hard and polishes when rubbed on the finger-nail, readily adheres to the tongue, breaks down very slowly in water.

$CaCO_3$, a trace:—One small fragment of a molluscan shell.

Siliceous organisms, a trace:—Radiolaria and a few sponge spicules.

Minerals 5 per cent. A few fairly large fragments, m. di. 0·16 mm. rounded and angular, the larger fragments being well rounded:—Quartz, felspar (plagioclase, orthoclase, and microcline), green hornblende, hypersthene, augite, tourmaline, volcanic glass, pumice, a few grains coated with manganese.

Fine washings 95 per cent:—Amorphous matter and small undeterminable mineral particles.

9. Station 246; February 20, 1903; lat. 69° 40′ S., long. 21° 50′ W.; depth 2558 fathoms.

Glacial Clay.—Only a small quantity off the sounding-lead. In appearance similar to the upper layers of No. 8. When dry, of a darker shade, and is a hard clay. Breaks down rather more readily in water than No. 8 does, and is more gritty to the touch.

$CaCO_3$:—Nil.

Siliceous organisms, a trace:—Sponge spicules.

Minerals 10 per cent., m. di. 0·07 mm.:—A very few larger fragments, some of which are well rounded, and one or two appear to be striated. Quartz, plagioclase, volcanic glass, hornblende, biotite, serpentine, and (?) tourmaline.

Fine washings 90 per cent.:—Amorphous matter and small mineral particles. The number of the latter under 0·02 mm. is large.

10. Station 273; February 28, 1903; lat. 69° 22′ S., long. 26° 36′ W.; depth 2587 fathoms.

Glacial Clay.—Obtained in considerable quantity from Admiralty sounding-tube. Drab grey in colour, light grey when dry. Clayey, but not quite so tough as No. 8. Soapy feeling between the fingers, but with a considerable number of gritty particles.

$CaCO_3$:—A trace.

Siliceous organisms, a trace:—Radiolaria.

Minerals 10 per cent., m. di. 0·08 mm.:—Quartz, most abundant; one grain, about 0·35 mm. in diameter, shows several striæ; all the larger grains are rounded or sub-angular. Green hornblende, felspar, both monoclinic and triclinic, magnetite, garnet. A very little manganese coating on some of the grains.

Fine washings 90 per cent.:—Composed largely of mineral particles under 0·05 mm. in diameter, and mostly much less. It is estimated that if particles down to 0·005 mm. were to be included under "Minerals," it would bring that heading up to about 60 per cent., and even then all the remainder would not be amorphous clayey matter, but would still contain very minute mineral particles.

11. Station 280; March 2, 1903; lat. 68° 40′ S., long. 30° 18′ W.; depth 2511 fathoms.

GLACIAL CLAY.—Obtained in quantity from the Buchanan sounding-tube, as were all the subsequent samples, unless mentioned to the contrary. Drab grey in colour, light grey when dry. No odour. A fairly tough clay, but with numerous gritty particles, less numerous, however, in the deep layers of the deposit.

$CaCO_3$:—Nil.

Siliceous organisms:—A trace.

Minerals—Upper part, 20 per cent., rounded and angular, m. di. 0·16 mm.:—Quartz, green hornblende, zircon, felspar, tourmaline, chlorite. Lower part, 10 per cent. m. di. 0·1 mm.:—Quartz, hornblende, felspar. One fragment of hornblende gneiss 5 mm. in diameter.

Fine washings:—Similar to No. 10.

12. Station 282; March 3, 1903; lat. 68° 31′ S., long. 32° 08′ W.; depth 2452 fathoms.

GLACIAL CLAY.—Bluish-grey when wet, dries a very light grey. Greasy clayey feeling with gritty particles.

$CaCO_3$:—Nil.

Siliceous organisms 1 per cent.:—Fragments of diatoms.

Minerals 15 per cent., angular and rounded, m. di. 0·07 mm.:—Quartz in abundance, some of it rosy red, a little felspar, biotite, hornblende, tourmaline, and (?) apatite, magnetite, zircon, some particles of volcanic glass, and a few manganese-coated grains.

Fine washings 84 per cent.:—Similar to No. 10, *i.e.* some amorphous clayey matter, but containing abundant very fine mineral particles.

13. Station 286; March 5, 1903; lat. 68° 11′ S., long. 34° 17′ W.; depth 2488 fathoms.

GLACIAL CLAY.—Greenish-grey in colour, light grey when dry. A greasy clay, but with more gritty particles palpable than in previous samples.

$CaCO_3$ 5 per cent. (Anal.):—*Globigerina dutertrei*, the largest scarcely 0·3 mm. in diameter, others much smaller.

Siliceous organisms:—Nil.

Minerals 15 per cent., m. di. 0·1 mm., many as large as 0·15 mm., all the larger being rounded or sub-angular:—Quartz and hornblende chiefly, felspar (orthoclase, plagioclase, and microcline), augite, glauconitic casts of foraminifera, (?) *Globigerina pachyderma*, a little dark volcanic glass, magnetite (rare), zircon (one), a few manganese nodules—one about 1 mm. in diameter.

Fine washings 80 per cent.:—Similar on the whole to previous samples, but contains undoubtedly more amorphous clayey matter.

Chief foraminifera:—Cassidulina subglobosa, Globigerina pachyderma, Nonionina pompilioides; none of them abundant.

14. Station 290; March 6, 1903; lat. 67° 39′ S., long. 36° 10′ W.; depth 2500 fathoms.

Glacial Mud or Clay.—Greenish-grey in colour, pale grey when dry. Does not feel so clayey when rubbed between the fingers, and there are a considerable number of gritty particles.

$CaCO_3$:—Nil.

Siliceous Organisms, a trace:—Fragments of diatoms, one sponge spicule.

Minerals 20 per cent.:—Fragments of quartz hornblende gneiss up to 5 mm. in diameter. All the larger grains rounded. Quartz abundant, one or two grains show distinct striæ. Magnetite, pumice, yellow volcanic glass, hornblende, augite, brown mica, a little felspar.

Fine washings 80 per cent.:—Similar to No. 10.

14*a*. Station 291; March 7, 1903; lat. 67° 33′ S., long. 36° 35′ W.; depth 2500 fathoms.

Glacial Mud or Clay.—From *trawl*. In addition to mud, the trawl brought up a large number of rock specimens, some angular, mostly rounded or sub-angular. Some are striated; some appear to be water-worn. Rocks include gneiss (abundant, a number of pieces with red felspars), soft decomposing granulite, hornblende schist, flaggy gneiss, schistose quartzite, pumice, and slate.

The washings from the trawl contained Echinoid spines and brittle-star arms, a few sponge spicules and radiolaria, also numerous arenaceous foraminifera.

Chief foraminifera:—Astrorhiza crassatina (en masse), abundant; *Hyperammina ramosa*, fragments; *H. elongata*, also only fragments; *Hormosina normani*, also only fragments. *Miliolina bucculenta* is the only lime-builder found.

15. Station 295; March 10, 1903; lat. 66° 40′ S., long. 40° 35′ W.; depth 2425 fathoms.

Glacial Clay.—Very similar to No. 13. More clayey than No. 14, but also containing numerous gritty particles.

$CaCO_3$:—Nil.

Siliceous organisms:—Nil.

Minerals 20 per cent. m. di. 0·07 mm.:—A few sub-angular rock fragments up to 2 mm. in diameter, but the great majority of the mineral particles are small. Quartz, hornblende, felspar (monoclinic, triclinic, and microcline), grains like serpentine, magnetite, both by itself and embedded in volcanic glass, chlorite.

Fine washings 80 per cent.:—Largely minute mineral particles, although there is a considerable amount of amorphous clay. No fragments of siliceous organisms.

From the *trawl* were obtained a number of pebbles similar in their general characters to those from No. 14*a*, chiefly pieces of hornblende gneiss, quartzite, and granulite; also a piece of hæmatite, numerous flakes of biotite, a trachyte, and a fine-grained tuff containing crystals of augite and olivine.

A few arenaceous *foraminifera*, chiefly *Astrorhiza crassatina*, also three specimens of *Hormosina globulifera*.

16. Station 300; March 12, 1903; lat. 65° 29′ S., long. 44° 06′ W.; depth 2500 fathoms.

Glacial Clay.—Drab grey in colour; light grey when dry, almost uniform, but with a few dark specks. A fairly tough clay, with gritty particles.

$CaCO_3$ 2 per cent. (Anal.):—Foraminifera.

Siliceous Organisms:—Nil.

Minerals 12 per cent., m. di. 0·08 mm., sub-angular and angular, the larger pieces being all sub-angular:—One quartz pebble stained with limonite 4 mm. long, not striated. Quartz, hornblende, mica, magnetite in grains and embedded in volcanic glass, serpentine, felspar, glauconite grains.

Fine washings 86 per cent.:—More amorphous clayey matter than in any previous sample.

Chief foraminifera:—*Globigerina dutertrei*, *G. pachyderma*, *Truncatulina pygmæa*, *Proteonina difflugiformis*, *Haplophragmoides subglobosum*, *Cyclammina pusilla*; none of them abundant.

17. Station 301; March 13, 1903; lat. 64° 48′ S., long. 44° 26′ W.; depth 2485 fathoms.

Glacial Mud.—Of a dark drab-grey colour when wet, drying into a hard light-greenish-grey mass. Much less clayey than previous samples, having no clayey odour when breathed upon. The tongue adheres only very slightly to the dry specimen. It takes a lustrous polish, but the streak on porcelain, of a greenish-brown colour, is not shiny. It breaks down readily in water into a flaky condition almost without rubbing, and there is only the slightest unctuous feeling when rubbing down.

$CaCO_3$:—A trace.

Siliceous organisms, a trace:—Sponge spicules and radiolaria.

Minerals 10 per cent., m. di. 0·08 mm., rounded and angular:—Quartz, felspar, hornblende, mica, zircon, magnetite, and augite. Fragments of slate and of quartzite.

Fine washings 90 per cent:—Chiefly very fine material particles, very little amorphous matter.

Rock specimens obtained from *trawl*:—A few rock fragments, some angular, others rounded, and several showing glacial striæ. Two pieces of granulite evidently been recently dropped, the side which has been embedded in the mud being covered by a

dark stain, while the uncovered part is clean. The pieces are all either dark hornblende gneiss, quartzite, or granulite.

Foraminifera:—No pelagic or porcellaneous forms observed. Arenaceous forms not abundant, but the commonest is *Reophax pilulifera*. Other forms are *Reophax nodulosa*, *Saccammina sphærica*, and *Bathysiphon filiformis*.

18. Station 303; March 14, 1903; lat. 64° 24′ S., long., 43° 18′ W.; depth 2547 fathoms.

Glacial Mud or Clay.—More bluish-grey in colour, light grey when dry. Rather more clayey than No. 17, but not so much so as previous samples. A fair number of gritty particles.

$CaCO_3$:—Nil.

Siliceous organisms, a trace:—Fragments of diatoms.

Minerals 15 per cent. m. di. 0·08 mm., sub-angular and angular:—Quartz, biotite, hornblende, felspars, magnetite, tourmaline, (?) apatite.

Fine washings 85 per cent.:—Some amorphous clayey matter, chiefly very minute mineral particles.

19. Station 309; March 16, 1903; lat. 63° 51′ S., long. 41° 50′ W.; depth 2550 fathoms.

Glacial Clay.—Drab grey in colour. A tough clay again without many gritty particles.

$CaCO_3$:— Nil.

Siliceous organisms, a trace:—Fragments of diatoms.

Minerals 10 per cent., m. di. 0·07 mm., sub-angular and angular:—Quartz, mica, hornblende. One piece of red felspar 2 mm. long; a similar sized piece of slaty-looking rock. Some small pieces of volcanic rock enclosing magnetite.

Fine washings 90 per cent.:—More clayey matter, but still chiefly composed of fine mineral particles.

20. Station 312; March 17, 1903; lat. 62° 56′ W., long. 42° 20′ W.; depth 1956 fathoms.

Glacial Mud.—Similar to No. 18, but with fewer gritty particles. Much less clayey than No. 19.

$CaCO_3$:—Nil.

Siliceous organisms 1 per cent.:—Sponge spicules.

Minerals 10 per cent., m. di. 0·06 mm., angular and sub-angular:—Quartz, felspar, mica, hornblende, magnetite in grains alone and enclosed in volcanic glass.

Fine washings 89 per cent:—Similar to No. 18.

21. Station 313; March 18, 1903; lat. 62° 10′ S., long. 41° 20′ W.; depth 1775 fathoms.

GLACIAL MUD OR SAND.—Sounding-tube contained only a small scraping of mud, and came up with a considerable dent on one side as if it had struck on rock, but a considerable quantity of mud was obtained from the trawl later. This may have been partly washed on its way up; but from the manner in which it was fixed in the trawl, it cannot have been much so, and probably very closely represents the true state of the bottom. A bluish-grey sand or mud with almost no clayey feeling about it. Very gritty, and with very little cohesion. Needs almost no rubbing to separate its contents: merely washing and decantation.

$CaCO_3$ 2 per cent. (Anal.):—Foraminifera.

Siliceous organisms, a trace:—Diatoms (*Coscinodiscus*), and radiolaria.

Minerals 70 per cent., m. di. 0·25 mm., sub-angular and angular:—Quartz, felspar, mica, and hornblende in abundance.

Fine washings 28 per cent.:—Chiefly small mineral particles, some amorphous material.

Rock specimens from trawl:—A large number of boulders, including some weighing as much as 2 cwts., besides many smaller. A great variety of rocks, although metamorphic rocks predominate largely. A few show striations. Coarse hornblende gneiss, hornblende patches from fine-grained gneisses, also pieces of felspathic veins, coarsely granitoid and fine granulitic gneiss, garnetiferous gneiss, schistose quartzite, hornblende schist, hornfels, mica schist, phyllite, slate, clayey limestone, clay concretion fairly rich in iron (? from limestone), one piece of fossiliferous limestone with specimens of *Archæocyathinæ*, basalts, quartz dolerite, rhyolite, tuffs, greywacké (not resembling the S. Orkney, Laurie Island rock).

Chief foraminifera:—Numerous arenaceous forms belonging to the genera *Psammosphæra*, *Saccammina*, *Pelosina*, *Rhabdammina*, *Hyperammina*, *Reophax*, *Hormosina*, *Trochammina*, *Cribrostomoides*, *Cyclammina*, and *Gaudryina*.

Benthoic lime-builders are represented by *Miliolina bucculenta* and *Cassidulina subglobosa*; the Globigerinidæ by *G. dutertrei* and *G. pachyderma*.

22. Station 317; March 19, 1903; lat. 61° 12′ S., long. 42° 44′ W.; depth 210 fathoms.

PEBBLES.—Two pebbles brought up in the snapper, washed quite free from mud. One, a pebble $1 \times \frac{3}{4} \times \frac{1}{2}$ inch, rounded and water-worn, composed of dark-coloured banded quartzitic rock with carbonaceous particles; very similar to the greywacké of the S. Orkneys, and probably derived from there. The other, a pebble $\frac{3}{4} \times \frac{3}{4} \times \frac{7}{8}$ inch, apparently recently broken in two, one face being rough and slightly convex, the other part being well rounded and water-worn, and showing traces of striation, composed of material similar to the other. Both might quite well from their appearance be beach pebbles from the S. Orkneys which had been carried out frozen in bay-ice and deposited on melting. Mud would probably have been found had a sounding-tube been used.

23. Station 319; March 20, 1903; lat. 61° 05′ S., long. 43° 20′ W.; depth 214 fathoms.

SAND.—Brought up in the snapper. A muddy sand of a greenish-fawn colour with black specks. Dries much lighter in colour. Almost no coherence, very gritty, and contains rounded water-worn pebbles similar to those of No. 22 up to $\frac{1}{2}$ inch in diameter.

$CaCO_3$:—Not tested for.

Siliceous organisms 3 per cent.:—Diatoms: *Coscinodiscus, Fragilaria, Actinocyclus*, etc.

Minerals 90 per cent.:—Rather more than half being particles of gravel about 2 mm. in diameter, the remainder sand averaging 0·13 mm. in diameter. The sand grains are rounded and sub-angular; the gravel, angular and sub-angular, *i.e.* less well water-worn. They show no signs of striæ. The grains consist chiefly of quartz with black carbonaceous particles and a green scaly mineral resembling chlorite. This corresponds closely with the constitution of the greywackés of the S. Orkneys. There are also one or two grains of magnetite, and one piece of green hornblende.

Fine washings 7 per cent.:—Composed of fine mineral particles and fragments of diatoms.

24*a*. Uruguay Cove, Laurie Island, S. Orkneys; April 20, 1903; depth 5 to 10 fathoms.

SAND.—Obtained in dredge. A fine greenish-grey sand composed of a mixture of dark- and light-coloured particles. The grains do not vary much in size, the average being 0·15 mm. in diameter, the largest being 0·30 mm. The grains are rounded and sub-angular. Compared with the gravel and sand obtained by sifting the mud from the trawl of March 18, 1903 (No. 21, 1775 fathoms), the grains are much more uniform in size and more rounded and polished than the small grains of that sample, but, if anything less so than the larger gravelly grains. The grains are chiefly quartz, some clear but mostly cloudy with chlorite, carbonaceous matter, and (?) kaolin. A little hornblende.

Siliceous organisms 5 per cent.:—Diatoms: numerous littoral and ice forms. See p. 676, Dr GRAN's report on the diatoms.

24*b*. Station 325; Scotia Bay, Laurie Island, S. Orkneys; July 22, 1903; depth $36\frac{1}{2}$ fathoms.

MUD.—Brought up in the snapper sounding-lead. A fairly tenacious mud when brought up, of a dark greenish-drab colour, and smelling strongly of H_2S. Rubs down easily with a feeling like that of clay and fine sand mixed.

$CaCO_3$:—Nil.

Siliceous organisms 5 per cent.:—Diatoms: a mixture of pelagic and littoral forms. See p. 676 for Dr GRAN'S report on the diatoms. Sponge spicules.

Minerals 50 per cent., m. di. 0·07 mm., angular and sub-angular :—Chiefly quartz, some clear but mostly clouded with grey, green, and black particles. A very little hornblende, mica, and (?) zircon.

Fine washings 45 per cent. :—Fine mineral particles and diatoms.

24*c*. Station 325; Scotia Bay, S. Orkneys, near *Scotia's* anchorage; January 2, 1904; depth 5 to 10 fathoms.

Muddy Sand.—Similar to No. 24*a*, but the grains are not so regular in size, m. di. 0·09 mm., largest about 0·15 mm., angular and sub-angular; the larger grains (over 0·1 mm.) rounded and distinctly water-worn :—Composition of grains like those of No. 24*a*. Diatoms abundant, littoral and ice forms. See p. 676 for Dr Gran's report on the diatoms.

25*a*. Station 334; November 27, 1903; 14 hours; about $1\frac{1}{2}$ miles off Coronation Island, S. Orkneys; depth $41\frac{1}{2}$ fathoms.

Sand.—A dark greenish-grey slightly muddy fine sand. Very finely gritty to the touch. Very little cohesion. One or two pebbles up to $\frac{1}{4}$ inch in diameter of a schistose quartz and hornblende rock apparently, m. di. of mineral particles 0·15 mm., sub-angular, rounded, and angular. Quartz clear and clouded with dark inclusions, flakes of muscovite and biotite, especially the former, chlorite also fairly abundant, hornblende, a little felspar, some calcite. A few diatoms and sponge spicules. The diatoms include both pelagic and littoral forms. See p. 676 for Dr Gran's report on the diatoms.

25*b*. Station 335; November 27, 1903; 16 hours; off Conception Point, Coronation Island, S. Orkneys; depth 90 fathoms.

Sand.—A very small quantity similar in its general characters to No. 25*a*, and containing several small quartz pebbles. Composed chiefly of quartz, hornblende, chlorite, and a little biotite.

26*a*. Station 337*a*; November 28, 1903; 9 to 11.15 hours; lat. 59° 43′ S., long. 48° 10′ W.; depth 2110 fathoms.

Glacial Sandy Mud bordering on Diatom Ooze.—A brownish-grey mud with numerous dark specks of mineral particles. Slight greasy clayey feel to the finger, with numerous fine gritty particles. Very easily rubbed down in water.

$CaCO_3$ 1 per cent. :—Foraminifera.

Siliceous organisms 10 per cent. :—Chiefly diatoms, radiolaria fairly common, and sponge spicules.

Minerals 60 per cent., m. di. 0·13 mm., larger particles rounded, others sub-angular and angular :—Quartz, chiefly clear, some clouded like that of the S. Orkney rocks. Hornblende (very clear green and also brown), felspar (microcline, kaolinised,

and clear plagioclase), a little biotite and chlorite, one or two grains of pumice, magnetite, and (?) garnet. A few glauconite grains.

Fine washings 29 per cent. :—Small angular mineral particles, fragments of diatoms, and a little amorphous matter.

Chief foraminifera :—Hyperammina ramosa, Reophax difflugiformis, Haplophragmium agglutinans, Clavulina communis, Spiroplecta biformis; none of them abundant.

26*b*. Station 338; November 28, 1903; 18 to 20 hours; lat. 59° 23′ S., long. 49° 08′ W.; depth 2180 fathoms.

Diatom Ooze or Volcanic Sand.—A soft greenish-brown mud. Preserved in spirit, and in the bottle has sorted out into layers, light in colour on top, dark mineral layer on the bottom. Not much cohesion, being very easily rubbed down, leaving a residue of fine sand composed of a mixture of grey and dark, almost black grains, with some glittering flakes of mica. The lighter, more superficial part has a floury feeling.

$CaCO_3$:—A trace.

Siliceous organisms 15 per cent. :—Diatoms, radiolaria, a few sponge spicules.

Minerals 60 per cent., m. di. 0·1 mm., sub-angular, rounded, and angular :—Quartz (not volcanic), many fragments of brown basaltic glass with felspars and magnetite, cloudy felspars, magnetite, augite, brown hornblende, green hornblende, palagonite, a few chlorite scales on quartz grains, garnet.

Fine washings 25 per cent. :—Chiefly fragments of diatoms, also minute mineral particles.

Chief foraminifera :—Rhizammina algæformis, Reophax difflugiformis, Ammobaculites agglutinans, Gaudryina pseudofiliformis, Globigerina bulloides (dwarfed), *G. dutertrei, G. pachyderma*; none of them abundant.

27. Station 339; November 29, 1903; lat. 58° 28′ S., long. 51° 56′ W.; depth 2168 fathoms.

Diatom Ooze (?) or Volcanic Sand.—Valves of the sounding-tube remained open so that the deposit must have been much washed coming up. The deposit may have been a Diatom ooze, but it does not seem likely that the diatoms could have been so completely washed out if it were. As obtained, it is a brownish-green earthy sand. To the naked eye it seems more mineral and rock particles than mud.

Minerals 80 per cent., a mixture of fine grey sand, m. di. 0·1 mm., and gravel up to 10 mm., mean about 1·5 mm., sub-angular and angular. Much dark volcanic glass, pumice, palagonite, magnetite, quartz with limonite coating many of the grains, felspar, some cloudy but chiefly clear, brown hornblende, augite, green hornblende.

Fine washings 20 per cent. :—Fine mineral particles and some diatoms.

28. Station 342; November 30, 1903; lat. 56° 54′ S., long. 56° 24′ W.; depth 1946 fathoms.

GLOBIGERINA OOZE.—Dark brown in colour with numerous light-coloured specks (foraminifera). Light brown when dry. Moderately coherent, but easily rubbed down in water. Slight clayey feeling. Gritty.

$CaCO_3$ 24 per cent. (Anal.):—Foraminifera and a few fragments of lamellibranch shells.

Residue 76 per cent. :—Dark grey in colour.

Siliceous organisms 2 per cent. :—Diatoms and radiolaria.

Minerals 40 per cent., m. di. 0·07 mm., angular and sub-angular:—Felspars, some fresh and clear, but mostly cloudy and weathered, including two pieces of plagioclase 2 to 3 mm. in length, augite, magnetite, quartz, brown hornblende, volcanic glass, and some brown mica.

Fine washings 34 per cent. :—Fine mineral particles, diatom fragments, and a little amorphous matter.

Foraminifera :—No less than twenty-nine genera and sixty species in this deposit, including practically all the types characteristic of the Globigerina oozes of the S. Atlantic, the Globigerinidæ being quantitatively the most abundant.

29. Station 346:—December 1, 1903; lat. 54° 25′ S., long. 57° 32′ W.; on the Burdwood Bank; depth 56 fathoms.

HARD GROUND.—Only a very minute fragment of brownish clay containing a few specimens of *Globigerina dutertrei* and *G. pachyderma*. The *trawl*, however, brought up a large number of masses of calcareous shelly and foraminiferal sand varying in size up to that of an orange, and from these some eighty species of foraminifera were obtained, chiefly of shallow-water Antarctic facies, the most abundant being *G. bulloides*, *G. dutertrei*, *Truncatulina variabilis*, and *Polystomella crispa*. Arenaceous types very rare, being represented only by *Trochammina nitida*.

30. Station 387; February 26, 1904; lat. 65° 59′ S., long. 33° 06′ W.; depth 2625 fathoms.

GLACIAL CLAY.—A brown tenacious clay with a bluish tinge. Grey in colour when dry. Very clayey and very little grit.

$CaCO_3$, a trace :—Foraminifera.

Siliceous organisms, a trace :—Radiolaria.

Minerals 5 per cent., angular, m. di. 0·12 mm. :—A few larger rounded mineral particles, chiefly quartz, about 1 mm. in diameter. One showing distinct striæ. Remainder small and angular. Quartz, green augite, felspar (microcline and plagioclase), brown mica, yellow and brown palagonite grains, a few small grains of magnetite, a little green hornblende.

Fine washings 95 per cent. :—Fine mineral particles with a considerable amount of true amorphous clayey material.

Foraminifera:—Exceedingly few in number, *Globigerina dutertrei*, *G. pachyderma* and *Proteonina difflugiformis* being the only forms noted.

31. Station 391; February 27, 1904; lat. 66° 14′ S., long. 31° 18′ W.; depth 2630 fathoms.

GLACIAL CLAY.—A soft clay of a drab grey colour. Requires much rubbing down: it is so tenacious. Very little grittiness.

$CaCO_3$:—Nil.

Siliceous organisms, a trace:—Radiolaria.

Minerals 3 per cent., angular and sub-angular, m. di. 0·09 mm.; a few quartz particles up to 0·5 mm. sub-angular, all others angular:—Quartz (one angular fragment 5 mm. long), a little felspar, augite, magnetite, volcanic glass, and palagonite.

Fine washings 97 per cent.:—Fine mineral particles and a considerable amount of amorphous clayey matter.

Note.—In both this sample and No. 30 the minerals, with the exception of the quartz, are chiefly of volcanic origin.

32. Station 394; February 28, 1904; lat. 66° 43′ S., long. 27° 55′ W.; depth 2685 fathoms.

GLACIAL CLAY.—A loose soft clay of a drab grey colour. Very greasy and requires much rubbing down. Almost no grittiness.

$CaCO_3$:—Nil.

Siliceous organisms:—Nil.

Minerals 2 per cent., angular, m. di. 0·05 mm. Estimated that if particles down to 0·01 mm. were included, the percentage would be about 5. Quartz, magnetite, augite, felspar, biotite, pumice.

Fine washings 98 per cent.:—A considerable amount of amorphous clayey material, but largely unrecognisable mineral particles under 0·01 mm. in size.

Note.—Although the fine washings make up such a large part of this and the preceding two samples, in this respect resembling a Red clay, none of them contain so much real clay as a true Red clay does, none are so difficult to rub down as a true Red clay is, and in all the fine washings contain far too much minute mineral particles —"rock flour"—for them to be regarded as true Red clays.

33. Station 406; March 3, 1904; lat. 72° 18′ S., long. 17° 59′ W.; depth 1131 fathoms.

GLACIAL MUD OR CLAY.—Of a dark greenish-brown colour. A fairly tough clay, but with a considerable number of gritty particles.

$CaCO_3$:—Nil.

Siliceous organisms 2 per cent.:—Chiefly sponge spicules. A few whole diatoms (*Coscinodiscus*), and some fragments, and a few small radiolaria.

Minerals 20 per cent. angular and sub-angular, the larger being the more rounded, m. di. 0·17 mm.:—Quartz, felspar, augite, hornblende, serpentine, chlorite, brown mica,

magnetite. Some fragments of white sandstone, the grains of it having a limonite coating, also fragments of greenish slate.

Fine washings 78 per cent. :—A fair amount of true amorphous clayey matter. The minute mineral particles are, on the whole, distinctly larger than those of No. 32.

34. Station 411; March 10, 1904; lat. 74° 01′ S., long. 22° 00′ W.; depth 161 fathoms.

PEBBLES.—Three pebbles brought up in the snapper sounding-lead. No mud adherent to them.

(1) A piece of mica schist containing garnets and iron pyrites 1·2 × ·9 × ·7 inch, sub-angular, smoothed on two sides.

(2) Piece of brownish-pink sandstone, ·8 × ·6 × ·3 inch; sub-angular, composed of well-rounded quartz grains from 0·15 to 0·3 mm. in diameter, many of them coated with limonite, bound together by a calcareous matrix.

(3) Piece of dark hornblende gneiss, ·7 × ·6 × ·5 inch, sub-angular.

35. Station 414; March 15, 1904; lat. 71° 50′ S., long. 23° 30′ W.; depth 2102 fathoms.

GLACIAL MUD OR CLAY.—A brownish-grey mud with a certain amount of greasy clayey feel about it, but it breaks down in water without very much rubbing. Very little grittiness.

$CaCO_3$:—Nil.

Siliceous organisms, a trace :—Sponge spicules.

Minerals 25 per cent., angular, m. di. 0·06 mm., typical "rock-flour," very few large pieces :—Quartz, mostly clear, some grains coated with limonite, a few rather larger grains with what looks like chlorite scales, flakes of brown mica, felspar, hornblende (green and brown), augite, magnetite, olivine, chlorite, tourmaline.

Fine washings 75 per cent. :—Chiefly fine mineral particles, only a moderate amount of amorphous clay.

36. Station 415; March 16, 1904; lat. 71° 28′ S., long. 22° 32′ W.; depth 2338 fathoms.

GLACIAL MUD OR CLAY.—Only scrapings off the outside of the sounding-tube. There was no valve at the top of the sounding-tube, and so the plug of mud had all escaped. Brownish when wet, slaty-grey when dry. Microscopically it consisted almost entirely of "fine washings," mostly amorphous clay; but as it must have been washed on the way up, it cannot be regarded as in any way representative of the condition of the deposit *in situ*.

37. Station 416; March 17, 1904; lat. 71° 22′ S., long. 18° 15′ W.; depth 2370 fathoms.

GLACIAL MUD OR CLAY.—A greenish-grey mud, otherwise very similar in character to No. 35.

$CaCO_3$, a trace :—Ostracod valve.

Siliceous organisms, a trace :—Sponge spicules and radiolaria.

Minerals 15 per cent., angular, m. di. 0·06 mm. :—Quartz, magnetite, brown mica, some flakes up to 1·5 mm., these three making up the main bulk of the mineral particles; some augite, volcanic glass, felspar, mostly kaolinised, olivine, garnet, some glauconitic grains.

Fine washings 85 per cent. :—Similar to No. 35 in character.

Chief foraminifera:—Cyclammina pusilla, Reophax nodulosa, Psammosphæra fusca, Gordiammina charoides, Haplophragmoides scitulum.

38. Station 417; March 18, 1904; lat. 71° 22′ S., long. 16° 34′ W.; depth 1410 fathoms.

GLACIAL MUD OR CLAY.—Of a greenish-grey colour, light grey when dry. Not very tenacious; a distinctly greasy, clayey feeling, but rubs down fairly easily. Similar in this respect to Nos. 35 and 37. Rather gritty from the presence of foraminifera and rock particles.

$CaCO_3$ 4 per cent. (Anal.) :—Foraminifera.

Siliceous organisms 1 per cent. :—Sponge spicules and radiolaria.

Minerals 20 per cent., angular and sub-angular, m. di. 0·07 mm. :—The larger pieces (up to about 0·5 mm.) are almost rounded. Quartz, brown mica, hornblende, augite, magnetite, felspar, chlorite, volcanic glass, calcite, garnet. Glauconite grains.

Fine washings 75 per cent. :—Similar to Nos. 35 and 37 in character.

Rocks from the trawl:—Nearly ½ cwt. of boulders, sub-angular and rounded like rolled boulders from a stream. One weighing 14 lbs., half-a-dozen over 5 lbs.; many about size of an apple, and a large amount of coarse and fine gravel; nearly all with a dark surface manganese coating either in whole or part. Gneissic and schistose rocks of considerable variety, quartzites (white and red), granulites, a piece of gabbro, a quartz dolerite, several varieties of basalt—one being a typical spilite; another shows marked albitisation of the felspars; a third has a fine development of secondary epidote, —red and purple sandstone.

Chief foraminifera:—Globigerina bulloides, G. dutertrei, Truncatulina wuellerstorfi, T. tenuimargo, T. tenera. Numerous large arenaceous types such as :—*Rhabdammina, Psammosphæra, Saccammina, Pelosina, Hyperammina, Reophax, Hormosina, Haplophragmoides, Trochammina, Cyclammina, Textularia.*

39. Station 418; March 19, 1904; lat. 71° 32′ S., long. 17° 15′ W.; depth 1221 fathoms.

GLACIAL MUD OR CLAY.—Similar in general characters to No. 38, but is less gritty.

$CaCO_3$ 2 per cent. (Anal.) :—Foraminifera.

Siliceous organisms 2 per cent. :—Sponge spicules, radiolaria, diatoms (especially *Coscinodiscus*).

Minerals 15 per cent., angular and sub-angular, m. di. 0·08 mm. :—A few larger grains up to 3 mm. almost rounded in outline. Quartz, felspar (monoclinic and triclinic), brown mica, magnetite, green hornblende, augite, olivine, serpentine, volcanic glass.

Fine washings 81 per cent. :—Fine mineral particles chiefly ; if anything rather more amorphous clay than in No. 38.

Chief foraminifera :—Clavulina communis, Globigerina dutertrei, Cristellaria convergens, Bathysiphon filiformis, Psammosphæra fusca, Reophax nodulosa, Haplophragmoides rotulatum, Cribrostomoides bradyi.

40. Station 420 ; March 21, 1904 ; lat. 69° 33′ S., long. 15° 19′ W. ; depth 2620 fathoms.

Glacial Mud or Clay.—A brownish-grey mud ; clayey, but not very tenacious, and breaks down fairly easily. Fairly gritty.

$CaCO_3$:—Nil.

Siliceous organisms, trace :—Sponge spicules.

Minerals 20 per cent., m. di. 0·07 mm., angular chiefly, a few larger pieces sub-angular, one quartz grain 3 mm. long, smooth and rounded :—Quartz, brown mica, augite, magnetite, felspar, olivine, hornblende, (?) glaucophane, pumice.

Fine washings 80 per cent. :—Moderate amount of amorphous clayey matter, largely minute mineral particles under 0·01 mm. in diameter, *i.e.* of same type as No. 32.

Rocks from trawl :—Lost. Not identified.

Foraminifera :—Washings from trawl yielded a rich harvest of foraminifera, especially of arenaceous forms and also a few calcareous forms.

Representatives of most of the genera of the Astrorhizidæ are to be found, including no less than eight new species described by Mr Pearcey—viz., *Syringammina minuta, Technitella asciformis, Thurammina reticulata, Hormosina irregularis, Cyclammina contortum, Reophax robustum, Haplophragmoides umbilicatum,* and *Pelosina arborescens.*

There are also representatives of such rare forms as *Sorosphæra confusa, Crithionina pisum,* and *Keramosphæra fusca.* Dwarfed forms of *Globigerina dutertrei* and *G. pachyderma* are present in small numbers, along with *Pullenia sphæroides, Anomalina polymorpha,* and two species of *Truncatulina.*

41. Station 421 ; March 22, 1904 ; lat. 68° 32′ S., long. 10° 52′ W. ; depth 2487 fathoms.

Glacial Clay.—A light brownish-grey clay in colour, light grey when dry. More clayey than No. 40, and needs considerable rubbing down. Also a considerable number of gritty particles.

$CaCO_3$ 5 per cent. :—Foraminifera. These appear to be more abundant in the upper layers than in the deeper portions of the sample. The lot from which the percentage of $CaCO_3$ was estimated came from the top layers. Deeper layer 1 per cent. (Anal.).

Siliceous organisms, trace :—Sponge spicules.

Minerals 20 per cent., m. di. 0·08 mm., angular and sub-angular chiefly, a fair number of larger quartz grains, one about 5 mm. long, smooth and polished, and showing distinct striæ :—Quartz, jasper, felspar (orthoclase, plagioclase, and microcline, one piece 2 mm. long), dark mica, green hornblende, magnetite, tourmaline, augite; one piece of angular gneissic quartz-hornblende rock, 1 cm. long, stained black with manganese.

Fine washings 75 per cent. :—Fair amount of amorphous clay. Minute mineral particles not markedly of the No. 32 type, as a considerable proportion of them are between 0·01 and 0·05 mm. in size.

Chief foraminifera :—Globigerina dutertrei, *G. bulloides*, and *G. dubia*, *Truncatulina wuellerstorfi*, and *Pullenia sphæroides*.

42. Station 422; March 23, 1904; lat. 68° 32′ S., long. 12° 49′ W.; depth 2660 fathoms.

Glacial Clay.—A light brown unctuous clay similar in character to No. 41.

$CaCO_3$:—Nil.

Siliceous organisms, trace :—Sponge spicules.

Minerals 20 per cent., m. di. 0·07 mm., angular and sub-angular, one piece of hornblende 2 mm. long :—Quartz, mica, hornblende, a little volcanic glass, felspar, mostly plagioclase, magnetite, augite, tourmaline, garnet, serpentine, palagonite, olivine.

Fine washings 80 per cent. :—Of No. 32 type.

43. Station 428; March 27, 1904; lat. 66° 57′ S., long. 11° 13′ W.; depth 2715 fathoms.

Glacial Clay.—Light brown in colour. Somewhat flocculent, very smooth, almost no grittiness, not very unctuous except the final portions when rubbing down, which require almost as much rubbing as does a Red clay to break it up completely.

$CaCO_3$:—Nil.

Siliceous organisms, trace :—Sponge spicules.

Minerals 5 per cent., angular and sub-angular, m. di. 0·07 mm. :—Quartz, some grains with a limonite coating, felspar, green hornblende, augite, magnetite, zircon, mica, tourmaline.

Fine washings 95 per cent. :—Considerable quantity of amorphous clay. Many minute mineral particles, a large proportion of them under 0·001 mm. in size.

44. Station 432*a*; March 30, 1904; lat. 61° 21′ S., long. 13° 02′ W.; depth 2764 fathoms.

GLACIAL CLAY.—A greyish-brown tough clay requiring a great deal of rubbing down. Almost no grittiness.

$CaCO_3$:—Nil.

Siliceous organisms, trace:—Sponge spicules.

Minerals 3 per cent., angular, m. di. 0·08 mm.:—Quartz (clear and limonite-coated), magnetite, volcanic glass and pumice, red palagonite, augite, felspar, green hornblende, mica.

Fine washings 97 per cent.:—A much larger proportion of amorphous clay than in any other specimen obtained. It approximates really closely to a Red clay in this respect. The minute mineral particles in the fine washings are correspondingly diminished in amount; those that are present are mostly under 0·005 mm. in size, there being few between that and 0·05 mm.

45. Station 438; April 3, 1904; lat. 56° 58′ S., long. 10° 03′ W.; depth 2518 fathoms.

DIATOM OOZE OR VOLCANIC SAND.—Of a light straw colour speckled with black. No odour. Very little cohesion, but numerous gritty particles. Readily breaks down in water, and can be separated into two portions, one faintly yellow straw-coloured, composed almost entirely of diatoms; the other dark, almost black, of mineral particles.

$CaCO_3$:—Nil.

Siliceous organisms 55 per cent.:—Diatoms and radiolaria.

Minerals 40 per cent., angular, m. di. 0·11 mm.:—Volcanic glass and pumice, red palagonite, augite, magnetite, felspar, a little quartz, biotite, and hornblende. A few large fragments of pumice.

Fine washings 5 per cent.:—Fragments of diatoms and minute mineral particles.

Foraminifera:—*Cyclammina pusilla*, rare.

46. Station 447; April 9, 1904; lat. 51° 07′ S., long. 9° 31′ W.; depth 2103 fathoms.

DIATOM OOZE.—No deposit in the sounding-tube, which seemed to have been on hard ground. A few balls of ooze were obtained from the trawl. These were of a light straw colour when wet, almost pure white when dry. Very little cohesion, soft floury feel, almost no grit. Possibly slightly washed or sorted out in coming up, so that it may not be really quite typical of the deposit *in situ*.

$CaCO_3$ 9 per cent. (anal.):—Foraminifera, echinoid spines, a few ostracod valves.

Siliceous organisms 80 per cent.:—Diatoms chiefly, also radiolaria and sponge spicules.

Minerals 5 per cent., m. di. 0·15 mm.—Rounded and sub-angular quartz grains, and a few pieces of volcanic glass.

Fine washings 6 per cent:—Fragments of siliceous organisms.

Chief foraminifera:—Arenaceous types represented by nine genera, the most

characteristic forms being *Proteonina difflugiformis, Rhizammina algæformis, Reophax nodulosa, Cyclammina cancellata, C. pusilla, Trochammina globigeriniformis,* and *Ammochilostoma paucilocculata.* The Miliolinidæ are represented by *Biloculina depressa* and *Miliolina venusta*; the Textularidæ by *Gaudryina, Clavulina,* and *Cassidulina*; the Lagenidæ by four species, including the rare forms *L. staphyllearia* and *L. fieldeniana. Globigerina dutertrei* common, three species of *Pullenia,* two of *Truncatulina,* two of *Pulvinulina,* two *Nonionina,* and one *Rotalia.*

47. Station 451; April 13, 1904; lat. 48° 06′ S., long. 10° 05′ W.; depth 1742 fathoms.

Diatom Ooze or Globigerina Ooze.—Only a small amount of deposit obtained off the swabs attached to the trawl, which contained numerous pebbles. The deposit has almost certainly been washed in coming up, so may not represent quite truly the character *in situ.* Of a greyish colour, with a tinge of yellow when wet, a pure white cement-looking substance when dry. Readily crumbles between the fingers, and breaks down almost of its own accord in water, without rubbing.

$CaCO_3$ 55 per cent. :—Foraminifera.

Residue light brown in colour.

Siliceous organisms 30 per cent. :—Diatoms, radiolaria fairly abundant, sponge spicules.

Minerals 5 per cent., angular and rounded :—Quartz, felspar, augite, volcanic glass, magnetite.

Fine washings 10 per cent. :—Chiefly fragments of diatoms and radiolaria.

Rocks from trawl :—Nearly half a hundredweight of rock fragments, mainly under 2 inches in diameter. Angular and sub-angular chiefly, a few showing glacial striæ, particularly one rounded pebble of black shale. White quartzite most abundant; granite, diorite, greywacke, shale, slate, hard fireclay (one piece), a few volcanic rocks, mostly scoriaceous, some compact basalts. Some clean, most with a black coating of manganese.

Chief foraminifera :—Globigerina inflata, G. dutertrei, G. pachyderma. Also rather numerous more northern types, such as *Bolivina nobilis, B. reticulata, Bulimina aculeata, B. buchiana, Uvigerina pygmæa, Truncatulina lobatula, Pulvinulina canariensis, P. crassa, Nonionina umbilicatula.* Only two arenaceous forms, *Proteonina difflugiformis, Gordiammina charoides.*

48. Station 454; April 15, 1904; lat. 45° 56′ S., long. 10° 05′ W.; depth 1799 fathoms.

(?) Ooze.—Nothing in sounding-tube. Merely a small scraping obtained from the outside of the tube. Probably a Globigerina ooze.

49. Station 459; April 20, 1904; lat. 41° 30′ S., long. 9° 55′ W.; depth 1998 fathoms.

GLOBIGERINA OOZE.—Of a light fawn colour. Coherent and slightly plastic while wet.

$CaCO_3$ 71 per cent. (Anal.):—Foraminifera. Coccoliths fairly numerous, rhabdoliths a few.

Siliceous organisms 5 per cent. :—Diatoms, radiolaria, sponge spicules.

Minerals 5 per cent., angular, m. di. 0·06 mm. :—Felspar, magnetite, volcanic glass, augite, olivine.

Fine washings 19 per cent. :—Amorphous clayey matter chiefly; some minute mineral particles and fragments of siliceous organisms.

Chief foraminifera:—Globigerinidæ make up the bulk of the deposit, especially *Globigerina bulloides* (by far the most abundant), *G. dutertrei*, *G. inflata*, *G.* (*Orbulina*) *universa*, *Pulvinulina canariensis*, *P. micheliniana*, *P. exigua*, and *Pullenia obliquiloculata*. All species more or less dwarfed. Also nine species of Miliolinidæ, seven Textularidæ, and nineteen Lagenidæ, including the rarer forms *L. stelligera*, *L. fieldeniana*, and *L. truncata*. Arenaceous types rare; they include:—*Reophax distans*, *Proteonina difflugiformis*, *Cribrostomoides bradyi*, *Ammochilostoma galeata*, and *Spiroplecta americana*.

50. Station 467; April 28, 1904; lat. 40° 08′ S., long. 1° 50′ E.; depth 2645 fathoms.

GLOBIGERINA OOZE.—Deposit only obtained off trawl. Probably partly washed in coming up. Of a light reddish-brown colour with white specks (foraminifera). Coherent, slightly plastic.

$CaCO_3$ 46 per cent. :—Foraminifera. Coccoliths fairly abundant, no rhabdoliths. Echinoid spines and ostracod valves.

Residue reddish in colour.

Siliceous organisms 3 per cent. :—Diatoms, radiolaria, and sponge spicules.

Minerals 1 per cent. :—A few rounded quartz grains and felspars.

Fine washings 50 per cent. :—Chiefly minute mineral particles, some amorphous clay, and fragments of siliceous organisms. Not sufficient clay to call the sample a transitional form between Globigerina ooze and Red clay.

Chief foraminifera:—*Globigerina inflata*, *G. bulloides*, *G. dutertrei*. Numerous other calcareous and arenaceous foraminifera—the variety large, the numbers of each being few, and their size as a rule small.

51. Station 468; April 29, 1904; lat. 39° 48′ S., long. 2° 33′ E.; depth, no sounding taken; probably about the same as No. 50.

GLOBIGERINA OOZE.—Deposit obtained from the trawl. Certainly partly washed in coming up, so that it is not typical of the deposit *in situ*. Brown in colour with white specks (foraminifera). Coherent, more clayey than No. 50, and not so easily rubbed down in water.

$CaCO_3$ 40 per cent. :—Foraminifera. Coccoliths fairly abundant, no rhabdoliths.

Residue red in colour.

Siliceous organisms 3 per cent. :—Diatoms, radiolaria, sponge spicules.

Minerals 1 per cent. :—The only recognisable piece is a fragment of pumice 0·75 mm. in size.

Fine washings 56 per cent. :—Similar to No. 50, but distinctly more amorphous clay, almost sufficient to term the deposit a transition form to Red clay.

A few small pebbles from trawl, angular and sub-angular. Probably ice-carried from their variety, but no striæ seen on any of them. (Specimens lost.)

Chief foraminifera :—Globigerina bulloides and *G. inflata* are the most numerous forms. Fewer bottom-living forms than in No. 50. *Truncatulina* seems to take the place of *Lagena* so far as numbers go. Arenaceous types include *Psammosphæra fusca*, *Rhabdammina discreta*, and *Proteonina difflugiformis*.

Summary of the Three Main Types of Deposits obtained.

Globigerina Ooze.

Samples of Globigerina ooze from the S. Atlantic were obtained by the *Scotia* in two localities: (1) between Falkland Islands and the S. Orkney group, and (2) to the south and east of Gough Island. In the former area the Globigerina ooze forms a narrow zone between the S. American terrigenous deposits and the circumpolar Diatom-ooze band. Only one typical sample was obtained in this locality, viz. No. 28, from 56° 54′ S., 56° 24′ W., 1946 fathoms, containing 24 per cent. of $CaCO_3$ by analysis, the lime being chiefly derived from the shells of foraminifera. Mr Pearcey has separated no less than twenty-nine genera and sixty species of foraminifera from this sample, of which twelve genera are of arenaceous types. The calcareous forms include practically all the types characteristic of the Globigerina oozes of the S. Atlantic, the most abundant being the small cold-water forms *Globigerina dutertrei*, *G. pachyderma*, *G. bulloides*, and *G. inflata*. The mineral particles of this deposit, like those of the Diatom oozes to the south-east, are largely of volcanic origin. On the Burdwood Bank, although no ooze was actually brought up in the sounding-tube, the material obtained in the trawl, containing, as it did, much foraminifera and shelly, sandy material, points to the eastern portion of the Bank at all events, if not the whole of it, lying within the Globigerina ooze area, and outside the region of deposition of land-derived material from the S. American continent. Some eighty species of foraminifera were obtained, the general facies being an Antarctic shallow-water one, with few arenaceous species.

South of Gough Island, on the Mid-Atlantic rise, the Globigerina ooze extends to about 48° S. lat. Sample No. 47, from 48° 06′ S., 10° 05′ W., from a depth of 1742 fathoms, must be classed as a transitional form of deposit, containing, as it does, 55 per cent. $CaCO_3$, and also 30 per cent. of siliceous organisms. The foraminifera from this place consist predominatingly of the cold-water Globigerinidæ, *G. inflata*, *G. dutertrei*,

and *G. pachyderma*; but there are also considerable numbers of more northern species of *Bolivina*, *Bulimina*, *Uvigerina*, *Truncatulina*, *Pulvinulina*, and *Nonionina*. Arenaceous forms are conspicuously rare. The trawl at this station brought up a large number of small rock-fragments of considerable variety, some of them showing fine glacial striæ.

In 41° 30′ S., 9° 55′ W., not far to the south of Gough Island, the percentage of $CaCO_3$ rises to 71, and the coccoliths and rhabdoliths are present in addition to foraminifera. A large number of species of foraminifera are present, although the cold-water surface Globigerinidæ are easily the most abundant; all forms tend to be of small size, and the others are few in number individually, although of many varieties. Arenaceous species are not abundant. To the east of Gough Island, almost midway between it and the Cape of Good Hope, in 40° 08′ S., 1° 50′ E., and in 39° 48′ S., 2° 33′ E., the $CaCO_3$ falls to 46 per cent. and 40 per cent. respectively, while the "fine washings" (clayey matter principally) rise to 50 and 56 per cent. The depth here is over 2600 fathoms, and the bottom material shows an approach to the Red clay, an area of which lies to the west and south-west of the Cape of Good Hope. The pelagic foraminifera are here similar to the previous samples; the benthoic calcareous forms are considerably less numerous.

Diatom Ooze.

The circumpolar Diatom ooze band was crossed by the *Scotia* in two regions, viz. to the north of the S. Orkneys and along the meridian of 10° W. long. In the former area, where the Diatom ooze band is undoubtedly a narrow one, five samples were obtained which might fall under this heading, but only one was procured under circumstances allowing of full identification. This sample, No. 26*b*, from lat. 59° 23′ S., long. 49° 08′ W., 2180 fathoms, contains 15 per cent. of siliceous organisms, chiefly diatoms, but also a good many radiolaria. There are a large number of mineral particles of volcanic origin, a feature still more pronounced in No. 27, obtained a little to the north-west; so that these specimens, although included in the Diatom ooze area, might, with perhaps greater accuracy, be described as volcanic sands. It is the influence of the volcanic activity in the S. Shetlands and neighbouring parts of the Antarctic continent which is doubtlessly making itself felt here.

Along the meridian of 10° W. long. three samples of Diatom ooze were obtained, from 56° 58′ S., 51° 07′ S., and 48° 06′ S.—the centre one of these three being the only Diatom ooze, however, corresponding to the classical type of this form of deposit, *i.e.* of a light straw colour when wet, almost pure white when dry, very like the finest flour in appearance and to the touch, with very little cohesion, and composed predominatingly of the siliceous skeletons of diatoms. The most southerly is a transitional form to volcanic sand, coming within the influence of the S. Sandwich group; the most northerly, to Globigerina ooze. The amount of lime in these three shows an interesting transition from nil in the most southerly, through 9 per cent. in the centre, to 55 per

cent. in the most northerly. The siliceous organisms constitute respectively 55, 80, and 30 per cent. of the whole, going from south and north. Diatoms in all three make up the greater part of this, but radiolaria are also always present. The predominant species are given below in Dr GRAN's report. MURRAY and PHILIPPI, in their *Valdivia* report, refer to the absence in the deposits of certain species common in the surface waters, presumably through solution during the long process of sinking; whether this holds good also in the Weddell Sea and S. Atlantic area it is not yet possible to say, until the results of the examination of the tow-netting specimens are available. The absence of clayey matter and rock flour in these Diatom oozes, particularly in the most southerly, is very striking. Evidently the transition from the glacial clay to the south, in which the "fine washings" of the most northerly sample obtained formed 97 per cent. of the whole deposit, is a fairly sharp one. The transition to Globigerina ooze on the northern side of the Diatom ooze band in this region appears, on the other hand, to be more gradual. This is in keeping with the results obtained by the *Valdivia* and the *Gauss*; but no isolated patches of Globigerina ooze within the Diatom ooze area, or between it and the glacial clay, as found by the *Valdivia*, were come across by the *Scotia*.

The relative amounts of diatoms in the surface waters and in the bottom material from the same place form a very marked contrast. Diatoms live entirely in the upper layers of the ocean, within the depth to which light permeates, and within the pack-ice area are exceedingly abundant, colouring the ice as it is seen broken up in summer, of a brownish colour. Over the whole of the Weddell Sea area, where the bottom material is a glacial clay, diatoms flourish in the surface waters, but in the deposits they are either entirely absent or in insignificant amounts (under 2 per cent.). Where they are most predominant in the deposits—in about 51° or 52° S.—on the other hand, they are comparatively infrequent in the surface waters. How is this striking difference to be accounted for? It is not a question of depth and solution before reaching the bottom, for the difference in the two zones is inconsiderable—about 2400 to 2700 fathoms for the glacial clays, and 2100 to 2500 fathoms for the Diatom oozes. Nor can the rapid accumulation of glacial detritus with hiding of the diatoms account for this remarkable distribution, for in deposit No. 44 from 61° 21′ S., 13° 02′ W.—the most northerly glacial clay obtained in this area, and where the accumulation of detritus must be much slower than nearer the Antarctic continent—not a single diatom could be found. Carrying away of the diatoms by surface currents set in motion by the prevailing winds also fails as an explanation, for in the southern part of the Weddell Sea the drift is to the west, in the northern portion to the east, whereas a northerly carriage is required to fit in with the facts of distribution. One is thrown back on the explanation tentatively put forward by Dr PHILIPPI (6) in his preliminary report on the deposits obtained by the German Antarctic Expedition, and subsequently elaborated by himself. This is in the existence of a northerly undercurrent produced by the melting of ice within the pack-ice zone. Some indication of strong undercurrents was got by the *Scotia* while trawl-

ing (7); although this was south of 70° S. lat., it is possibly a widespread condition. Further evidence of their presence is afforded by the movements of icebergs, the deeply immersed portions of which are influenced by this current, carrying them northward despite the absence of prevalent winds from the south. The diatom skeletons, being light, are carried off by this current and only sink to the bottom farther north, where, presumably, the current is dissipated. The heavier glacial material, carried chiefly in the base of the bergs (ground morainic matter)—which parts melt early—sinks easily and is deposited nearer the Antarctic land. Much of the finest rock flour, however, is carried, perhaps partly within the ice of the bergs, but largely in suspension, to a very considerable distance from Antarctic land into the S. Atlantic. Whilst this theory provides a working hypothesis to account for the peculiar distribution of diatoms, it seems to me not quite satisfying in its failure to account completely for the rapid transition from glacial clay composed largely of rock flour and containing no diatoms to a diatom ooze with almost no clay or rock flour. The distribution of the glacial clay and Diatom ooze and the limits within which pack-ice occurs—so far as we know these two sets of facts (8)—also do not seem to correspond sufficiently closely to be explained fully by this theory. The *Gauss* and *Valdivia* reports read almost as if the margin of the glacial deposits corresponded exactly with the pack-ice zone, the coarser glacial detritus sinking mainly within the inner portion of the pack-ice zone, the diatoms and fine rock flour being carried northwards by the current set up by the melting surface ice, to sink outside the pack-ice area. In a general way this is probably true. Where pack-ice is known to come far north—as, for instance, in the eastern part of the S. Atlantic—the Diatom ooze area also extends further northwards, but there ought also by rights to be a considerable admixture of fine rock flour in the ooze, which does not appear to be the case. Observations on the rates of sinking of diatom frustules and rock flour would throw further light on this interesting point, and further data on the distribution of ice and of the circumpolar glacial clay and Diatom ooze are required before a completely satisfactory explanation is forthcoming. (See also under "Glacial Muds and Clays," p. 677 *et seq.*)

Diatoms in Deposits.

A selected series of deposits containing diatoms was sent to Professor H. H. Gran of Christiania, who kindly offered to examine and report upon them. The selection included not merely those deposits classified as Diatom oozes, but also a few specimens of glacial clays in which I had noted the presence of diatoms in my examination, and of shallow-water deposits from the coast and neighbourhood of the S. Orkneys. It is convenient to include them all at this point. The following is Professor Gran's preliminary report on the samples, which he has been good enough to allow me to make use of pending his complete identification and description.

"The samples are of two different types—

"(1) Deep-sea deposits of a very uniform character [as regards their diatoms

—J. H. H. P.], containing the strongest silicified remains of pelagic diatoms. To this type belong the following samples :—

No. 3.	Diatom ooze from	58° 22′ S., 45° 00′ W.,	1698 fathoms.
4.	„ „	59° 32′ S., 43° 10′ W.,	2307 „
5.	„ „	59° 42′ S., 34° 13′ W.,	1325 „
23.	Sandy mud from	61° 05′ S., 43° 20′ W.,	214 „
26*a*.	Transitional Glacial mud—Diatom ooze from	59° 43′ S., 48° 10′ W.,	2110 „
26*b*.	Diatom ooze or Volcanic sand from . .	59° 23′ S., 49° 08′ W.,	2180 „
27.	„ „ „ . .	58° 28′ S., 51° 56′ W.,	2168 „
39.	Glacial clay from	71° 32′ S., 17° 15′ W.,	1221 „
45.	Diatom ooze or Volcanic sand from . .	56° 58′ S., 10° 03′ W.,	2518 „
46.	Diatom ooze from	51° 07′ S., 9° 31′ W.,	2103 „

" Common to all the samples are the following species :—

Fragilaria antarctica (Schwartz), Castraçane.
Rhizosolenia styliformis, Brightw., ends of cells.
„ *bidens*, Karst, ends of cells.
Eucampsia Balaustium, Castr.
Biddulphia Weissflozii, Jan.
Actinocyclus Oliverianus, O'Meara.
Coscinodiscus planus, Karst (and other closely connected forms).
Coscinodiscus oculus iridis, Ehr., different forms, difficult to identify with certainty from the often corroded specimens.

I cannot point out any clear difference between the various samples of this type.

"(2) Deposits from the littoral zone of the S. Orkneys :—

No. 24*a*.	Uruguay Cove	5–10	fathoms.
24*b*.	Scotia Bay	36½	„
24*c*.	Scotia Bay	5–10	„
25*a*.	Off Coronation Island . . .	41½	„

These samples are all very rich in littoral and ice diatoms. Nos. 24*b* and 25*a* [the former from well out in the centre of Scotia Bay, the latter from open water on the north coast of Coronation Island—J. H. H. P.] contain also the same plankton species as the samples of type 1. But dominant are the following species, which occur more or less abundantly in all the samples :—

Amphora proteus, Greg.
Navicula aspera (Ehr.).
„ *brasiliensis*, Grun.
„ *directa*, W. Sm., dominant in 24*a*.
„ *jejunoides*, Van Heurck.
„ *quadratarea*, A. Schmidt, dominant in 24*c*.
„ *Smithii*, Breb.
Pleurosigma kerguelense, Grun.
„ *mediterraneum*, Cleve.
Gomphonema kamtschaticum, Grun.
Amphiprora Kjellmanii, Cl.
Acynanthes grœnlandica, Grun.
Cocconeis antigua, Temp. and Brun, with varieties.
Cocconeis costata, Greg, with varieties.
Nitzschia distans, Greg.
Entopyla australis, Ehr.
Lichmophora Reichardtii, Grun.
Grammatophora monilifera, Brun.
Melosira sol (Ehr.), Kutz.
Podosira maxima, (Kutz), Grun.
Isthmia enervis, Ehr.
Biddulphia arctica (Brightw.).
„ *Ottomulleri*, Van Heurck.
Chætoceras, sp., resting spores.
Actinoptychus undulatus, Ehr.
Arachnodiscus Ehrenbergii, Bail., var. *indicus*, Grun.

"It is a very interesting mixture of Arctic, special Antarctic, and subtropical species. There are also some others difficult to determine with certainty from the preparations I have made so far, but I hope to be able to give you a final report soon.

"(Signed) H. H. GRAN."

Terrigenous Deposits, particularly Glacial Muds and Clays.

The greater number of the deposits collected by the *Scotia*, including practically all those obtained in the Weddell Sea south of the 60th parallel, are of terrigenous origin, of the type which I propose to designate as glacial mud or clay. This is composed almost entirely of material derived from Antarctic lands and distributed in the surrounding seas partly in suspension in the water, partly through the medium of floating ice, especially icebergs. In the *Challenger* report and map this deposit is not distinguished from other Blue muds of terrigenous origin, and in my preliminary report on the deposits obtained by the *Scotia*, published in the *Scot. Geog. Mag.*, 1905, I also included it amongst the Blue muds, pointing out, however, some respects in which it differed from those surrounding non-glaciated lands, and, in particular, distinguishing certain samples as approaching Red clays in some of their characteristics, although differing markedly in others. PHILIPPI, in his report on the deposits obtained by the *Gauss*, first proposed the separation of this deposit from terrigenous deposits under the title "Glacialmarine-ablagerung," basing his classification on the following main differences:—

(1) Almost complete absence of $CaCO_3$ from the deposits.

(2) Small amount of organic constituents.

(3) Very unequal size of the mineral particles, especially of the coarser components.

(4) Character of the "fine washings"—these consist for the most part of exceedingly fine "rock flour," whereas in the Blue muds proper they consist chiefly of amorphous clayey material.

He says further that this marine glacial deposit consists essentially of a mixture of the finest ooze with sandy and gravelly constituents with, here and there, large fragments and stones. According to the size of the fragments and the preponderance of one or other component, one may get an oozy or muddy sand or gravel, or an ooze with sandy or gravelly constituents.

The deposit is in general the finer grained the farther it is from the ice edge and the deeper the water; only exceptionally within the pack-ice zone does it contain any lime and is usually free from diatom frustules—facts all the more striking seeing that the surface waters contain numerous Globigerinidæ and diatoms in enormous numbers.

With this description I am, from my examination of the *Scotia* deposits, in substantial agreement. Some of these deposits are most aptly described as muds, but many are unctuous tough clays requiring much rubbing to break them down in water. In ordinary parlance they would undoubtedly be described as "clays," and although microscopic examination reveals the fact that the finest constituents do consist for the

most part of minute mineral fragments or rock flour, produced by glacial action, there is nevertheless a considerable amount of amorphous clayey material. I propose, therefore, following Dr PHILIPPI's lead, to separate this group of deposits from the ordinary Blue muds and to designate them *glacial clays, muds, or sands*, according to their physical characteristics.

The following table gives in grouped form the depth, colour, and composition of all the marine glacial deposits obtained, with the exception of a few comparatively shallow-water deposits, mostly from the neighbourhood of the S. Orkneys :—

No.	Depth.	Colour.	$CaCO_3$ Percentage.	Siliceous Organisms. Percentage.	Mineral Particles.		Fine Washings. Percentage.
					Percentage.	Mean Diam. in mm.	
7	2250	Green-grey	...	Trace	...	...	...
8	2739	,,	Trace	Trace (Rad.)	5	0·16	95
9	2558	...	0	Trace (Sp.)	10	0·07	90
10	2587	Grey	Trace	Trace (Rad.)	10	0·08	90
11	2511	,,	0	Trace	20 10	0·16 0·10	80 (upper portion) 90 (lower portion)
12	2452	Blue-grey	0	1 (Di.)	15	0·07	84
13	2488	Green-grey	5	0	15	0·10	80
14	2500	,,	0	Trace (Di.)	20	...	80
15	2425	,,	0	0	20	0·07	80
16	2500	Grey	2	0	12	0·08	86
17	2485	Dark grey	Trace	Trace (Sp.)	10	0·08	90
18	2547	Blue-grey	0	Trace (Di.)	15	0·08	85
19	2550	Grey	0	,,	10	0 07	90
20	1956	,,	0	1 (Sp.)	10	0·06	89
21	1775	Blue-grey	2	Trace (Rad., Di.)	70	0·25	28
26*a*	2110	Brown-grey	1	10 (Di.)	60	0·13	29
30	2625	Brown	Trace	Trace (Rad.)	5	0·12	95
31	2630	Grey	0	,,	3	0·09	97
32	2685	,,	0	0	2	0·05	98
33	1131	Green-brown	0	2 (Sp., Di., Rad.)	20	0·17	78
35	2102	Brown-grey	0	Trace (Sp.)	25	0·06	75
36	2338	...	...	...	...	...	...
37	2370	Green-grey	Trace	Trace (Sp., Rad.)	15	0·06	85
38	1410	,,	4	1 (Sp., Rad.)	20	0·07	75
39	1221	,,	2	2 (Sp., Rad., Di.)	15	0·08	81
40	2620	Brown-grey	0	Trace (Sp.)	20	0·07	80
41	2487	,,	Upper 5 Lower 1	,,	20	0·08	75
42	2660	Light brown	0	,,	20	0·07	80
43	2715	,,	0	,,	5	0·07	95
44	2764	Grey-brown	0	,,	3	0·08	97
30 samples	2343	...	...	...	16·7	0·09	82 (average)

It will be seen that the average depth from which these thirty samples come is 2343 fathoms, the greatest being 2764 fathoms, and the least 1131 fathoms.

Appearance.—The ground colour as brought up from the bottom is a slaty-grey,

with a green, blue, or brown tone in different samples; when dried, the colour is, as a rule, much lighter, being a pale grey or dirty white.

Physical Characters.—The majority of the glacial deposits from the Weddell Sea south of 60° S., are distinctly clay-like in character, being coherent, tough, unctuous to the touch (although always containing more or less gritty particles), and requiring a considerable amount of rubbing to break them down into their component parts for microscopic examination. The deep-water deposits never had any smell of H_2S when brought up, but some of the muds from the shallow water of the enclosed bays of the S. Orkneys had. When dried, these deep-sea glacial clays become hard; they take a lustrous polish when rubbed on the finger and leave a shiny streak on porcelain. The tongue readily adheres to a piece of the dried clay, and there is a distinct clayey odour when the mass is breathed upon. The clayey character is, as a general rule, more pronounced the further one is away from the Antarctic continent.

This is so striking that in a former report (*Scot. Geog. Mag.*, Aug. 1905) I distinguished a group of these as approximating to Red clays in some of their characteristics. As one approaches the continent and the seaward edge of the inland ice, the clayey character becomes less marked, the deposits becoming rather muds, but even within a few miles of the ice-barrier, as at 72° 18′ S., 17° 59′ W., 1131 fathoms (No. 33), there is still so much of the clayey character present that the deposit can only be described as clayey mud.

In the samples from between 61° and 66° S., almost due south of the S. Orkneys, there seems to be a rather erratic variation in the "mud-clay" distribution: No. 16 (from 65° 29′ S., 44° 06′ W., 2500 fathoms) being noted as the most clayey met with up till that time; No. 17 (from less than a degree to the north, 2485 fathoms) is a mud with very little clayey character; No. 19 (from 63° 51′ S., 41° 50′ W., 2550 fathoms) is again a tough clay; No. 20 a mud; and No. 21 (from 62° 10′ S., 41° 20′ W., 1775 fathoms) a muddy sand. The explanation of this irregular distribution is not quite clear; probably it is connected with the drift of the icebergs out of the Weddell Sea in its western portion, and may indicate proximity to land in the neighbourhood of 66° S., 48° W., where MORRELL in 1823 and Ross in 1843 reported "appearance of land." No. 21 seems to be too far away from the S. Orkneys to have its sandy character accounted for by proximity to them, although there is no other obvious factor to explain it; Nos. 22 and 23, on the other hand, pebbles and sand from 210 and 214 fathoms respectively, obviously, both from their physical character and mineralogical composition, largely take their origin locally from the rocks of these islands. The several samples of Nos. 24 and 25 are shallow-water sands and muds from the S. Orkneys; No. 26*a* (from 59° 43′ S., 48° 10′ W., 2110 fathoms), on the north side of the S. Orkneys, is a sandy mud bordering on Diatom ooze.

For comparison with a Weddell Sea glacial clay I examined a sample of clay from the Portobello brickfield, on the east side of the city of Edinburgh. This is, in ordinary parlance, undoubtedly a clay and is a formation which has been laid down in the Great

Ice Age as a glacial deposit in shallow water. In its physical characteristics and also in the proportion of mineral particles contained, and microscopic character of the "fine washings" (largely composed of rock flour), it proved to be practically indistinguishable from a typical Weddell Sea glacial clay. I have intentionally laid some stress upon the clayiness of most of these deposits, because it appears to me from my reading of the *Gauss* reports to be more pronounced in this part of the Antarctic than in the regions lying to the south of the Indian Ocean. The width of the marine glacial deposit belt is certainly much wider to the south of the Atlantic than to the south of the Indian Ocean. The greater concentration of the coarser mineral particles within a narrower zone in the latter region would account for their being of a more muddy or sandy character; but in that region also, as one goes further from the inland ice, the deposits become of a more oozy or clayey nature.

$CaCO_3$.—Of twenty-eight of these glacial marine deposits, sixteen contained no lime, five merely a trace, and seven amounts varying from 1 to 5 per cent. This paucity or absence of lime is one of the features distinguishing these glacial deposits from the ordinary Blue muds of terrigenous origin in which it is usually abundant. Foraminifera are tolerably abundant in the surface waters, and the trawl showed the presence of numerous living benthoic organisms (fish, brittle-stars, mollusca, etc.) containing lime in the glacial deposit area, so that its absence must be attributed to a strong solvent action of the bottom cold layers of water. The samples which contained small amounts of lime are irregularly distributed, and bear no obvious relationship to the depth, position, etc. This patchy distribution of lime was also noted by the *Gauss*, and a somewhat similar condition by the *Valdivia*. On the latter expedition an area of peculiar Globigerina ooze was found between lime-free Diatom ooze and Glacial mud.

The principal calcareous foraminifera in these deposits is *Globigerina dutertrei*; others occurring are *G. dubia*, *G. bulloides*, *G. pachyderma*, *Truncatulina wuellerstorfi*, *T. pygmæa*, *T. tenuimargo*, *T. tenera*, *Cassidulina subglobosa*, *Pullenia sphæroides*, *Miliolina bucculenta*, *Clavulina communis*, and *Cristellaria convergens*. Ostracod valves were noted a few times.

Siliceous Organisms.—Of twenty-seven samples four contain no siliceous organisms, seventeen a mere trace—and that more often sponge spicules and large radiolaria than diatoms—five from 1 to 2 per cent., and one (No. 26*a*, bordering on Diatom ooze) 10 per cent. The absence of diatoms is another of the remarkable features of these glacial deposits, and one which has been already commented upon in speaking of the Diatom oozes. The surface waters over these deposits simply teem with diatoms, but apparently they are all carried off northwards by an under-current set up by the melting ice, and only sink to the bottom far beyond their region of maximum occurrence in life. Their absence is as striking in the more northerly part of the glacial clay, where the accumulation is presumably slower, as in the deposits from nearer the Antarctic continent, where it is more rapid, so that mere hiding of the diatoms through rapidity

of deposition of rock debris will not explain their absence. To account for them being so completely lacking until the Diatom ooze belt is reached, it seems necessary to postulate that they sink more slowly than even the minutest mineral particles and clayey matter constituting such a preponderating part of the glacial clays furthest from the inland ice.

Another possibility is that the rock flour is liberated at such a depth below the surface so as never to come to the same extent as the diatoms under the influence of the north-going current which carries them off. It therefore sinks to the bottom before the diatoms do.

Agglutinative foraminifera with a siliceous cement are common, and where a large amount of material was available from the trawl they were often obtained in large numbers.

Minerals: (1) *Rocks.*—The trawl frequently brought up large quantities of rock fragments varying in size from fine gravel up to boulders weighing two cwts. or more. The larger boulders are mostly sub-angular in shape, exactly like those which occur in boulder clays, and they frequently show glacial striæ; the smaller fragments may be either rounded or angular. A number of the rock specimens have part of their surface clean and fresh, and part coated with a brownish stain of manganese or iron oxide; the shape indicates that the latter part has been embedded in the bottom mud, while the former has projected into the overlying bottom water. The association at one spot, along with fine-grained mud or clay, of rock fragments which, according to their size, if assembled together would be called boulders, shingle, gravel, or sand, is one of the characteristic features of the glacial deposits, dependent upon their mode of formation.

In all other terrigenous deposits, not influenced by ice, the size of the component particles at one place is pretty constant, all lying close to a certain average, which gives the deposit at that place its peculiar character: gravel, sand, mud, etc. But this is not the case with the glacial deposits, for the grain size, when the larger constituents are taken into account as well as the finer, at any particular locality follows no such rule but shows the utmost variation. This is to be accounted for readily by the mode of formation of these deposits. Most of the material composing them probably comes off the Antarctic land as "ground moraine," along with the inland ice-sheet or glacier tongue protrusions thereof, forming a thick layer or sole to the bergs as they break off. A smaller amount will be frozen in more deeply in the bergs—surface morainic material or ground morainic material which has risen passing some sub-glacial obstruction. As the bergs melt, this material is set free and deposited, the finer-grained debris probably drifting a considerable distance in suspension before it finally settles down on the bottom. Close to the Antarctic shores the glacial deposits are undoubtedly richer in the larger materials, as a great part of the "bottom moraine" is probably liberated very early, perhaps even before the bergs actually calve off the parent ice-sheet; whilst those deposits far off from land and in deeper water contain proportionately much larger amounts of fine-grained material, but in both situations the intimate admixture of large

rock fragments and coarse mineral particles with fine-grained particles is typical of the glacial deposits. We had not on the *Scotia*, unfortunately, an opportunity of making a haul with the dredge in the shallow water off the ice-barrier at Coats Land; a direct examination of the material accumulating at the face of the barrier would be of the greatest interest.

A considerable variety of rocks occurs amongst these larger specimens; but by far the most common are metamorphic gneissic and schistose rocks, granulites, quartzites amphibolites, portions of acid and basic veins of banded gneiss, coarse granitoid forms, garnetiferous gneiss, mica and chlorite schists, cleaved phyllitic slate and hornfels. Igneous plutonic rocks, fairly abundant, are represented chiefly by granites, a few pieces of gabbro and diorite; volcanic rocks, not very abundant, chiefly by basalts, also by pumice, some pieces of tuff, trachyte, andesite, rhyolite, quartz dolerite, and—of great interest in conjunction with the Cambrian fossils—a characteristic spilitic basalt. Of sedimentary rocks there occur several varieties of sandstone, shale, slate, greywacké, a clay concretion from limestone, and pieces of limestone one of which is of particular interest, containing several species of that peculiar fossil form *Archæocyathina*. This find, although not *in situ*, points to the probable occurrence of Cambrian rocks on this side of the Antarctic similar to those in which these fossils were found on the Shackleton Expedition in Victoria Land. The general facies of the rock fragments, however, presuming that they come from the land to the south of the Weddell Sea, indicates the presence there chiefly of metamorphic rocks allied in character to those occurring on the western side of Graham Land (9) and to the gneisses of S. Victoria Land (10).

(2) *Smaller Mineral Particles.*—The smaller mineral particles obtained from the ordinary samples of deposit as brought up by the sounding-tube and including everything down to 0·05 mm. in diameter, and a certain amount of even smaller fragments (down to about 0·02 mm.), constitute on an average 16·7 per cent. of the deposit, the figure in the great majority being between 10 and 20 per cent. In one sample of pure glacial deposit (No. 21), whose peculiar sandy character is referred to in describing the physical characters of those deposits, the percentage rises to 70, whilst in six it falls to 5 per cent. or less. All these six lie in the portion of the Weddell Sea furthest from land, within the area I described in my preliminary report as Blue mud approximating in some respects to Red clay. The mean diameter of the mineral particles in the various samples works out on an average at 0·09 mm., the means varying between 0·05 and 0·25 mm. Although the sample (No. 32) with the smallest percentage of mineral particles is also the one with the lowest mean diameter of the particles, it cannot be said that all over there is very much difference in the average size of the smaller mineral particles, between the samples comparatively close to land and those far from it; there is certainly not the same marked contrast as there is in the amounts of the mineral particles.

Some of the mineral particles are well rounded, particularly the larger ones, and on

a few glacial striæ are to be seen; but sub-angular and angular particles are just as common.

The majority of the grains, like the larger rock specimens, are of "continental" origin—quartz, felspar of various kinds, and green hornblende being the commonest. Fairly common also are biotite and magnetite, many others in less abundance. Volcanic glass and minerals of volcanic origin are widespread, although not abundant; they are distinctly relatively more numerous in the specially clayey deposits in the part of the Weddell Sea furthest from land, and it is noteworthy that these same samples show the presence of a little palagonite—a point in which they resemble the abyssal Red clays. PHILIPPI points out that the absence of palagonite from these deposits is one feature of distinction from the Red clays, he not having found any in his samples. The palagonite particles I have seen are certainly very small, nothing, in size or amount, like those in which it occurs in the true Red clays, and it is only present in a few of the samples from the deepest portions of the Weddell Sea, and those furthest from land, where the deposit is of more pronouncedly clayey character.

Manganese is common as a thin pellicle or coating staining the surface of many of the rocks and smaller mineral particles of a brownish colour; but manganese nodules, such as occur so plentifully in the Red clays, do not occur. A few small manganese grains occur in some of the samples, but only of minute size and very sparingly.

Glauconite is present in a few samples, but also very sparingly, and when present is usually in the form of casts of foraminiferal shells.

Fine Washings.—The composition of the "fine washings," *i.e.* that portion of the deposit which is removed by the first decantation after the sample has been completely broken down into its constituent parts by stirring and rubbing in a considerable quantity of water, is one of the most characteristic features of the glacial marine deposits. They are to a very large extent made up of minute mineral fragments, the finest "rock flour" produced by the abrading action of the Antarctic inland ice, although there is also always a certain amount of amorphous clayey material. These are practically the only two constituents of the fine washings of the glacial deposits, particles of siliceous organism being so scanty as scarcely to come into consideration. In my estimate of the amount of fine washings I include under the heading of "Minute Mineral Particles" everything under 0·02 mm. in diameter along with a certain variable, but usually small, amount of those between 0·02 and 0·05 mm. In twenty-nine samples the average percentage of the fine washings is 82. Two samples (Nos. 21 and 26*a*, one a sandy deposit from 1775 fathoms; the other a deposit bordering a Diatom ooze) give a figure of under 30; six of 95 per cent., or over: all samples from that portion of the Weddell Sea furthest from the Antarctic continent; the remainder are all between 75 and 90. An estimate was made—it is nothing more—that if under the heading "Mineral Particles" all particles down to 0·005 mm. were included, the average percentage of these would be nearer 70 than 16·7, as it is recorded; and even then the remaining fine washings would not be all amorphous clayey matter, but would still

include very minute fragments of minerals. There is, however, a sufficiency of clayey material in practically all the glacial deposits of the Weddell Sea, and more so in some than in others, to give them the gross character of a clay; and, as already mentioned, their microscopic constitution is indistinguishable from the clay of the Portobello brick-field, a shallow-water glacial deposit. This character also serves to differentiate them from most Blue muds or terrigenous deposits laid down uninfluenced by the action of ice, some of which may be described as clays, but the majority are rather earthy than clayey in character.

The clayey nature, both microscopically and in its gross characteristics, is distinctly more pronounced in the deposits from the deeper and more northerly portions of the Weddell Sea furthest from the Antarctic inland ice. The colour of these tends to be of a brown shade of grey rather than the more common green or blue-grey of the others; they are more unctuous to the touch, very tenacious, and require more rubbing to break them down for microscopic examination. Their mineral particles amount only to from 2 to 5 per cent., whilst their fine washings constitute from 95 to 98 per cent. of the whole deposit, and of this a greater amount than elsewhere consists of amorphous clayey material, although even here that plays a much smaller rôle quantitatively than "rock flour." The different character of this group is so marked that in my preliminary account of these deposits I distinguished this area as one of "Blue mud approximating to Red clay in some of its characters." The points in which they resemble Red clays are (1) tough clayey character; (2) brownish colour; (3) paucity of mineral particles, those present consisting more largely of volcanic minerals; (4) occasional presence of palagonite; (5) absence of lime. I would not now, however, press this resemblance, although having drawn attention to it has served to emphasise the change in type of the glacial deposits with increasing distance from the land whence their constituent parts are drawn. The points of difference from a true abyssal Red clay are obvious enough, more particularly—as I quite recognised and pointed out at the same time—the character of the fine washings. These are not predominatingly clay as in the Red clays, but land-derived mineral particles, the finest rock flour resulting from the grinding and abrading action of the Antarctic ice-sheets and glaciers.

This rock flour from the ground moraine of the Antarctic ice-sheets is probably liberated largely within a comparatively short distance of the land, although a certain amount embedded more deeply in the lowest portion of the bergs is doubtlessly only set free further north as melting of the berg ice proceeds. Suspended in the water, it is carried for great distances before it settles down; but naturally the finest particles remain in suspension longest, and it is therefore only these that are found in the area furthest from Antarctica, although rocks and some mineral particles are to be expected as the result of immediate deposition by the setting free of deeper contained debris as the bergs are melting in lower latitudes. Sea-ice plays very little part in the distribution of the material making up these glacial deposits.

To sum up, the terrigenous deposits of the Weddell Sea may be distinguished from

the Blue muds of terrigenous origin laid down in oceans free from the influence of ice, under the term "glacial deposits," on account of:—

(1) The absence or paucity of lime in the deposit.

(2) The scarcity of organic constituents.

(3) The very irregular size of the mineral components, especially the larger pieces.

(4) The peculiar character of the "fine washings," chiefly rock flour.

The lime poverty is probably due to a strong solvent action of the bottom water.

The scarcity of diatoms, so numerous in the surface waters, is particularly striking, and is probably to be accounted for by their being swept off northward by currents which are set up by the melting of the sea ice.

Distribution by icebergs is responsible for the irregular size of the mineral constituents of these deposits.

Despite the irregular distribution of the mineral constituents, the glacial deposits are, on the whole, the finer grained, the further they are from the Antarctic continent.

In the Weddell Sea the glacial deposits are chiefly clays and muds, rarely sands. Those most remote from the Antarctic continent are the most clayey and approach the abyssal Red clays in some respects, but can always be differentiated by the excess of "rock flour" over true clay.

The rock flour resulting from glacial abrasion, which constitutes the greater part of the "fine washings," reaches its destination largely in suspension.

Further information is required as to the sinking rates of rock flour and of diatoms, and also as to the currents set up by the melting of sea ice within the pack-ice zone to account for the comparatively sudden transition on the northern border of the glacial deposits (in the Weddell Sea area) from diatom-free glacial clay to Diatom ooze containing comparatively little rock flour.

Chart of Deposits.

This is based upon the information gathered by the *Scotia*, the map in the *Challenger* volume on deep-sea deposits, Murray and Philippi's report on the deposits of the *Valdivia*, and Schott's atlas (11). Some slight changes are made upon my chart published in the *Scot. Geog. Mag.*, 1905—*e.g.* the deletion of the special area of "Blue mud approximating to Red clay"—since, although the special characters of the glacial deposit in this area are still insisted upon, it is now more clearly recognised that these characters are due to the greater distance of this area from the inland ice and that the clay of this area is simply the finest grained type of glacial deposit. There are also some alterations in the zone between S. Georgia and Buenos Ayres, consequent upon the preliminary information received from Dr Heim of Lieut. Filchner's Expedition.

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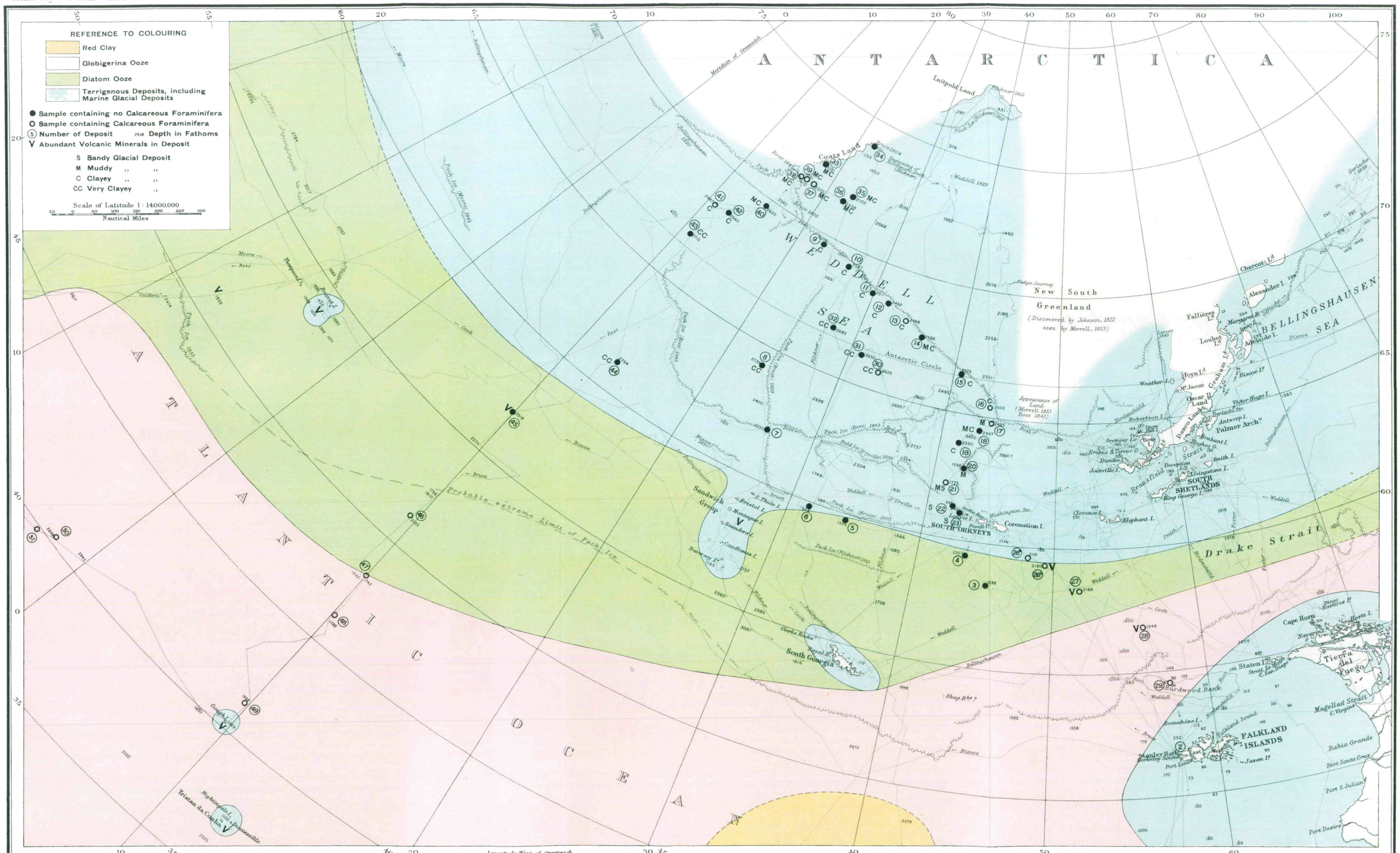
DEEP SEA DEPOSITS OF THE SOUTH ATLANTIC OCEAN AND WEDDELL SEA

BY J. H. HARVEY PIRIE, B.Sc., M.D.



The Edinburgh Geographical Institute

J. G. Bartholomew