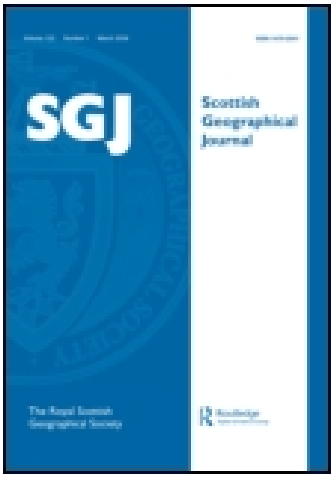

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3. DEEP-SEA DEPOSITS OF THE SOUTH ATLANTIC OCEAN AND WEDDELL SEA.

By J. H. Harvey Pirie, B.Sc., M.B.

(*With Map.*)

The deep-sea deposits of the area traversed by the *Scotia* include three main types, viz. Globigerina Ooze, Diatom Ooze, and Blue Muds of Terrigenous origin.

Globigerina Ooze.—The Globigerina Ooze area of the South Atlantic was crossed in two localities: (1) On the passage between the South Orkneys and the Falkland Islands. Here it forms a narrow band between the South American terrigenous deposits and the Diatom Ooze band. One sample only was obtained from a depth of 1946 fathoms: it contains 10 per cent. $CaCO_3$, and the commonest forms of Foraminifera are *Globigerina dutertrei, G. inflata*, and *G. bulloides* (dwarfed); less common *G. pachyderma, Pulvinulina canariensis, P. crassa*, and *P. elegans*; rare forms *Spiroloculina tenuis, P. micheliniana, Truncatulina pygmæa* and *T. hutemplei*; also numerous arenaceous forms. The mineral particles of this deposit are largely of volcanic origin. (2) To the south and east of Gough Island. The southern edge of the Globigerina Ooze is here about 48° S. lat. A sample from 48° 6′ S. 10° 6′ W. from a depth of 1742 fathoms might be classed either as a Globigerina Ooze or as a Diatom Ooze, containing as it does 55 per cent. $CaCO_3$ and 30 per cent. siliceous organisms. The trawl at this station brought up numerous pebbles, some of them showing fine glacial striæ; these pebbles include pieces of quartzite, greywacké, slate, granite, diorite, and basalt. In 41° 30′ S. 9° 55′ W. the $CaCO_3$ rises to 71 per cent., and Coccoliths and Rhabdoliths are met with in addition to Foraminifera. To the east of Gough Island in 40° 8′ S. 1° 50′ E. and 39° 48′ S. 2° 22′ E. the $CaCO_3$ falls to 46 per cent. and 40 per cent. respectively, while the "fine washings" (clayey matter and minute mineral particles under 0·5 mm. in diameter) rise to 50 per cent. and 56 per cent. The depth here is 2645 fathoms. This shows an approach to the Red Clay, an area of which lies to the SW. of the Cape of Good Hope.

Diatom Ooze.—The circumpolar Diatom Ooze band was likewise crossed in two regions: (1) Between the Falkland Islands and the South Orkneys. The band is here very narrow. Owing to heavy weather sounding was carried out with great difficulty, and only one really good sample was obtained, from a depth of 2180 fathoms in 59° 23′ S. 49° 8′ W. This contains about 15 per cent. siliceous organisms, including Diatom species of *Navicula, Coscinodiscus, Fragillaria, Hemiaulus, Actinocyclus, Rhizosolenia*, etc.; Radiolaria are also fairly abundant. As in the Globigerina Ooze further north, volcanic mineral particles are numerous, and the samples might indeed be classed as volcanic Muds or Oozes. These particles may be the product of submarine volcanic activity, but are quite possibly derived from the active volcanoes or volcanic rocks of West Antarctica or the South Shetlands. (2) Along the meridian of 10° W.

long. The band is here much wider, extending from about 48° S. to about 59° S. The transition from the Blue Mud on the southern edge is probably pretty sharp—in the Blue Mud from 61° 21′ S. 13° 2′ W. there are no Diatoms, in the Ooze from 56° 58′ S. 10° 3′ W. they form 55 per cent. of the whole deposit, in 51° 7′ S. 9° 31′ W., 2103 fathoms, the percentage rises to 70. The former sample contains 40 per cent. of mineral particles, mostly volcanic, including volcanic glass, pumice, palagonite, augite, magnetite, felspar, and a little quartz, biotite, and hornblende. As this sounding lies directly to the east of the South Sandwich group, which, so far as is known, is entirely volcanic, the probability is that these particles have been carried thence by the prevalent westerly winds or by floating ice.

The relative amounts of Diatoms in the surface waters and in the deposits form a marked contrast. Over the whole of the Blue Mud area of the Weddell Sea Diatoms are extremely abundant in the surface waters; in the deposits, on the other hand, they are either entirely absent or present only in very small quantity. Their maximum occurrence on the bottom is in about 51° or 52° S., where, in the surface waters, they are comparatively infrequent. Can this absence in the Blue Mud be accounted for by the rapid accumulation of the glacial detritus hiding them? I think not—for a reason that is given in the paragraph dealing with the Blue Mud resembling Red Clay. It is not a question of depth, for the difference is inconsiderable—about 2400-2700 fathoms for the Blue Mud, and 2100-2500 fathoms for the Diatom Ooze; nor can it be accounted for by the surface currents —in the southern part of the Weddell Sea these are westerly, and in the northern part about the boundary of the Blue Muds and Diatom Ooze, easterly. One is thrown back on the explanation tentatively put forward by Dr. Phillipi, who found the same condition on the German Antarctic Expedition,[1]* viz., a northerly undercurrent which carries off the Diatoms northward. Some indication of a strong undercurrent was got on the *Scotia* while trawling[2]; although this was south of 70° S. lat., it may be a widespread condition, and possibly the study of the temperatures and salinities at different depths will throw further light on this question.

Blue Mud.—The northern boundary is, in the area under consideration, a little to the north of the parallel of 60° S., and the deposit extends from there southwards to Antarctica. Within this area most of the material carried off Antarctic lands is deposited through the gradual dissolution of the icebergs. I say most of the material, because some is met with in the Diatom Ooze, and in the Globigerina Ooze at least as far north as the parallel of 40°, but in much less amount.

A typical specimen from the sounding-tube has the following characteristics. It is of a greenish-grey or bluish-grey colour, and is a coherent, moderately tough mud with a sufficiently clayey character to give it an unctuous feeling, but when rubbed between the finger-tips one can always feel some gritty particles. When dried it is of a light grey

* The figures refer to the references at the end of the paper.

colour and has a slightly clayey odour when breathed upon, and is capable of taking a lustrous polish when rubbed on the finger-nail. There is never any smell of sulphuretted hydrogen as in many terrigenous muds. Of $CaCO_3$ there is in most cases none, but every now and again a certain amount occurs, varying from a mere trace up to 6 per cent. This is from the shells of Foraminifera, principally *G. dutertrei*, more rarely also *Truncatulina wuellerstorfi*, *T. pygmæa*, *G. bulloides*, *G. dubia*, *G. pachyderma* and *Pullenia sphæroides*. This patchy occurrence of calcareous Foraminifera was also noted on the German Expedition[3]; and a somewhat similar condition on the *Valdivia* Expedition, where a patch of Globigerina Ooze was found between lime-free Blue Mud and Diatom Ooze areas.[4] The localities from which lime-containing samples were obtained are distinguished on the chart from those where the deposits contained no calcareous matter.

Siliceous organisms as before mentioned are extremely rare; they may be entirely absent or there may be from a trace up to 1 per cent. or 2 per cent., and these are chiefly sponge spicules and fragments of Radiolaria, very rarely Diatoms.

Mineral particles over 0·05 mm. in diameter form 10 per cent. to 20 per cent. of the deposit; the majority are angular in shape, but the larger fragments up to 2 or 3 mm. in diameter are generally sub-angular, and occasionally glacial striæ may be detected on them. Quartz grains predominate largely, but a great variety of other minerals occurs. Glauconite is rare, being only found as casts in a few of the samples in which there are calcareous Foraminifera. Manganese is common as a thin pellicle over other mineral particles, and a few very small grains occur, but there are no nodules such as are found in the abyssal Red Clays.

The remainder of the deposit is made up of "fine washings." When examined microscopically this part is found to contain occasional fragments of siliceous organisms and a small amount of true amorphous clayey matter, but it largely consists of minute mineral fragments under 0·05 mm. in size, the majority being probably between 0·02 and 0·005 mm. These represent the "rock flour" produced by the abrasive action of the Antarctic ice-sheets; this is carried out to sea partly in the ice of the icebergs, but, no doubt, largely also suspended in the water.

Additional information with regard to the deposits is given by the trawl. This usually brought up a large quantity of mud and rocks. The latter vary in size from fine gravel up to boulders weighing over two cwts. Most are typical sub-angular boulders such as occur in boulder clays, and they frequently show striations. Some of the rock specimens have part of their surface clear, and part coated with manganese; the shape indicates that the latter part must have been embedded in the mud, while the former projected out into the water. A great variety of rocks are present, plutonic igneous rocks being perhaps the most common—gabbro, diorite, quartz-porphyry and, especially, granites: of volcanic rocks, basalts are the most numerous; there occur also andesites and trachytes, pumice, scoriæ, and indurated tuff. Of sedimentary rocks, sandstones, limestones, shales, slate, grey-

wacke, quartzite, and a clay ironstone nodule were brought up. The following metamorphic rocks occurred: Hornblende gneiss, chlorite schist, mica schist, cleaved phyllitic slate, and garnetiferous quartzite.

The presence of these plutonic, sedimentary, and metamorphic rocks, as pointed out by Sir John Murray,[5] clearly indicates the continental character of the Antarctic land, although it is impossible, unfortunately, to locate the origin of these various boulders. Large numbers of arenaceous Foraminifera were also obtained from the mud in the trawl, belonging to many different genera. It is noteworthy that only one whale's ear-bone was brought up. As whales are probably quite as numerous, if not more so, in this area than in the Red Clay area of the Pacific, the explanation can only be that they are buried by the rapidity with which this deposit is accumulating as contrasted with the extreme slowness of the Red Clays.

For comparison, a sample of clay from the Portobello brick-field was similarly examined. In most of its physical characters, and in the proportion of mineral particles, and nature of the "fine washings," it was found to be practically indistinguishable from a typical Weddell Sea Blue Mud. This clay is one which has been laid down during the Ice Age as a glacial deposit in shallow water.

Blue Mud approximating to Red Clay.—The area of Blue Mud shaded on the map approaches Red Clay in many of its characters. The colour is more of a brownish grey than the blue or green grey of the typical Blue Mud: it is more tenacious and clayey, and it is not so easily rubbed down for microscopic examination, but still much more easily than a typical Pacific or Atlantic Red Clay. The mineral particles average only about three per cent., of which a considerable number are of volcanic origin, but too much reliance cannot be put on this for classification, as volcanic minerals are quite common in the Blue Muds. Ninety-five to ninety-eight per cent. of the deposit consists of "fine washings," but it is the character of these that differentiates the deposit from the true Red Clays. There is certainly a considerably larger proportion of true clay than in the typical Blue Muds, but there is still a large amount of very minute land-derived mineral particles—the finest rock-flour—which has probably reached its destination largely in suspension. This area is, on the whole, about 200 fathoms deeper than the surrounding seas, but the difference in the character of the bottom is probably mainly accounted for by the comparative infrequency of bergs within this area owing to the set of the currents. Here the rate of accumulation must be slower than in the main Blue Mud area, but as not a single Diatom was noted in any of the samples, one is precluded from accepting the hypothesis that these get lost amidst the glacial detritus.

Beyond the area from which samples were obtained by the *Scotia* the boundaries of the deposits as shown on the accompanying chart are mainly as given by Sir John Murray in the *Challenger* reports,[6] and within that area the chief change made on his map is a shifting northwards of the Diatom Ooze band, and the differentiation of the area of Blue Mud which resembles a Red Clay in some respects.

As no detailed account of the deposits obtained by the *Valdivia* from the area to the N. and E. of Bouvet Island has yet been published, I have drawn the probable boundaries of the different deposits in that region from the information given in Dr. Schott's Atlas[7] as to the nature of the bottom samples.

I have to express my great indebtedness to Sir John Murray for instruction at the *Challenger* office in the general methods of examining deep-sea deposits, which methods have been used in the investigation of the *Scotia* samples; also to Professor James Geikie, in whose laboratory the present work was carried on; and to Mr. F. G. Pearcey for the identification of the Foraminifera.

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[1] Phillipi. *Veröffentlichungen des Instituts für Meereskunde und des Geographischen Instituts an der Universität Berlin.* Heft. Oct. 5. 1903, pp. 137-140.

[2] Cf. this *Magazine*, January 1905, p. 5.

[3] Phillipi. *loc. cit.*

[4] Murray and Phillipi. *Centralblatt für Mineralogie*, 1901, No. 17.

[5] Murray and Renard. *Challenger Reports*, Deep Sea Deposits, p. 164.

[6] Murray and Renard. *Challenger Reports*, Deep Sea Deposits, Chart 1.

[7] Schott. *Wissenschaftliche Ergebnisse der Deutschen Tiefsee-Expedition.* Band 1, Tafel iii.

4. METEOROLOGY.

By ROBERT C. MOSSMAN, F.R.S.E.

(*With Illustrations.*)

In the report of the first Antarctic voyage of the *Scotia*[1] a somewhat detailed account was given of the meteorological work down to the end of October 1903. The data further available for discussion are as follows:—(1) The observations made at Laurie Island, South Orkneys, from November 1, 1903, to December 31, 1904. (2) The observations made on the *Scotia* while at sea on her voyage to and from Buenos Aires, and also from the South Orkneys to Coats Land, and thence to Cape Town *via* Gough Island. (3) The observations made between Cape Town and home. (4) Complete data from a base station at Cape Pembroke, Falkland Islands, consisting of eye observations every four hours for the two years 1903 and 1904, supplemented by barograph and sunshine records. As regards the above data the discussion will be confined in the present instance almost wholly to the observations made at Laurie Island, South Orkneys. The other observations are at present being reduced, but fully a year will elapse before the examination is

[1] See this *Magazine*, vol. xx. pp. 113-120.

Scottish National Antarctic Expedition

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