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# DEEP-SEA DEPOSITS AND DREDGINGS

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## CHAPTER XIII.

# DEEP-SEA DEPOSITS AND DREDGINGS.

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(*Written in March* 1923.)

## INTRODUCTION.

THE monumental work of the late Sir John Murray[1] and A. F. Renard on the nature of deep-sea deposits, their classification, the methods of obtaining them and of examining them, is a compendium of information which will be the *vade mecum* of every ocean explorer. It is therefore sufficient that this memoir deal with the particular samples under consideration, referring only in the briefest manner to some of the facts appertaining to marine deposits in general.

The term " deep-sea " deposit is accepted as referring to the materials which form the ocean-bottom at depths exceeding 100 fathoms.

Deep-sea deposits may be classified very simply thus :—

| | | |
|---|---|---|
| (*a*) Pelagic deposits .. | Red clay.<br>Radiolarian ooze (siliceous chiefly).<br>Diatomaceous ooze (siliceous chiefly).<br>Globigerina ooze (calcareous chiefly).<br>Pteropod ooze (calcareous chiefly). | |
| (*b*) Terrigenous deposits | Blue mud ..<br>Red mud ..<br>Green mud ..<br>Volcanic mud..<br>Coral mud .. | Materials brought down by rivers, worn from coasts, carried by icebergs or by atmospheric currents. |

A deposit is often found to contain a mixture of two or more of the above together with some secondary or chemical products (clayey matter arising from the decomposition of pumice, felspars, and other minerals ; manganese nodules ; palagonite and zeolitic materials ; phosphatic concretions, iron and calcareous concretions, etc.), and not infrequently there can be distinguished

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[1] Murray (J.) and Renard (A. F.).—Report of the Scientific Results of the Voyage of H.M.S. *Challenger* during the years 1873–76. Deep-Sea Deposits, 1891.

planetesimal dust (cosmic spherules of iron and nickel chondrites with lamellar structure, etc.).[1]

The hydrographer and electrician[2] of the Shackleton-Rowett Antarctic Expedition obtained for the geologist[3] sixteen bottom-samples from the Atlantic and Southern Oceans. Of these fourteen were true pelagic deposits and two were dredgings of rocks and pebbles (see pp. 9-10).[4] The number is small compared with the number of soundings recorded, chiefly because of the difficulty of winding in from 1,000 to 3,000 fathoms of wire without losing either the sample from the tube or snappers, or the end portion of the wire itself carrying the tube or snappers, by sudden breaking stresses due to ice or to the high seas and excessive rolling and pitching of the ship.

The Kelvin and the Lucas sounding machines were used, the former for shallow water (up to 300 fathoms), the latter for greater depths (Brunton wire in coils of 6,000 fathoms, diameter 0·028 in., weight 12·3 lbs. per 1,000 fathoms, breaking strain 175 lbs.). It was found advisable to attach a strong flexible rope of about 10 fathoms in length to the end of the wire, and then fasten the weights and snappers or Buchanan tube to the end of the rope. This arrangement proved more satisfactory than attaching the weights, etc., directly to the wire. The length of rope was then added to the depth recorded on the drum. A point of interest arises in the attempt to find the relation between true depth and apparent depth when the ship is drifting—this will be discussed at the close of this chapter.

## EXAMINATION OF SAMPLES.

The samples had been dried to some extent and placed in small glass sample-bottles with the exception of two or three which were wrapped in filter paper and put in tins. This latter method is not satisfactory as the remaining moisture produced rust, which ate through the filter paper and worked deep into the sample. The terrigenous deposits were very much embedded in tallow and before it was possible to examine them in any way they had to be simmered gently for several hours in a sodium bicarbonate solution. Only distilled water was used for this purpose in order to eliminate any deposition of lime, etc. Care was taken never to bring the liquid containing any of the samples

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[1] Fowler (G. H.).—The Science of the Sea, 1912.

[2] Commander F. A. Worsley, D.S.O., O.B.E., R.D., R.N.R., and J. Dell, C.P.O., R.N.

[3] G. Vibert Douglas, M.C., M.Sc.

[4] Geogr. Journ., 1923, vol. 61, p. 101.

to boiling point in order to prevent the finer particles from being aggregated or the larger particles from disintegrating.

The sizes of the samples of pelagic deposit varied from about 30 gms. to such small quantities that when slides had been made there was little or nothing left. Where there was 0·5 gm. or more the specific gravity was determined by means of a pyknometer.

The microscopic examination of the deposits and slides yields much information regarding the nature of their constituents, but in order to obtain the distribution curve representing the relative proportions of particles of different sizes it is necessary to employ a method of soil analysis devised by Dr. Sven Odén of Upsala,[1] and afterwards applied by him to some marine deposits sent him from the *Challenger* Office. His results[2] are of much interest, not only because each type of deposit showed a distinctive form of curve, but also because the same type of deposit exhibited definite peculiarities according to the ocean from which it had come.

*Sven Odén's Method.*—One pan of a balance is placed near the bottom of a vessel containing an aqueous suspension of the sample. By continuous weighing the rate of deposit on the pan is obtained and this cumulative weight, $P$, is plotted against the time, $t$, forming an "accumulation" curve. The following points were established :—

(1) If the height, $h$, of the water column above the pan be varied, the accumulation curve for any given sample remains practically unaltered if the values of $t$ for the abscissa are reduced to some standard value of $h$—say $h = 10$ cm., by the factor $10/h$.

(2) The accumulation curve is independent of the total weight of the sample, within reasonable limits, if $P$ be the percentage of the total weight.

(3) Care must be taken to avoid, or correct for, temperature variations since the rate of fall of the particles varies inversely as the viscosity of the liquid, and for water this changes very rapidly with temperature. [$\eta = 0{\cdot}01307$ at 10° C. to $0{\cdot}01004$ at 20° C.]

(4) The "effective radius" calculated from Stokes's law,

$$v = \frac{2}{9} g \frac{\sigma_1 - \sigma_2}{\eta} r^2$$

has a real physical significance where the number of particles dealt with is so great as to render the investigation statistical rather than individual.

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[1] Internationale Mitteilungen für Bodenkunde, 1915, vol. 4, p. 257. [Obtainable on loan from Ministry of Agric. and Fisheries, 10, Whitehall Place, London, S.W. 1.]

[2] Proc. Roy. Soc. Edinburgh, 1917, vol. 36 (for 1915–1916), pp. 219–36.

(5) From the accumulation curve, $P = f(t)$, it is possible by a mathematical analysis to obtain a function $F(r)$ such that the area $F(r)\,dr$ represents the proportion by weight of particles having an effective radius between the limits $r$ and $r + dr$. It is found that

$$F(r) = -\frac{2t^2}{r}\frac{d^2P}{dt^2} = -\frac{2t}{r}\frac{dP}{dt}\frac{dz}{dx}$$

where $z = \log\frac{dP}{dt}$, and $x = \log t$, the auxiliary curve $(x, z)$ being adaptable for graphic treatment.

It has been objected by Prof. C. G. Knott[1] that the use of Stokes's law may give entirely fallacious results due to the irregular shapes of the particles, many of which may be of flat flaky form. This objection is emphasized by the recent success of Dr. E. W. Wetherell[2] in photographing the tracks of flat solids falling through water. It has nevertheless seemed to the writer that it was worth while following Sven Odén's method in view of the extraordinary consistency of the results, the large number[3] of particles involved, and the fact that especially in Globigerina ooze the predominance of spheroidal forms is very marked (see ref. 1, pls. 12–15).

*Experimental Arrangement.*—The apparatus employed by Sven Odén depended on an automatic electrical release whereby counterbalancing weights were introduced on to the second pan of the balance as the particles were deposited on the immersed pan. The writer has substituted a very simple and apparently satisfactory method of compensation consisting of allowing one or more drops of distilled water to fall from a small orifice, at the end of a drawn-out glass tube joined to the base of an ordinary burette, into a small beaker on the second balance pan. The times when successive drops were required in order to maintain a balance were noted, also the number of drops, and these two items provide the data from which the accumulation curve can be drawn. Readings were taken at intervals over twenty-four hours at least, then the major portion of the water was syphoned off and the amount of undeposited residue obtained. To the cumulative total was added the equivalent weight of the residue which would have settled on the pan in time $t = \infty$, thus giving the total weight corresponding to the value $P = 100$ per cent.

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[1] Proc. Roy. Soc. Edinburgh, 1917, vol. 36 (for 1915–1916), pp. 237–39.

[2] Nature, 1922, vol. 110, p. 845.

[3] In a sample of deposit weighing 10 gms., whose average density is 2·6 and whose radius is $20\mu$ the approximate number of particles is $10^8$.

It was found that the drops formed a sufficiently accurate scale of weights ; and by using a glass receptacle of very small diameter the correction for evaporation during twenty-four hours was so small as to be practically negligible.

*Results.*—The numerical work involved in evaluating $F(r)$ is considerable. It was carried out in tabular form with the following sequence of columns :—

$(^1)$ Actual time $t'$ in seconds.
$(^2)$ Calculated time $t = 10/h \cdot t'$.
$(^3)$ First differences of $(^2)$. $t_n - t_{n-1}$.
$(^4)$ $\log_{10} t_n = x_n$.
$(^5)$ First differences of $(^4)$. $x_n - x_{n-1}$.
$(^6)$ Number of drops (cumulative).
$(^7)$ $P =$ percentage of total weight.
$(^8)$ First differences of $(^7)$. $P_n - P_{n-1}$.
$(^9)$ $dP/dt = (^8)/(^3)$.
$(^{10})$ $\log_{10} dP/dt = z = \log_{10} (^9)$.
$(^{11})$ First differences of $(^{10})$. $z_n - z_{n-1}$.
$(^{12})$ $dz/dx = (^{11})/(^5)$.
$(^{13})$ $r$ (as given by Stokes's law) $= \sqrt{\frac{h}{ct}}$, where $c = \frac{2}{9}\,g\,\frac{\sigma_1 - \sigma_2}{\eta}$ and $h = 10$. The evaluation of $c$ involves $g = 981$, $\sigma_1 =$ density of ooze, $\sigma_2 =$ density of water, $\eta =$ viscosity of water at the temperature at which the experiment was carried out. Express $r$ in units of $\mu$.
$(^{14})$ Mid-point of interval $dr$ $[= \frac{1}{2}(r_n + r_{n-1})]$.
$(^{15})$ $F(r) = -\frac{2t}{r}\frac{dP}{dt}\frac{dz}{dx}$.

Columns $(^{14})$ and $(^{15})$ then form the abscissæ and ordinates respectively of the distribution curve.

It should be remarked that it was frequently evident that a slight smoothing of the first difference columns was necessary before proceeding to the next step. This was easily effected by plotting.

In the following tables and accompanying graphs the results obtained by the above method are given for six pelagic oozes. The values of $r$ are the mid-points of the intervals $dr$ corresponding to the respective values of $F(r)$, and the unit of measurement of $(r)$ is $\mu$ (= 0·0001 cm.). The figures in brackets are the percentages by weight which remain ungraded. $\Sigma\, F(r)\,dr +$ percentages ungraded = 100 per cent.

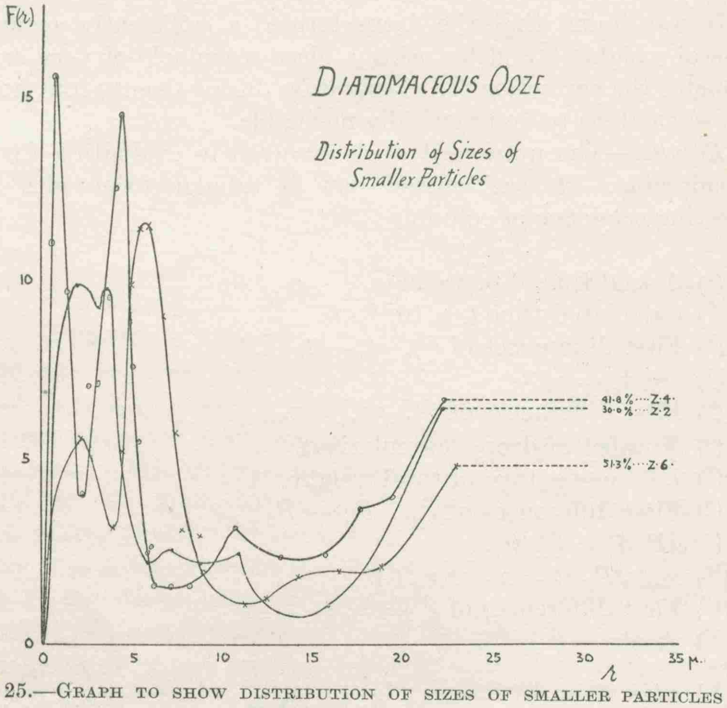

FIG. 25.—GRAPH TO SHOW DISTRIBUTION OF SIZES OF SMALLER PARTICLES IN DIATOMACEOUS OOZE.

TABLE I.

*Values of r and F(r) for Diatomaceous Oozes.*

| Z 2 |  | Z 4 |  | Z 6 |  |
|---|---|---|---|---|---|
| *r* | *F*(*r*) | *r* | *F*(*r*) | *r* | *F*(*r*) |
| — | (1·80) | — | (3·00) | — | (4·11) |
| 1·9 | 9·85 | 0·5 | 11·00 | 2·1 | 5·65 |
| 3·2 | 9·16 | 0·6 | 15·70 | 3·8 | 3·13 |
| 3·5 | 9·74 | 1·3 | 9·70 | 4·4 | 5·23 |
| 4·0 | 7·23 | 2·2 | 4·06 | 4·9 | 9·83 |
| 4·8 | 3·47 | 2·5 | 7·05 | 5·4 | 11·31 |
| 5·8 | 2·20 | 3·1 | 7·13 | 5·8 | 11·48 |
| 7·2 | 2·50 | 3·7 | 9·50 | 6·6 | 8·98 |
| 8·7 | 2·16 | 4·1 | 12·50 | 7·4 | 5·75 |
| 10·8 | 2·48 | 4·4 | 14·50 | 7·7 | 3·04 |
| 13·0 | 0·79 | 4·7 | 8·71 | 9·2 | 2·87 |
| 15·8 | 1·00 | 5·0 | 7·52 | 11·1 | 1·04 |
| 22·0 | 6·45 | 5·4 | 5·50 | 12·4 | 1·23 |
| — | — | 5·7 | 2·41 | 14·2 | 1·76 |
| — | (30·00) | 6·0 | 1·52 | 16·4 | 1·88 |
| — | — | 6·6 | 1·56 | 18·8 | 2·02 |
| — | — | 8·1 | 1·58 | 22·9 | 4·84 |
| — | — | 8·8 | 1·90 | — | — |
| — | — | 10·6 | 3·16 | — | — |
| — | — | 13·2 | 2·28 | — | (51·30) |
| — | — | 15·7 | 2·33 | — | — |
| — | — | 17·6 | 3·52 | — | — |
| — | — | 19·4 | 3·89 | — | — |
| — | — | 22·2 | 6·63 | — | — |
| — | — | — | (41·80) | — | — |

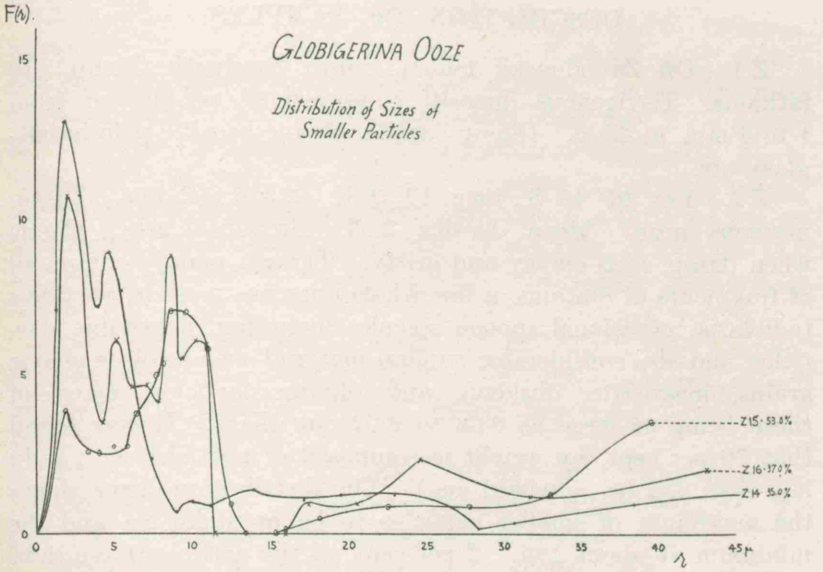

FIG. 26.—GRAPH TO SHOW DISTRIBUTION OF SIZES OF SMALLER PARTICLES IN GLOBIGERINA OOZE.

TABLE II.

*Values of r and F(r) for Globigerina Oozes.*

| Z 14 |  | Z 15 |  | Z 16 |  |
|---|---|---|---|---|---|
| *r* | *F*(*r*) | *r* | *F*(*r*) | *r* | *F*(*r*) |
| — | (2·44) | — | (1·50) | — | (1·85) |
| 1·3 | 7·10 | 2·0 | 3·88 | 2·1 | 10·65 |
| 1·9 | 13·05 | 3·4 | 2·53 | 4·3 | 3·48 |
| 2·8 | 10·70 | 4·1 | 2·50 | 5·2 | 6·08 |
| 4·0 | 7·12 | 5·0 | 2·72 | 6·1 | 4·54 |
| 4·7 | 8·85 | 5·8 | 2·73 | 7·2 | 4·67 |
| 5·5 | 7·64 | 6·4 | 3·73 | 7·9 | 4·06 |
| 7·4 | 2·35 | 7·1 | 4·26 | 8·6 | 8·75 |
| 8·9 | 0·65 | 7·6 | 4·96 | 9·4 | 5·45 |
| 9·8 | 0·97 | 8·1 | 5·24 | 10·1 | 6·06 |
| 11·1 | 0·78 | 8·6 | 7·00 | 10·9 | 5·92 |
| 13·8 | 1·29 | 9·6 | 7·00 | 13·6 | 0·00 |
| 17·0 | 0·94 | 10·9 | 5·80 | 17·2 | 0·90 |
| 19·4 | 1·21 | 12·4 | 0·88 | 20·4 | 0·83 |
| 22·7 | 1·19 | 14·3 | 0·00 | 24·5 | 2·26 |
| 25·9 | 1·09 | 15·8 | 0·04 | 31·6 | 1·08 |
| 28·2 | 0·16 | 18·0 | 0·42 | 43·1 | 2·07 |
| 30·5 | 0·24 | 22·4 | 0·78 | — | — |
| 33·4 | 0·49 | 27·6 | 0·83 | — | (37·0) |
| 38·3 | 0·95 | 32·9 | 1·24 | — | — |
| 51·2 | 1·28 | 39·5 | 3·52 | — | — |
| — | (29·70) | — | (53·00) | — | — |

## DESCRIPTION OF SAMPLES.

Z 1.—Off Zavodovskii Island, South Sandwich Group. 19 fathoms. Terrigenous deposit[1] composed of pebbles of from 1 to 5 mm. in diam. Glassy basalts, olivine-basalts, pale basalt-glass, etc.

Z 2.—Lat. 67° 40′ S., long. 17° 0′ E. 2,356 fathoms. Diatomaceous ooze.[2] Mean density 2·53. Brownish grey, plastic when damp, feels clayey and gritty. Though mainly composed of fragments of diatoms, a few whole ones are present, very few radiolaria, occasional sponge spicules including dictyonine particles, and also considerable mineral material such as clear quartz grains, magnetite, obsidian, and olivine particles, many of these being as large as 0·08 to 0·02 cm. diam. It was found that 70 per cent. by weight is composed of particles with radii less than 22$\mu$ ($\mu$ = 0·0001 cm.). The distribution curve shows the maximum of smaller particles to be at about 2$\mu$ and the minimum at about 14$\mu$. 2 per cent. of the particles have radii less than 0·7$\mu$ and were still in suspension after twenty-four hours.

Z 3.—Lat. 67° 48′ S., long. 16° 1′ E. 2,163 fathoms. Small rounded pebble of ægirine-granite and diatomaceous ooze. Apparently very similar to Z 2, but the amount obtained was only sufficient for two slides.

Z 4.—Lat. 69° 18′ S., long. 17° 11′ E. 1,089 fathoms. Small rounded pebble of ægirine-granite and diatomaceous ooze. Mean density of ooze 2·67. Brownish grey, plastic when damp, feels clayey, very fine-grained. More whole diatom frustules than in Z 2, fragments of sponge spicules, no coarse terrigenous particles but sprinkled with very finely divided magnetite and other minerals, and contains a large amount of excessively fine particles which keep the water opalescent even after standing for several days. 60 per cent. by weight is composed of particles with radii less than 22$\mu$. The curve indicates maxima at 0·6$\mu$ and at 4·4$\mu$ and a pronounced minimum from 6$\mu$ to 8$\mu$. 3 per cent. of the particles have radii less than 0·46$\mu$ and had not settled after forty-two hours. This sample came from the farthest point South that has been reached at that longitude.

Z 5.—Lat. 68° 29′ S., long. 16° 3′ E. 1,925 fathoms. Diatomaceous ooze. Very small sample, sufficient only for two slides, which resemble Z 2 and Z 3.

Z 6.—Lat. 66° 52′ S., long. 14° 27′ E. 2,341 fathoms. Diatomaceous ooze. Mean density 2·75. Brownish grey, clayey and fairly fine-grained. Chiefly diatom fragments, one irregular 2 mm. pebble of quartz with augite, otherwise very little quartz but considerable magnetite of sizes from 0·28 mm. diam. downwards. 50 per cent. by weight is composed of particles having radii less than about 23$\mu$. The curve shows a main maximum at about 6$\mu$ and minimum at 11$\mu$. 4 per cent. of the particles have radii less than 0·57$\mu$ and had not fallen within twenty-four hours.

Z 7.—Lat. 65° 43′ S., long. 16° 25′ W. 2,766 fathoms. Diatomaceous ooze. Mean density 2·51. Brownish grey, clayey and fairly fine-grained. Mainly diatom fragments. Very small sample. Resembles Z 6.

Z 8.—Lat. 66° 7′ S., long. 38° 11′ W. 2,622 fathoms. Diatomaceous ooze. Mean density 2·69. Very similar to Z 6 but with more quartz grains and less magnetite.

Z 9.—Lat. 64° 38′ S., long. 45° 0′ W. 2,446 fathoms. Diatomaceous ooze. Light brownish grey, sample quite small, but resembles Z 6, though with much less frequent magnetite particles.

Z 10.—Lat. 64° 29′ S., long. 45° 43′ W. 2,331 fathoms. Diatomaceous ooze. Several whole Navicula-like specimens, also whole radiolaria. Light brownish grey, fine-grained with very few magnetite or coarse mineral particles. When left in suspension the water remains muddy opalescent for over a day whereas all the others, with the exception of Z 4, clear in half a day. This sample came from near the non-existent "Ross's appearance of land."

Z 11.—Lat. 68° 3′ S., long. 16° 6′ E. 2,163 fathoms. Diatomaceous ooze. Composed mainly of diatom fragments, with radiolaria and sponge spicules and mud-like débris. Very small sample.

Z 12.—Lat. 65° 22′ S., long. 10° 17′ W. 2,762 fathoms. Diatomaceous ooze. Similar to Z 11. Very small sample.

Z 13.—Lat. 63° 49′ S., long. 44° 39′ W. 1,758 fathoms. Terrigenous deposit consisting of chips and fragments of rock. (See report of W. Campbell Smith, chapter v, p. 65.)

Z 14.—Lat. 39° 13′ S., long. 10° 28′ W. 1,880 fathoms. Globigerina ooze. Mean density 1·93. Greyish creamy white, partly caked, very hard and brittle and not easy to get into suspension in its ultimate particles. Very rich in various species of Globigerinidæ (*Globigerina dubia, rubra, bulloides, sacculifera*

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[1] Mr. W. Campbell Smith has examined and reported upon this deposit (see p. 64).

[2] Mr. R. Kirkpatrick, of the British Museum (Nat. Hist.), has kindly examined the micro-slides and identified the deposits and the various foraminifera mentioned in this report.

have been thought to be identified by the writer from pls. 12 and 13 of ref. 1). Many of these shells are beautifully preserved, and the largest ones, oval, globular, kidney-shaped, or resembling acorns, were measured under the microscope and found to range from many about 0·2 mm. to occasional ones up to 0·7 mm. in length. No magnetite or coarse mineral grains are present. 70 per cent. by weight is composed of particles having radii less than about $60\mu$. The curve indicates maximum distribution at $2\mu$ and at $4{\cdot}5\mu$ and low values throughout the range $9\mu$ to $35\mu$. 2 per cent. of the particles have radii less than $0{\cdot}8\mu$ and remained in suspension after twenty-four hours.

Z 15.—Lat. 35° 40′ S., long. 5° 1′ W. 1,942 fathoms. Globigerina ooze. Mean density 2·05. Very like Z 14. One pebble of arkose about 1 mm. long, with white mica. 50 per cent. by weight is made up of particles having radii less than $43\mu$. It is evident from the curve that there is maximum distribution between $r = 2\mu$ and $r = 11\mu$, and there appear to be no particles within the range $13{\cdot}3\mu$ to $15{\cdot}2\mu$ though the curve begins to ascend gradually beyond the latter value. 1·5 per cent., having radii less than $0{\cdot}8\mu$, had not settled within twenty-four hours.

Z 16.—Lat. 35° 41′ S., long. 5° 10′ W. 1,989 fathoms. Globigerina ooze. Mean density 2·44. Very similar to Z 14 and 15, but with noticeably more of the exceptionally large shells. 63 per cent. by weight consists of particles having radii less than $50\mu$ and these cluster chiefly within the range $2\mu$ to $11\mu$, there being apparently no particles within the region $11{\cdot}3\mu$ to $15{\cdot}8\mu$. 1·85 per cent. was found to have radii less than $0{\cdot}65\mu$ and had not fallen within twenty-four hours.

## MISCELLANEOUS REMARKS.

(1) *Sizes of Particles.*—The three diatomaceous oozes, the sizes of the particles of which were determined (Z 2, Z 4, Z 6), show certain features in common: (*a*) About half the weight settles within the first forty-five seconds (when $h = 10$ cm.) and is composed of particles having effective radii greater than $23\mu$; (*b*) of the finer particles the majority cluster about the sizes given by $2\mu < r < 6\mu$ and within this range there are two maxima, this "kink" being a feature of all the curves and appearing also in Sven Odén's curve for "Boden 117 Kosta." (ref. 2, p. 298).

The three Globigerina oozes (Z 14, Z 15, Z 16) also show common features: (*a*) from 35 per cent. to 50 per cent. is composed of relatively coarse particles falling within the first twenty-five seconds (when $h = 10$ cm.); (*b*) of the finer particles the distribution is greatest within the range $2\mu < r < 11\mu$; (*c*) in one case there are comparatively few and in the other cases no particles recorded having radii approximately $13\mu$ to $15\mu$. This result is of special interest because Sven Odén found a complete absence of particles having radii within $12\mu < r < 20\mu$ for Globigerina ooze from the Atlantic (the gap for the Pacific Ocean having slightly different limits). This range embraces that obtained by the writer and suggests that this genus of foraminifera is of two classes—"giants" and "dwarfs"—and that the former at least are not greatly affected by the dissolvent action of sea-water, otherwise such a gap as that found by Sven Odén and in part confirmed by this investigation would be most improbable.

(2) *Radioactivity.*—The radium content of certain typical deep-sea deposits has been determined by Prof. J. Joly[1] and shows the following progression: 3 to 5 × $10^{-12}$ for terrigenous deposits; 6 to 8 × $10^{-12}$ for calcareous deposits; 30 to 50 × $10^{-12}$ for red clay and siliceous deposits. The most slowly accumulating deposits are thus seen to be the most radioactive, as in them there is of necessity a higher proportion of the uranium which, originally brought into the sea by the denudation of igneous (or sedimentary) rocks, is gradually precipitated all over the ocean. Time did not permit of the precise determination of the radioactivity of the particular samples under consideration, but rough tests were made on Z 2, 4, 6, 7, 8, 14, 15, 16, which indicated that they were certainly not exceptionally high in their radium content.

(3) *Geographical Distribution.*—The three Globigerina oozes, Z 14, 15, 16, lie well within the extensive area of this type of ooze charted both by Murray[2] and by Harvey Pirie.[3]

The eleven diatomaceous deposits, Z 2–12 inclusive, all lie in a belt between lat. 64° S. and lat. 69° 18′ S., extending westwards from long. 17° 11′ E. to 45° 43′ W. This belt lies entirely within the region shown on Pirie's chart as terrigeneous deposits, his southern limit of diatom ooze being approximately between the 59th and 60th parallels. Murray, however, draws the limit of the diatom deposits as far south as lat. 68° between long. 0° and 16° E. Z 2, 3, 6 and 11 confirm this, while Z 4 and 5 indicate that the diatom area extends even farther south at this

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[1] Joly (J.).—Radioactivity and Geology, 1909. See also Phil. Mag., July 1908, ser. 6, vol. 16, p. 190.

[2] *Challenger* Report, Deep-Sea Deposits, 1891.

[3] Pirie (J. H. Harvey).—Scottish National Antarctic Expedition, 1902–04: Deep-Sea Deposits. Trans. Roy. Soc. Edinburgh, 1913, vol. 49, pp. 645–86.

longitude. Z 12 lies approximately on the edge of Murray's diatom area. Z 8, 9 and 10 lie within the region shown by Murray as terrigenous, his southern limit of the diatom belt being between lat. 61° and 62° at about long. 40° to 45° W., while Pirie's limit is at 59° S. approximately. Z 13, however, was a dredging composed entirely of rock chips and fragments, and as the South Orkney Islands lie in this region it is likely that much of the sea-bottom is strewn with terrigenous material, in addition to that deposited from icebergs.

(4) *Deep-sea Soundings.*—Reference has already been made to the problem of correcting for the curvature and lag of the wire when a sounding is made while the ship is drifting. If $l$ be the length of wire indicated on the drum when bottom is reached; $t$ the time from the commencement of the sounding until bottom is reached; $v$ the velocity with which the wire is let out $(= l/t)$; $V$ the velocity of drift of the ship; $\theta$ the angle which the wire makes with the vertical at the ship; $d$ the true depth; then the problem is to express $d$ as some function of $l$, $v$, $V$ and $\theta$. The problem is of more than mere theoretic interest when it is considered that the correction may very probably exceed 5 per cent. under certain conditions. It is not intended to discuss the various formulæ which have been worked out,[1] as much further work is necessary and more data are required in order to test their value; but the writer desires to take this opportunity to solicit from every possible source suggestions and information, in particular reliable data for actual values of $l$, $t$ (or $v$), $V$, and a series of values of $\theta$ during the time $t$.[2]

(5) *Acknowledgments.*—The writer has pleasure in expressing gratitude to Prof. Sir E. Rutherford for his courtesy in allowing the investigation to be carried out in the Cavendish Laboratory; to Dr. C. T. Heycock for kindly lending a balance from the Metallurgical Department; and to Mr. G. Vibert Douglas, who provided the material, drew attention to the work of Dr. Sven Odén when suggesting the investigation, and continually aided and advised in many ways.

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[1] The writer is indebted to Capt. A. L. Alington, R.N., for one formula.
[2] Address to G. Vibert Douglas, Royal Societies Club, London.

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# DEEP-SEA DEPOSITS AND DREDGINGS.

# DEEP-SEA DEPOSITS AND DREDGINGS.

## INTRODUCTION.

The monumental work of the late Sir John Murray (1) and Rev. A.F. Renard on the nature of deep-sea deposits, their classification, the methods of obtaining them and of examining them, is a compendium of information which will be the vade mecum of every ocean explorer. It is therefore sufficient that this Memoir deal with the particular samples under consideration referring only in the briefest manner to some of the facts appertaining to marine deposits in general.

The term "deep-sea" deposit is accepted as referring to the materials which form the ocean bottom at depths exceeding 100 fathoms.

Deep-sea deposits may be classified very simply thus:-

| | | |
|---|---|---|
| A. Pelagic deposits | Red Clay | |
| | Radiolarian ooze | (siliceous chiefly) |
| | Diatom ooze | ( " " ) |
| | Globigerina ooze | (calcareous " ) |
| | Pteropod ooze | ( " " ) |

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(1) Murray & Renard: Report of the Scientific Results of the Exploring Voyage of H.M.S.Challenger (1873-76). Deep-Sea Deposits (1891).

| | | |
|---|---|---|
| B. Terrigenous deposits | Blue Mud<br>Red Mud<br>Green Mud<br>Volcanic Mud<br>Coral Mud | Materials brought down by rivers, worn from coasts, carried by icebergs or by atmospheric currents. |

A deposit is often found to contain a mixture of two or more of the above together with some secondary or chemical products (clayey matter arising from the decomposition of pumice, felspars and other minerals; manganese nodules; palagonite and zeolitic materials; phosphate concretions, iron and calcareous concretions, etc.) and not infrequently there can be distinguished planetesimal dust (cosmic spherules of Fe and Ni chondrites with lamellar structure, etc.) (2).

The Hydrographer and Electrician (3) of the Shackleton-Rowett Antarctic Expedition obtained for the Geologist (4) sixteen bottom samples from the Atlantic and Southern Oceans. Of these fourteen were true pelagic deposits and two were dredgings of rocks and pebbles. The number is small compared with the number of soundings recorded chiefly because of the difficulty of winding in from 1000 to 3000 fathoms

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(2) The Science of the Sea, G.H.Fowler, 1912.

(3) Com$^{der}$. F.A.Worsley, D.S.O.,O.B.E.,R.D.,R.N.R., and J.D.Dell, C.P.O.,R.N.,

(4) G.Vibert Douglas, M.C.,M.Sc.,

of wire without losing either the sample from the tube or snappers, or the end portion of the wire itself including tube or snappers, by sudden breaking stresses due to ice or to the high seas and excessive rolling and pitching of the ship.

The Kelvin and the Lucas Sounding machines were used, the former for shallow water (300 fathoms), the latter for greater depths (Brunton wire in coils of 6000 fathoms, diameter 0·028, weight 12·3 lbs per 1000 fathoms, breaking strain 600 lbs). It was found advisable to attach a strong flexible rope of about 10 fathoms in length to the end of the wire, and then fasten the weights and snappers or Buchanan tube to the end of the rope. This arrangement proved more satisfactory than attaching the weights, etc., directly to the wire. The length of rope was then added to the depth recorded on the drum. A point of interest arises in the attempt to find the relation between true depth and apparent depth when the ship is drifting - this will be discussed at the close of this Appendix.

## EXAMINATION OF SAMPLES.

The samples had been dried to some extent and placed in small glass sample bottles with the exception of two or three which were wrapped in filter paper and put in tins. This latter method is not satisfactory as the remaining moisture produced rust which ate through the filter paper and worked deep into the sample. The terrigenous deposits were very much embedded in tallow and before it was possible to examine them in any way they had to be simmered gently for several hours in a sodium bicarbonate solution. Only distilled water was used for this purpose in order to eliminate any deposition of lime, etc. Care was taken never to bring the liquid containing any of the samples to boiling point in order to prevent the finer particles from being aggregated or the larger particles from disintegrating.

The sizes of the samples of pelagic deposit varied from about 30 gms. to such small quantities that when slides had been made there was little or nothing left. Where there was 0·5 gm. or more the specific gravity was determined by means of a pycnometer.

The microscopic examination of the deposits and slides yields much information regarding the nature of their constituents, but in order to obtain the distribution curve representing the relative proportions of particles of different sizes it is necessary to employ a method of soil analysis devised by Dr. Sven Odén of Uppsala (5), and

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(5) Internationale Mitteilungen für Bodenkunde, V.4.p.257. 1915. (Obtainable on loan from Ministry of Agric. and Fisheries, 10 Whitehall Place, London, S.W. 1.)

afterwards applied by him to some marine deposits sent him from the Challenger Office. His results (6) are of much interest not only because each type of deposit showed a distinctive form of curve but also because the same type of deposit exhibited definite peculiarities according to the Ocean from which it had come.

[redacted] Odén's Method:- One pan of a balance is placed near the bottom of a vessel containing an aqueous suspension of the sample. By continuous weighing the rate of deposit on the pan is obtained and this cumulative weight, P, is plotted against the time, t, forming an "accumulation" curve. The following points were established:-

(1) If the height, h, of the water column above the pan be varied, the accumulation curve for any given sample remains practically unaltered if the values of t for the abscissa are reduced to some standard value of h - say h = 10 cm. by the factor $\frac{10}{h}$.

(2) The accumulation curve is independent of the total weight of the sample, within reasonable limits, if P be the per cent of the total weight.

(3) Care must be taken to avoid or correct for temperature variations since the rate of fall of the particles varies inversely as the viscosity of the liquid, and for water this changes very rapidly with temperature. [$\eta$ = 0.01307 at 10°C. [illegible] 0.01004 at 20°C. ]

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(6) Proc.Roy.Soc.Edin. XXXVI. p.219.1915 - 16.

(4) The "effective radius" calculated from Stokes' Law, $v = \frac{2}{9} g \frac{\sigma_1 - \sigma_2}{\eta} r^2$ has a real physical significance where the number of particles dealt with is so great as to render the investigation statistical rather than individual.

Greek letters sigma + eta

(5) From the accumulation curve, $P = f(t)$, it is possible by a mathematical analysis to obtain a function $F(r)$ such that the area $F(r)\,dr$ represents the proportion by weight of particles having an effective radius between the limits $r$ and $r + dr$. It is found that

$$F(r) = -\frac{2t^2}{r}\frac{d^2P}{dt^2} = -\frac{2t}{r}\frac{dP}{dt}\frac{dz}{dx}$$

where $z = \log \frac{dP}{dt}$ and $x = \log t$, the auxiliary curve $(x, z)$ being adaptable for graphic treatment.

It has been objected by Professor C.G. Knott (7) that the use of Stokes' law may give entirely fallacious results due to the irregular shapes of the particles, many of which may be of flat flaky form. This objection is emphasized by the recent success of Dr. E.W. Wetherell (8) in photographing the tracks of flat solids falling through water. It has nevertheless seemed to the writer that it was worth while following Odén's method in view of the extraordinary consistency of the results, the large number (9) of

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(7) Proc.Roy.Soc.Edin. XXXVI.p.237 (1915-16).
(8) *Nature.* Dec.23,1922, p.845.
(9) see next page.

particles involved, and the fact that especially in Globigerina ooze the predominance of spheroidal forms is very marked. (see ref. 1. Plates XII - XV).

Experimental Arrangement. The apparatus employed by [redacted] Odén depended on an automatic electrical release whereby counterbalancing weights were introduced on to the 2nd pan of the balance as the particles were deposited on the immersed pan. The writer has substituted a very simple and apparently satisfactory method of compensation consisting of allowing one or more drops of distilled water to fall from a small orifice, at the end of a drawn-out glass tube joined to the base of an ordinary burette, into a small beaker on the 2nd balance pan. The times when successive drops were required in order to maintain a balance were noted, also the number of drops, and these two items provide the data from which the accumulation curve can be drawn. Readings were taken at intervals over 24 hours at least, then the major portion of the water was syphoned off and the amount of undeposited residue obtained. To the cumulative total was added the equivalent weight of the residue which would have settled on the pan in time $t = \infty$, thus giving the total weight corresponding to the value $P = 100\%$.

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Note from previous page.

(9) In a sample of deposit weighing 10 gms. whose average density is 2.6 and whose radius is 20 $\mu$ the approximate number of particles is $10^8$.

It was found that the drops formed a sufficiently accurate scale of weights; and by using a glass receptacle of very small diameter the correction for evaporation during 24 hours was so small as to be practically negligible.

Results. The numerical work involved in evaluating F(r) is considerable. It was carried out in tabular form with the following sequence of columns:-

(1) Actual time t' in seconds.

(2) Calculated time $t = \frac{10}{h} t'$ .

(3) First differences of (2). $t_n - t_{n-1}$ .

(4) $\log_{10} t_n = x_n$ .

(5) First differences of (4). $x_n - x_{n-1}$ .

(6) No. of drops (cumulative).

(7) P = percentage of total weight.

(8) First differences of (7). $P_n - P_{n-1}$ .

(9) $dP/dt = (8)/(3)$ .

(10) $\log_{10} dP/dt = Z, = \log_{10}$ (9).

(11) First differences of (10). $Z_n - Z_{n-1}$.

(12) $dZ/dx = (11)/(5)$ .

(13) r (as given by Stokes' law) $= \sqrt{\frac{h}{Ct}}$ where $C = \frac{2}{9} g \frac{\sigma_1 - \sigma_2}{\eta}$ and h = 10. The evaluation of C involves g = 981, $\sigma_1$ = density of ooze, $\sigma_2$ = density of water, $\eta$ = viscosity of water at the temperature at which the experiment was carried out. Express r in units of μ.

(14) Mid-point of interval dr $\left[ = \frac{1}{2}(r_n + r_{n-1}) \right]$.

(15) $F(r) = - \frac{2t}{r} \frac{dP}{dt} \frac{dz}{dx}$.

Columns (14) and(15) then form the abscissae and ordinates respectively of the distribution curve.

It should be remarked that it was frequently evident that a slight smoothing of the First difference columns was necessary before proceeding to the next step. This was easily effected by plotting.

In the following Tables and accompanying graphs the results obtained by the above method are given for six pelagic oozes. The values of r are the mid-points of the intervals *dr* corresponding to the respective values of *F(r)*, and the unit of measurement of r is $\mu$ (= ·0001 cm.). The figures in brackets are the percentages by weight which remain ungraded. $\Sigma F(r)$ dr + percentages ungraded = 100 %.

Greek letter
Sigma

## TABLE I.

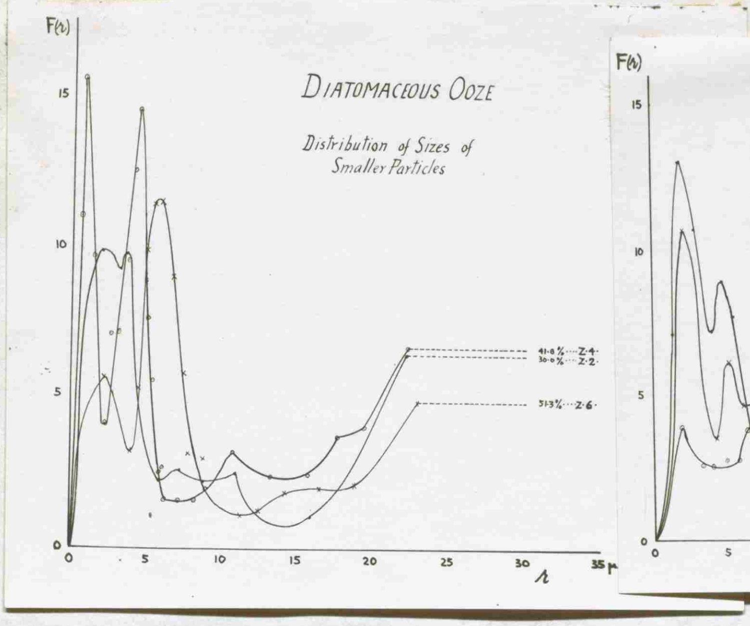
Values of r and F(r) for Diatomaceous Oozes.

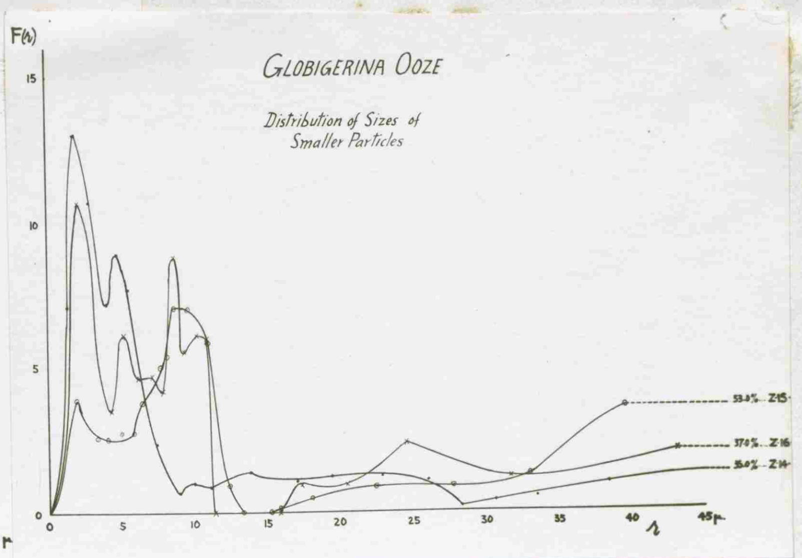
| Z.2. | | Z.4. | | Z.6. | |
|---|---|---|---|---|---|
| r | F(r) | r | F(r) | r | F(r) |
| - | (1·80) | - | (3·00) | - | (4·11) |
| 1·9 | 9·85 | 0.5 | 11·00 | 2·1 | 5·65 |
| 3·2 | 9·16 | 0·6 | 15·70 | 3·8 | 3·13 |
| 3·5 | 9·74 | 1·3 | 9·70 | 4·4 | 5·23 |
| 4·0 | 7·23 | 2·2 | 4·06 | 4·9 | 9.83 |
| 4·8 | 3·47 | 2.5 | 7·05 | 5·4 | 11·31 |
| 5·8 | 2·20 | 3·1 | 7·13 | 5·8 | 11·48 |
| 7·2 | 2·50 | 3·7 | 9.50 | 6.6 | 8·98 |
| 8·7 | 2·16 | 4·1 | 12·50 | 7·4 | 5·75 |
| 10·8 | 2·48 | 4·4 | 14·50 | 7·7 | 3·04 |
| 13·0 | 0·79 | 4.7 | 8·71 | 9·2 | 2.87 |
| 15·8 | 1.00 | 5.0 | 7·52 | 11·1 | 1·04 |
| 22·0 | 6·45 | 5·4 | 5·50 | 12·4 | 1·23 |
| | | 5·7 | 2·41 | 14·2 | 1·76 |
| - | (30·00) | 6·0 | 1·52 | 16.4 | 1·88 |
| | | 6·6 | 1·56 | 18·8 | 2.02 |
| | | 8·1 | 1·58 | 22·9 | 4·84 |
| | | 8·8 | 1·90 | | |
| | | 10·6 | 3·16 | | |
| | | 13·2 | 2·28 | - | (51·30) |
| | | 15·7 | 2·33 | | |
| | | 17·6 | 3·52 | | |
| | | 19·4 | 3·89 | | |
| | | 22·2 | 6·63 | | |
| | | - | (41·80) | | |

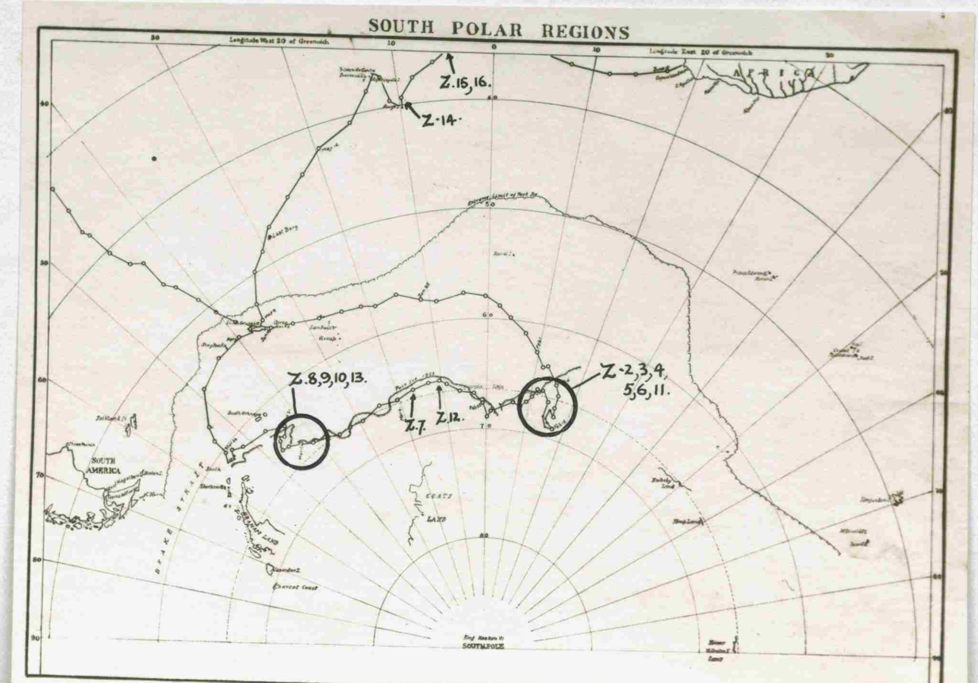
# TABLE II.

Values of r and F(r) for Globigerina Oozes.

| Z.14. | | Z.15. | | Z.16. | |
|---|---|---|---|---|---|
| r | F(r) | r | F(r) | r | F(r) |
| - | (2·44) | - | (1·50) | - | (1·85) |
| 1·3 | 7·10 | 2.0 | 3·88 | 2·1 | 10·65 |
| 1.9 | 13·05 | 3·4 | 2·53 | 4·3 | 3·48 |
| 2·8 | 10·70 | 4·1 | 2·50 | 5·2 | 6·08 |
| 4·0 | 7·12 | 5·0 | 2.72 | 6·1 | 4·54 |
| 4·7 | 8.85 | 5·8 | 2·73 | 7·2 | 4·67 |
| 5·5 | 7·64 | 6·4 | 3.73 | 7·9 | 4.06 |
| 7·4 | 2·35 | 7.1 | 4·26 | 8·6 | 8·75 |
| 8·9 | 0·65 | 7·6 | 4·96 | 9·4 | 5·45 |
| 9·8 | 0·97 | 8·1 | 5·24 | 10·1 | 6.06 |
| 11·1 | 0·78 | 8·6 | 7·00 | 10·9 | 5·92 |
| 13·8 | 1·29 | 9.6 | 7·00 | 13.6 | 0.00 |
| 17·0 | 0·94 | 10·9 | 5·80 | 17·2 | 0·90 |
| 19·4 | 1·21 | 12·4 | 0·88 | 20·4 | 0·83 |
| 22·7 | 1·19 | 14·3 | 0·00 | 24·5 | 2·26 |
| 25·9 | 1·09 | 15·8 | 0·04 | 31·6 | 1·08 |
| 28·2 | 0·16 | 18·0 | 0.42 | 43·1 | 2·07 |
| 30·5 | 0·24 | 22·4 | 0·78 | | |
| 33·4 | 0·49 | 27·6 | 0·83 | - | (37·0) |
| 38·3 | 0·95 | 32·9 | 1·24 | | |
| 51·2 | 1·28 | 39·5 | 3·52 | | |
| - | (29.70) | - | (53.00) | | |


F(r)
DIATOMACEOUS OOZE
Distribution of Sizes of Smaller Particles
41·8 % ··· Z·4·
30·0 % ··· Z·2·
51·3 % ··· Z·6·
0
5
10
15
0
5
10
15
20
25
30
35 μ.
r


F(r)
GLOBIGERINA OOZE
Distribution of Sizes of Smaller Particles
53·0% ··· Z·15·
37·0% ··· Z·16
35·0% ··· Z·14·
0
5
10
15
0
5
10
15
20
25
30
35
40
45 μ.
r


SOUTH POLAR REGIONS
Longitude West 20 of Greenwich
Longitude East 20 of Greenwich
AFRICA
SOUTH AMERICA
COATS LAND
SOUTH POLE
Z.15,16.
Z·14·
Z.8,9,10,13.
Z.7.
Z.12.
Z·2,3,4, 5,6,11.

## DESCRIPTION of SAMPLES.

Z.1. Off Zavodowski Island, South Sandwich Group. 19 fathoms. Terrigenous deposit (10) composed of pebbles of from 1 to 5 mm. in diam. Glassy basalts, olivine basalts, pale basalt glass, etc.,

Z.2. Lat.67° 40' S. Long.17° 0' E. 2356 fathoms. Diatomaceous ooze (11). Mean density 2·53. Brownish grey, plastic when damp, feels clayey and gritty. Though mainly composed of fragments of Diatoms, a few whole ones are present, very few Radiolaria, occasional sponge spicules including Dictyonine particles, and also considerable mineral material such as clear quartz grains and magnetite, obsidian and olivine particles, many of these being as large as 0·08 to 0·02 cm. diam. It was found that 70 % by weight is composed of particles with radii less than 22 μ.(μ = 0.0001 cm). The distribution curve shows the maximum of smaller particles to be at about 2 μ and the minimum at about 14μ. 2 % has radii less than 0·7 μ and was still in suspension after 24 hours.

Z.3. Lat.67° 48' S. Long. 16° 1' E. 2163 fathoms. Small rounded pebble of aegirine granite and diatomaceous ooze. Apparently very similar to Z.2. but the amount obtained was only sufficient for two slides.

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For Notes (10) & (11) see next page.

Z.4. Lat.69° 18' S. Long.17° 11' E. 1089 fathoms. Small rounded pebble of aegirine granite and diatomaceous ooze. Mean density of ooze 2·67. Brownish grey, plastic when damp, feels clayey and very fine grained. More whole Diatom frustules than in Z.2., fragments of sponge spicules, no coarse terrigenous particles but sprinkled with very finely divided magnetite and other minerals, and contains a large amount of exceesively fine particles which keep the water opalescent even after standing for several days. 60 % by weight is composed of particles with radii less than 22 μ. The curve indicates maxima at 0·6 μ and at 4·4 μ and a pronounced minimum from 6 μ to 8 μ. 3 % has radii less than 0·46 μ and had not settled after 42 hours. This sample came from the farthest point South that has been reached at that longitude.

Z.5. Lat.68° 29' S. Long.16° 3' E. 1925 fathoms. Diatomaceous Ooze. Very small sample, sufficient only for two slides which resemble Z.2. and Z.3.

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Notes from previous page.

(10) Mr.W.Campbell Smith, M.A., of the British Museum (Nat.Hist.) has examined and reported upon this deposit.

(11) Mr.R. Kirkpatrick of the British Museum (Nat.Hist.) has kindly examined the micro-slides and identified the deposits and the various ~~Foraminifera~~ organisms mentioned in this report.

Z.6. Lat.66° 52' S. Long.14° 27' E. 2341 fathoms. Diatomaceous ooze. Mean density 2·75. Brownish grey, clayey and fairly fine grained. Chiefly Diatom fragments, one irregular 2 mm. pebble of quartz with augite, otherwise very little quartz but considerable magnetite of sizes from 0·28 mm. diam. downwards. 50 % by weight is composed of particles having radii less than about 23 μ. The curve shows a main maximum at about 6 μ and minimum at 11 μ. 4 % has radii less than 0.57 μ and had not fallen within 24 hours.

Z. 7. Lat.65° 43' S. Long.16° 25' W. 2766 fathoms. Diatomaceous ooze. Mean density 2·51. Brownish grey, clayey and fairly fine grained. Mainly Diatom fragments. Very small sample. Resembles Z.6.

Z.8. Lat.66° 7' S. Long. 38° 11' W. 2622 fathoms. Diatomaceous ooze. Mean density 2·69. Very similar to Z.6. but with more quartz grains and less magnetite.

Z.9. Lat.64° 38' S. Long. 45° 0' W. 2446 fathoms. Diatomaceous ooze. Light brownish grey, sample quite small but resembles Z. 6. though with much less frequent magnetite particles.

Z.10. Lat.$64^\circ$ 29' S. Long.$45^\circ$ 43' W. 2331 fathoms. Diatomaceous ooze. Several whole Navicula-like specimens, also whole Radiolaria. Light brownish grey, fine grained with very few magnetite or coarse mineral particles. When left in suspension the water remains muddy opalescent for over a day whereas all the others with the exception of Z.4. clear in half a day. This sample came from near the non-existent "Ross" Appearance of land".

Z.11. Lat.$68^\circ$ 3' S. Long.$16^\circ$ 6' E. 2163 fathoms. Diatomaceous ooze. Composed mainly of Diatom fragments, with Radiolaria and Sponge spicules and mud-like débris. Very small sample.

Z. 12. Lat.$65^\circ$ 22' S. Long. $10^\circ$ 17' W. 2762 fathoms. Diatomaceous ooze. Similar to Z.11. Very small sample.

Z.13. Lat.$63^\circ$ 49' S. Long.$44^\circ$ 39' W. 1758 fathoms. Terrigenous deposit consisting of chips and fragments of rock — dolorite, gabbro, basalt, tuff, palagonite, sandstone quartzite, arkose and tillite (?). (See report of W.Campbell Smith, M.C.,M.A.,).

Z.14. Lat.$39^\circ$ 13' S. Long.$10^\circ$ 28' W. 1880 fathoms. Globigerina ooze. Mean density 1·93. Greyish creamy white, partly caked very hard and brittle and not easy to get into suspension in its ultimate particles. Very rich in various species of Globigerinidae (Globigerina _dubia_, _rubra_, _bulloides_, _sacculifera_ have been thought to be identified by the writer from Plates XII, XIII of Ref. 1). Many of these shells are beautifully preserved and the largest ones, oval, globular, kidney-shaped or resembling acorns, were measured under the microscope and found to range from many about 0·2 mm. to occasional ones up to 0·7 mm. in length. No magnetite or coarse mineral grains are present. 70 % by weight is composed of particles having radii less than about 60 μ. The curve indicates maximum distribution at 2 μ and at 4.5 μ and low values throughout the range 9 μ to 35 μ. 2 % has radii less than 0·8 μ and remained in suspension after 24 hours.

_Z.15._ Lat.35° 40' S. Long.5° 1' W. 1942 fathoms. Globigerina ooze. Mean density 2·05. Very like Z.14. One large particle of arkose about 1 mm. long, with white mica. 50 % by weight is made up of particles having radii less than 43 μ. It is evident from the curve that there is maximum distribution between r = 2 μ and r = 11 μ, and there appear to be no particles within the range 13·3 μ to 15·2 μ though the curve begins to ascend gradually beyond the latter value. 1·5 %, having radii less then 0·8 μ, had not settled within 24 hours.

Z.16. Lat.35° 41' S. Long.5° 10' W. 1989 fathoms. Globigerina ooze. Mean density 2·44. Very similar to Z.14. and 15 but with noticeably more of the exceptionally large shells. 63 % by weight consists of particles having radii less than 50 μ and these cluster chiefly within the range 2 μ to 11 μ, there being apparently no particles within the region 11·3 μ to 15·8 μ. 1.85 % was found to have radii less than 0·65 μ and had not fallen within 24 hours.

## MISCELLANEOUS REMARKS

see next page.

## MISCELLANEOUS REMARKS.

(1) Sizes of Particles. The three Diatomaceous oozes the sizes of the particles of which were determined (Z.2, Z.4, Z.6) show certain features in common:- (a) About half the weight settles within the first 45 seconds (if $h = 10$ cm.) and is composed of particles having effective radii greater than 23 $\mu$. (b) Of the finer particles the majority cluster about the sizes given by $2\,\mu < r < 6\,\mu$ and within this range there are two maxima, this "Kink" being a feature of all the curves and appearing also in Sven Oden's curve for "Boden 117 Kosta". (Ref. 2, p.298).

The three Globigerina oozes (Z.14, Z.15, Z.16) also show common features:- (a) From 35 % to 50 % is composed of relatively coarse particles falling within the first 25 seconds (if $h = 10$ cm.). (b) Of the finer particles the distribution is greatest within the range $2\,\mu < r < 11\,\mu$. (c) In one case there are comparatively few and in the other cases no particles recorded having radii approximately 13 $\mu$ to 15 $\mu$. This result is of special interest because [redacted] Odén found a complete absence of particles having radii within $12\,\mu < r < 20\,\mu$ for Globigerina ooze from the Atlantic (the gap for the Pacific Ocean having slightly different limits). This range embraces that obtained by the writer and suggests that this genus of Foraminifera are of two classes - "giants" and "dwarfs" - and that the former at least are not greatly affected by the dissolvent action of sea water, otherwise such a gap as that found by [redacted] Odén and in part confirmed by this investigation would be most improbable.

(2) Radioactivity. The radium content of certain typical deep-sea deposits has been determined by Joly (12) and shows the following progression: 3 to 5 x $10^{-12}$ for terrigenous deposits; 6 to 8 x $10^{-12}$ for calcareous deposits; 30 to 50 x $10^{-12}$ for red clay and siliceous deposits. The most slowly accumulating deposits are thus seen to be the most radio-active, as in them there is of necessity a higher proportion of the Uranium which, originally brought into the sea by the denudation of igneous (or sedimentary) rocks, is gradually precipitated all over the ocean. Time did not permit of the precise determination of the activity of the particular samples under consideration, but rough tests were made on Z.2, 4, 6, 7, 8, 14, 15, 16, which indicated that they were certainly not exceptionally high in their radium content.

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(12) J.Joly: Radioactivity and Geology. Also see Phil.Mag. July 1908, p.190.

(3) <u>Geographical Distribution</u>. The three Globigerina oozes, Z.14, 15, 16, lie well within the extensive area of this type of ooze charted both by Murray (1) and by Harvey Pirie(13).

The eleven Diatomaceous deposits, Z.2. - 12 inclusive, all lie in a belt between Lat.64° S. and Lat.69° 18' S. extending westwards from Long.17° 11' E. to 45° 43' W. This belt lies entirely within the region shown on Pirie's chart as Terrigeneous Deposits, his southern limit of Diatom ooze being approximately between the 59th and 60th parallels. Murray however draws the limit of the Diatom deposits as far south as Lat.68° ~~and~~ between Long.0° and 16° E. Z.2, 3, 6, and 11 confirm this, while Z.4, 5, indicate that the Diatom area extends even further south at this longitude. Z.12 lies approximately on the edge of Murray's Diatom area. Z.8, 9, 10 lie within the region shown by Murray as Terrigenous, his southern limit of the Diatom belt being between Lat.61° and 62° at about Long.40° to 45° W., while Pirie's limit is at 59° S. approximately. Z. 13 however was a dredging composed entirely of rock chips and fragments, and as the South Orkney Islands lie in this region it is likely that much of the sea bottom is strewn with terrigenous material, in addition to what is deposited from melting icebergs.

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(13). J.H.Harvey Pirie: Trans.Roy.Soc.Edin. XLIX.111.10. Scottish National Antarctic Expedition, 1902-4. Deep-sea Deposits.

(4) <u>Deep-sea Soundings</u>. Reference has already been made to the problem of correcting for the curvature and lag of the wire when a sounding is made while the ship is drifting. If $l$ be the length of wire indicated on the drum when bottom is reached; $t$ the time from the commencement of the sounding until bottom is reached; $v$ the velocity with which the wire is let out $(=\frac{l}{t})$; $V$ the velocity of drift of the ship; $\theta$ the angle which the wire makes with the vertical at the ship; $d$ the true depth; then the problem is to express $d$ as some function of $l$, $v$, $V$ and $\theta$. The problem is of more than mere theoretic interest when it is considered that the correction may very probably exceed 5 % under certain conditions. It is not intended to discuss the various formulae which have been worked out (14), as much further work is necessary and more data are required in order to test their value; but the writer desires to take this opportunity to solicit from every possible source suggestions and information, in particular reliable data for actual values of $l$, $t$, (or $v$), $V$, and a series of values of $\theta$ during the time $t$.(15).

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(14) The writer is indebted to Capt.A.L.Alington,R.N. for one formula.

(15) Address to G.Vibert Douglas, Royal Societies Club, London.

<u>Additional references</u>: Geology of Non-metallic Mineral Deposits: A.W.Graban, 1920.

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