A. Vibert Douglas "The sizes of Particles in certain Pelagic Deposits"

104.

A. Vibert Douglas

REPRINT FROM THE

PROCEEDINGS

OF THE

ROYAL SOCIETY OF EDINBURGH.

SESSION 1922-1923.

VOL. XLIII—PART II—(No. 16).

The Sizes of Particles in certain Pelagic Deposits.

By Miss A. Vibert Douglas, M.B.E., M.Sc.

EDINBURGH:

Published by ROBERT GRANT & SON, 126 Princes Street, and
WILLIAMS & NORGATE, 14 Henrietta Street, Covent Garden, London, W.C.2.

MDCCCCXXIII.

Price Ninepence.

XVI.—The Sizes of Particles in certain Pelagic Deposits. By Miss A. Vibert Douglas, M.B.E., M.Sc. *Communicated by* Professor Sir E. Rutherford, F.R.S.

(MS. received March 13, 1923. Read May 7, 1923.)

Introduction.

The monumental work of the late Sir John Murray * and Dr Renard on the examination and classification of deep-sea deposits has left little to be desired either as regards methods or results. There was, however, one respect in which they were handicapped—no satisfactory method was known of ascertaining the distribution of sizes of the particles of which a sample was composed.

In 1915 Dr Sven Odén † of Upsala made known a method of soil analysis whereby he obtained by a sedimentation process data from which he could construct the distribution curve representing the relative proportions of particles of various sizes. He later obtained from the Challenger Office several samples of different types of deep-sea deposit which he subjected to the same form of analysis. His results ‡ were of great interest, not only because each type of clay or ooze 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.

On the return of the *Quest* (Shackleton-Rowett Antarctic Expedition, 1921–22) it was thought desirable by the Geologist of the expedition § that the samples of deep-sea deposit which had been obtained in collaboration with the Hydrographer and the Electrician || should be examined by the above method. They were accordingly given to the writer for this purpose.

Outline of 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

* Report of Scientific Results of H.M.S. *Challenger* (1873–76). Deep-Sea Deposits (1891).

† *International Reports on Pedology*, vol. iv, p. 257, 1915. [Obtainable on loan, in German, from the Ministry of Agriculture and Fisheries, 10 Whitehall Place, London, S.W. 1.]

‡ *Proc. Roy. Soc. Edin.*, vol. xxxvi, p. 219, 1915–16.

§ G. Vibert Douglas, M.C., M.Sc.

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

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 have been made by Dr Sven Odén:—(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 expressed as 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, and for water the viscosity changes considerably with temperature. ($\eta=0\cdot01307$ at 10° C. to 0·01004 at 20° C.)

(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.

(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 effective radii 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 * 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 emphasised by the recent success of Dr E. W. Wetherell † 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 of particles involved,‡ and the fact that, especially in globigerina ooze, the predominance of spheroidal forms is very marked. (See *Challenger* Report, above referred to, plates xii–xv.)

* *Proc. Roy. Soc. Edin.*, vol. xxxvi, p. 237 (1915–16).

† *Nature*, December 23, 1922, p. 845.

‡ In a sample of deposit weighing 10 gms., whose average density is 2·6 and whose average radius is 20 μ, the approximate number of particles is 10^8.

Experimental Arrangement.

The apparatus employed by Odén depended on an automatic electrical release whereby counterbalancing weights were introduced on to the 2nd pan of the balance as the particles collected 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 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 obtained. Readings were taken at intervals over 24 hours at least, and 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.

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.

Sixteen bottom samples were brought home by the *Quest*. They included thirteen samples of pelagic deposits, of which seven consisted of such minute quantities that when slides had been made there was little or nothing left. The other six, however, varied from 10 gms. to 25 gms. Their densities were determined by means of a pycnometer.

Sample Z. 2. Lat. 67° 40′ S. Long. 17° 0′ E. 2356 fathoms.—A diatomaceous * ooze with considerable terrigenous material—particles of magnetite and quartz with diameters of 0·06 cm. downwards. Mean density 2·53. 70 per cent. by weight is composed of particles with radii less than 22 μ ($\mu=0\cdot0001$ cm.). The distribution curve shows the maximum of smaller particles to be at about 2 μ and the minimum at about 14 μ. 2 per cent. had radii less than 0·7 μ, and was still in suspension after 24 hours.

* Mr R. Kirkpatrick of the British Museum (Nat. Hist.) has kindly examined the micro-slides and named the deposits.

Sample Z. 4. Lat. 69° 8′ S. Long. 17° 11′ E. 1089 fathoms.—A diatomaceous ooze free from coarse terrigenous particles but sprinkled with very finely divided magnetite and quartz and containing a large amount of excessively fine particles which keep the water opalescent even after standing for several days. Mean density 2·67. 60 per cent. by weight is composed of particles with radii less than about 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 per cent. has radii less than 0·46 μ, and had not settled after 42 hours. This sample came from the furthest point south that has been reached at that longitude.

Sample Z. 6. Lat. 66° 52′ S. Long. 14° 27′ E. 2341 fathoms.—A diatomaceous ooze with considerable fine terrigenous material. Mean density 2·75. 50 per cent. 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 per cent. has radii less than 0·57 μ, and had not fallen within 24 hours.

These three show certain common features:—(1) About half the weight settles within the first 45 seconds ($h=10$ cm.), and is composed of particles having radii greater than 23 μ. (2) 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 Odén's curve for "Boden 117 Kosta." (See *Pedology* Report, above referred to, p. 298.)

Sample Z. 14. Lat. 39° 13′ S. Long. 10° 28′ W. 1880 fathoms.—A globigerina ooze. Mean density 1·93. 70 per cent. by weight is composed of particles having radii less than about 60 μ. The curve indicates maxima at 2 μ and 4·5 μ, and it runs fairly close to the abscissa throughout the range 9 μ to 35 μ, almost touching it at 28 μ. 2 per cent. has radii less than 0·8 μ, and remained in suspension after 24 hours.

Sample Z. 15. Lat. 35° 40′ S. Long. 5° 1′ W. 1942 fathoms.—A globigerina ooze. Mean density 2·05. 50 per cent. by weight is made up of particles with radii less than 43 μ. It is evident from the curve that there is maximum distribution between 2 μ and 11 μ, and there appear to be no particles within the range 13·3 μ to 15·2 μ, beyond which the curve begins to ascend gradually. 1·5 per cent. having radii less than 0·8 μ had not settled in 24 hours.

Sample Z. 16. Lat. 35° 41′ S. Long. 5° 10′ W. 1989 fathoms.—A globigerina ooze. Mean density 2·44. 63 per cent. by weight consists of particles having radii less than 50 μ, and these cluster chiefly around the same range as in Z. 15. There are apparently no particles within the

region 11·3 μ to 15·8 μ. 1·85 per cent. was found to have radii less than 0·65 μ, and had not fallen after the elapse of 24 hours.

These three fall naturally into one group, and have the following features in common:—(1) From 35 per cent. to 50 per cent. is composed of relatively coarse particles falling within 25 seconds ($h=10$ cm.). (2) Of the finer particles the distribution is greatest for $2\mu<r<11\mu$. (3) In one case there are comparatively few, and in the other cases no particles recorded having radii approximately 13 μ to 15 μ. This result is of special interest because Odén found a complete absence of particles having radii from 12 μ to 20 μ, for globigerina ooze from the Atlantic ocean, a range embracing that obtained by the writer in the case of Z. 15 and Z. 16. This suggests that this genus of Foraminifera is of two classes—"giants" and "dwarfs"—and that the former, at least, are not much affected by the dissolvent action of sea-water, otherwise such a gap as that found by Odén and in part confirmed by this investigation would be most improbable.

In the following tables summarising the results shown graphically below, the value of r is the mid-point of the interval dr corresponding to the value of $F(r)$, and is measured in terms of μ as unit. The figures in brackets are the percentages by weight remaining ungraded, and $\Sigma F(r)dr$ + percentages ungraded = 100 per cent.

In conclusion, the writer has pleasure in expressing gratitude to Professor Sir E. Rutherford for permitting the carrying out of the investigation in the Cavendish Laboratory; to Dr C. T. Heycock for the loan of a balance from the Metallurgical Department; and to Mr G. Vibert Douglas, who provided the material and drew attention to the work of Dr Sven Odén when suggesting the investigation.

Cavendish Laboratory, Cambridge,
March 1923.

[Table I.

Table I.—Diatomaceous.

Z. 2.		Z. 4.		Z. 6.	
r.	F(r).	r.	F(r).	r.	F(r).
	(1·80)		(3·00)		(4·11)
μ.		μ.		μ.	
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	5·6	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
		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		
		15·7	2·33		
		17·6	3·52		
		19·4	3·89		
		22·2	6·63		
	(30·0)		(41·8)		(51·3)

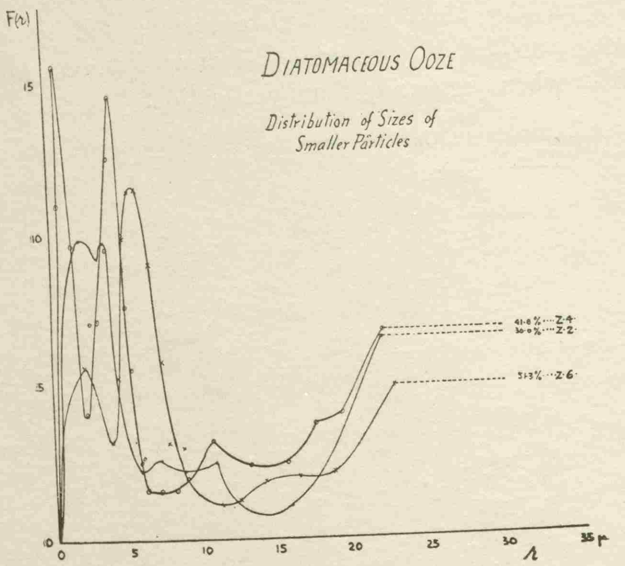
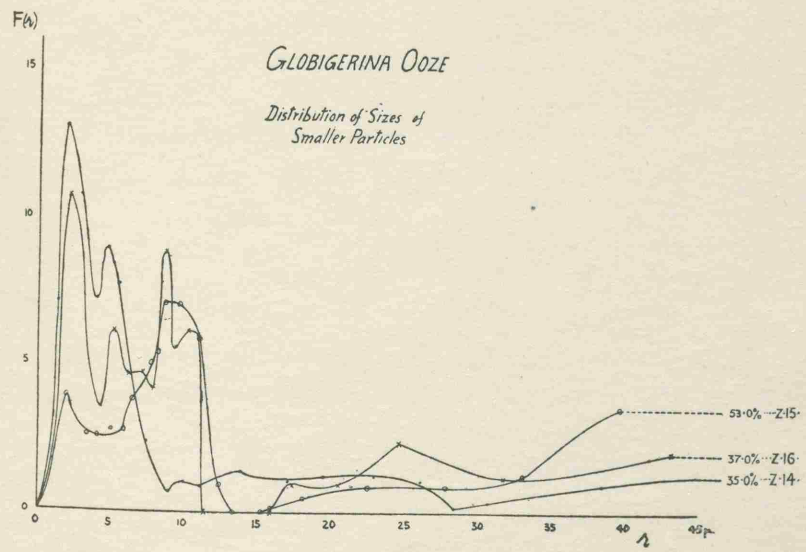


Table II.—Globigerina.

Z. 14.		Z. 15.		Z. 16.	
r.	F(r).	r.	F(r).	r.	F(r).
	(2·44)		(1·50)		(1·85)
μ.		μ.		μ.	
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		
38·3	0·95	32·9	1·24		
51·2	1·28	39·5	3·52		
	(29·7)		(53·0)		(37·0)



(*Issued separately October 5, 1923.*)