A STUDY OF THE SEDIMENTARY PARAMETERS OF GANGA SANDS, SOUTH-SOUTH-WEST OF RAMNAGAR, DISTRICT VARANASI, U.P.

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River Ganga makes a few meanders near Varanasi region in a distance of about ten miles. Between Hazipatti and Ramnagar Fort (District Varanasi) the river flows from ENE to NNW (downstream), making a meander and then again acquires an ENE course forming another meander. The sediments of the first meander, covering a distance of about six miles have been studied by the authors to evaluate the parameters of the Ganga sands according to the most recent concepts of measuring the size parameters.

INTRODUCTION

The holy river Ganga having its source in the mighty Himalayas, flows through the vast plains of India and finally merges into the Indian Ocean at the Bay of Bengal. Throughout this lengthy course, the river makes several meanders, one of which is near Varanasi region where the river flows due north through a few meanders. The first meander starts from near Hazipatti and ends near Ramnagar Fort, which is about four miles south-east of Varanasi city. The second meander starts from Ramnagar Fort and extends upto Malaviya Bridge for a distance of about four miles beyond which the river acquires an ENE course (Agrawal *et al.* 1966-67).

The present study deals with the sediments of the first meander in the vicinity (SSW) of Ramnagar Fort. Here the river flows from ENE to NNE and becomes NNW near Ramnagar. The area under investigation lies partly in the Survey of India Topo-sheet No. 63 0/3 and partly in 63 0/4. The sedimentation is confined only on the left bank (slip off side) while on the right bank the process of erosion is active.

SAMPLING

From Banaras Hindu University ghat to a distance of about two miles towards south on the left bank (slip off side) the ground is thoroughly ploughed. From this point further south sands were deposited in large magnitude. Unlike the sands on the east of the Varanasi ghats, which are frequently quarried for building purposes, the sands of this area were in their natural state of deposition, retaining at places the primary sedimentary structures like cross-lamination, ripple marks, mud-cracks, etc.

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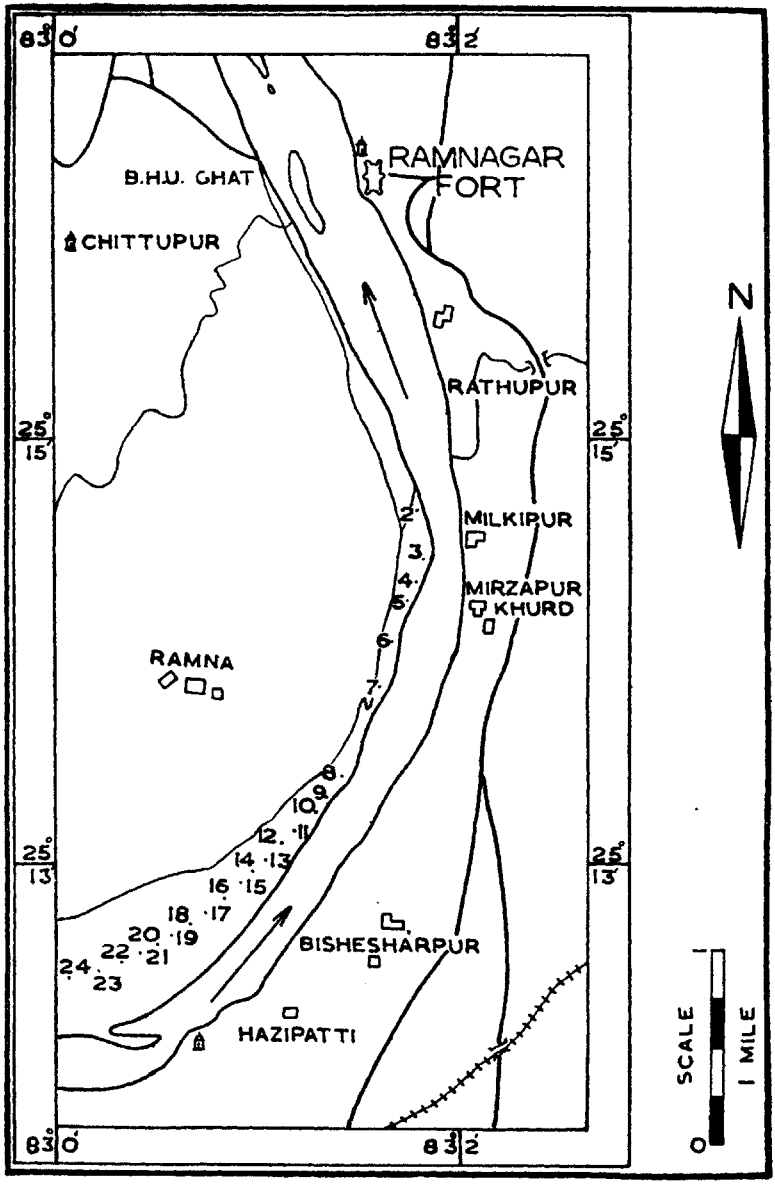
The first sample was taken from the tip of this undisturbed deposit which is approximately northwest of Milkipur. Subsequently twenty-two more samples were collected at an approximate distance of 200–220 yds. each. The first few samples were taken from near the water line and gradually the collection points were shifted to the middle of the deposit so as to have the best possible representation of the sediments.



Map showing the position of the samples.

Process of Analysis

The process of analysis of Ganga sands was essentially the one suggested by Krumbein and Pettijohn (1938). About 100 g of the Ganga sediments of each sample was taken in sieves starting from 0.75 ϕ and arranged at 0.5 ϕ interval in increasing *phi* unit for mechanical fractionation. Individual fractions were carefully recovered, weighed and percentage weights of different fractions were determined.

Statistical Measure and their Interpretation

The various parameters, viz., median siz, sorting, skewness and kurtosis were calculated from the data obtained from the cumulative frequency distribution curves drawn on *phi* probability graph paper (Otto 1939). The values of textural parameters and the grain size distribution of the samples are listed in Table I as computed by the formulae suggested by Inman (1952) and Folk and Ward (1957). Fig. 1 gives cumulative curves drawn on *phi* probability paper.

Fig. 2 illustrates the size-frequency curves of all the samples. Interpretation of the results are discussed and compared with those obtained by Agrawal, Dixit and Pandey (1966–67).

The Modes—It shows the grain size(s) of maximum concentration in a sample. A sample having one particular size of sediments dominating over others will be called 'unimodal' and will be represented on the size-frequency curve by a more or less conspicuous peak. Curves with two conspicuous peaks will be termed 'bimodal', and so on.

Fig. 2 illustrates that majority of the sediments are bimodal (sample Nos. 5–6, 9–11 and 14–24); their frequency curves show the first conspicuous peak situated around either 2.25 ϕ or 2.75 ϕ (both are fine sand) sizes. Only sample No. 23 shows that the maximum number of grains have accumulated around 1.75 ϕ (medium sand) size. In all cases the second peak is in the finest size class (in the present case) i.e., around or beyond 4.25 ϕ (silt) size.

Unimodal sediments are comparatively fewer and are represented by specimen Nos. 2–4, 7–8 and 12–13. Out of these, in sample Nos. 3, 8, 12 and 13 the conspicuous peaks are around the 2.75 ϕ (fine sand) size, while in specimen Nos. 2, 4 and 7, the largest size group lies on the finer side i.e. 3.25 ϕ and 3.75 ϕ (very fine sand) sizes, respectively.

Median Size—The 'phi mean diameter' (Inman 1952) and the 'graphic mean size' (Folk and Ward 1957) of the sediments vary from 1.675 ϕ to 3.325 ϕ and 1.67 ϕ to 3.25 ϕ, respectively, i.e., in both cases from 'medium' to 'very fine sand' sizes (Cadigan 1961). The finer sediments on this meander are coarser than that on the trans-Ganga region, opposite Varanasi city.

Sorting—Cadigan (1961) states that the function of sorting is inversely proportional to standard deviation; in other words :

$$\text{Sorting} \propto \frac{1}{\text{Standard Deviation}}$$

The 'phi deviation measure' (Inman 1952) and the 'inclusive graphic standard deviation' (Folk and Ward 1957) values of the sediments vary from 0.200 ϕ to 1.17 ϕ and 0.2112 ϕ to 0.9966 ϕ, indicating thereby 'very well sorted' and 'moderately

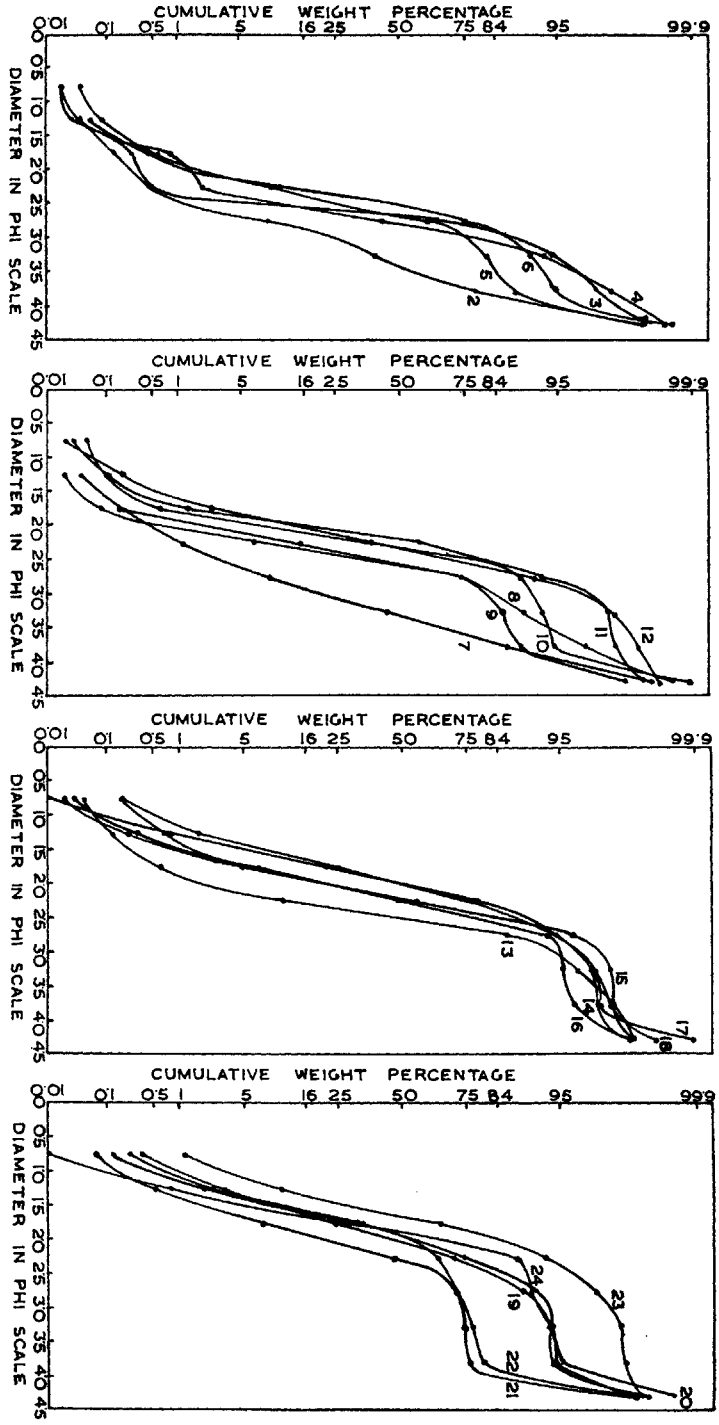

CUMULATIVE WEIGHT PERCENTAGE
0·01 0·1 0·5 1 5 16 25 50 75 84 95 99·9
DIAMETER IN PHI SCALE
0·0 0·5 1·0 1·5 2·0 2·5 3·0 3·5 4·0 4·5
1 2 3 4 5 6
7 8 9 10 11 12
13 14 15 16 17 18
19 20 21 22 23 24

FIG. 1

TABLE I

Textural parameters of the Ganga sands

Sample No.	Inman's Parameters (1952)					Folk and Ward's Parameters (1957)				*Phi* Percentiles						
	$M\phi$	$\sigma\phi$	$\alpha\phi$	$\alpha_2\phi$	$\beta\phi$	M_z	σ_1	Sk_1	KG	ϕ_5	ϕ_{16}	ϕ_{25}	ϕ_{50}	ϕ_{75}	ϕ_{84}	ϕ_{95}
2	3.325	0.475	—0.158	—5.789	0.368	3.35	0.4344	—0.1701	0.7610	2.70	2.85	3.00	3.40	.70	3.80	4.00
3	2.750	0.200	0.250	—11.500	1.000	2.73	0.2122	0.3750	1.6393	2.50	2.55	2.60	2.70	2.80	2.95	3.30
4	2.825	0.275	0.091	—8.545	0.636	2.82	0.2723	0.1010	1.0539	2.40	2.55	2.60	2.80	2.95	3.10	3.30
5	2.875	0.525	0.429	—3.286	0.762	2.80	0.5428	0.4440	1.4344	2.15	2.35	2.45	2.65	2.95	3.40	4.00
6	2.650	0.300	0.333	—5.917	1.592	2.62	0.3848	0.4409	1.8149	2.20	2.35	2.40	2.55	2.75	2.95	3.75
7	3.325	0.375	—0.067	—7.200	0.733	3.33	0.3844	—0.0718	1.0656	2.65	2.95	3.1	3.35	3.60	3.70	3.95
8	2.675	0.275	0.273	—7.000	1.454	2.65	0.3420	0.3401	1.8443	2.20	2.40	2.45	2.60	2.75	2.95	3.55
9	2.750	0.450	0.444	—3.556	1.111	2.68	0.5129	0.4854	1.9467	2.10	2.30	2.40	2.55	2.80	3.20	4.00
10	2.235	0.250	—0.460	—5.700	2.700	2.35	0.4053	0.2838	2.5273	1.95	2.10	2.20	2.35	2.50	2.60	3.80
11	2.300	0.300	0.333	—5.570	0.584	2.27	0.2939	0.3509	1.1124	1.90	2.00	1.10	2.20	2.45	2.60	2.85
12	2.325	0.275	..—0.091	—6.727	0.818	2.33	0.2890	—0.0909	1.1709	1.85	2.05	2.15	2.35	2.50	2.60	2.85
13	2.525	..0.225	0.111	—9.000	1.111	2.52	0.2564	0.2027	1.5574	2.15	2.30	2.40	2.50	2.65	2.75	3.10
14	2.175	0.225	—0.333	—7.667	1.333	2.20	0.2716	—0.1212	1.7213	1.75	1.95	2.05	2.25	2.30	2.40	2.80
15	2.250	0.250	0.000	—7.100	0.900	2.23	0.2689	—0.0263	1.2978	1.75	2.00	2.10	2.25	2.40	2.50	2.70
16	2.275	0.325	—0.078	—5.154	0.923	2.28	0.4019	0.025	1.1384	1.75	1.95	2.05	2.30	2.50	2.60	3.00
17	2.025	0.325	0.078	—4.231	0.923	2.02	0.3519	0.1385	1.2807	1.50	1.70	1.80	2.00	2.20	2.35	2.75
18	2.025	0.375	0.067	—3.533	0.800	2.02	0.3920	0.0993	1.2295	1.45	1.65	1.75	2.00	2.20	2.40	2.80
19	2.100	0.450	0.111	—1.889	1.667	2.08	0.5886	0.2848	1.0432	1.40	1.65	1.80	2.05	2.35	2.55	3.80

Cont'd.

Cont'd. TABLE I

Sample No.	Inman's Parameters (1952)				Folk and Ward's Parameters (1957)					*Phi* Percentiles						
	$M\phi$	$\sigma\phi$	$\alpha\phi$	$\alpha\phi$	$\beta\phi$	M_z	σ_1	SK1	KG	ϕ_5	ϕ_{16}	ϕ_{25}	ϕ_{50}	ϕ_{75}	ϕ_{84}	ϕ_{95}
20	2.025	0.425	0.176	—1.882	1.706	2.00	0.5609	0.3491	1.5710	1.40	1.60	1.70	1.95	2.30	2.45	3.70
21	2.950	1.000	0.650	—1.100	1.400	2.73	0.8727	0.8250	0.7225	1.70	1.95	2.05	2.30	3.40	3.95	4.10
22	2.775	1.175	0.745	—0.468	1.298	2.48	0.9966	0.6871	0.8512	1.40	1.60	1.70	1.90	3.00	3.95	4.10
23	1.675	0.325	0.077	—3.154	0.923	1.67	0.3519	0.0985	1.2807	1.10	1.35	1.45	1.65	1.85	2.00	2.35
24	1.975	0.275	0.091	—2.727	3.364	1.93	0.5011	0.2461	2.8103	1.45	1.65	1.75	1.95	2.10	2.20	3.85

$$M\phi=\frac{\phi_{84}+\phi_{16}}{2} \quad \text{.. Phi Mean Diameter}$$

$$\sigma\phi=\frac{\phi_{84}-\phi_{16}}{2} \quad \text{.. Phi Deviation Measure}$$

$$\alpha\phi=\frac{M\phi-\phi_{50}}{\phi} \quad \text{.. Phi Skewness Measure}$$

$$\alpha_2\phi=\frac{\phi_{95}-\phi_5-2\phi_{50}}{2\phi} \quad \text{.. 2nd Phi Skewness Measure}$$

$$\beta\phi=\frac{\phi_{95}-\phi_5-2\sigma\phi}{2\sigma\phi} \quad \text{.. Phi Kurtosis Measure}$$

$$M_z=\frac{\phi_{16}+\phi_{50}+\phi_{84}}{3} \quad \text{.. Graphic Mean Size}$$

$$\sigma_1=\frac{\phi_{84}-\phi_{16}}{4}+\frac{\phi_{95}-\phi_5}{6.6} \quad \text{.. Inclusive Graphic Standard Diviation}$$

$$Sk_1=\frac{\phi_{84}+\phi_{16}-2\phi_{50}}{2\phi_{(84}-\phi_{16)}}+\frac{\phi_{95}+\phi_5-2\phi_{50}}{2(\phi_{95}-\phi_5)} \quad \text{.. Inclusive Graphic Skewness}$$

$$K/G=\frac{\phi_{95}-\phi_5}{2.44\phi_{(75}-\phi_{25)}} \quad \text{.. Graphic Kurtosis}$$

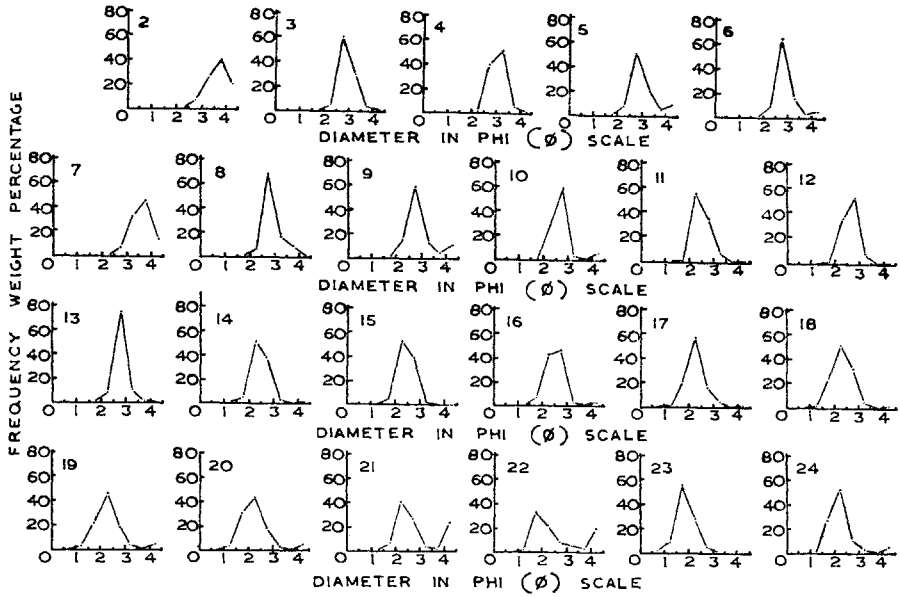


FIG. 2

well sorted' (Cadigan 1961) and 'very well sorted' to 'moderately sorted' (Folk and Ward 1957) sands, respectively. In the present case the sediments of the northern and middle part of the meander are very well sorted and the southern part is moderately sorted according to Cadigan's (1961) classification, while according to Folk and Ward (1957), the sediments on the northern part are 'well sorted', middle portion 'very well sorted' and the southern portion only 'moderately sorted'.

With the exception of sample number 2, all the bimodal samples show that the slope of the finer side of the respective cumulative curve is flatter than that of the coarser side indicating thereby the poorer sorting in the finer size. In the rest of the samples there does not seem much difference in sorting of the coarse, intermediate and fine fractions.

Skewness—It is the measure of symmetry around the mean. Mathematically, skewness is a function of standard deviation and is inversely proportional to it, i.e.

$$\text{Skewness} \propto \frac{1}{\text{Standard Deviation}}$$

In other words this can be stated as "a lack of symmetry in grain size distribution producing a lower skewness value than a similar lack of symmetry in a well sorted sediment" (Cadigan 1961).

In the present case the 'phi skewness measure' (Inman 1952) and 'inclusive graphic skewness' (Folk and Ward 1957) range from $-0.460\ \phi$ to $0.745\ \phi$ and $-0.1701\ \phi$ to $0.8250\ \phi$, respectively which according to Cadigan (1961) is 'negatively skewed' to 'slightly skewed' and according to Folk and Ward (1957) is 'negatively skewed' to 'very positively skewed'.

Agrawal *et al.* (1966–67) have mentioned that the sediments of the *cis-* and *trans-* sides show respectively symmetrical to moderate skewness and symmetrical to slight skewness, but their observation that the sediments are actually negatively skewed to slightly skewed (Cadigan 1961) on both the banks while according to Folk and Ward's classification the sediments on the *cis*-side are 'very negatively skewed' to 'nearly symmetrical' and 'very negatively skewed' to 'very positively skewed' on the *trans*-Ganga region are somewhat contradictory to facts.

Kurtosis—Cadigan (1961) defines it as ".....kurtosis, the measure of peakedness, would be affected by deviations near the centre of the distribution. The kurtosis values are similarly a function of the Standard Deviation....." Mathematically this can be re-stated as :

$$\text{Kurtosis} \propto \frac{1}{\text{Standard Deviation}}$$

and not $\propto$ the Standard Deviation (Agrawal *et al.* 1966–67).

According to Inman's formula (classified by Cadigan 1961) the 'phi kurtosis measure' of the sediments varies from $0.368\,\phi$ to $3.364\,\phi$ thereby suggesting 'normal' to 'moderately peaked' sediments. While according to Folk and Ward the 'graphic kurtosis value' for the sediments ranges between $0.7225\ \phi$ and $2.8103\ \phi$ indicating 'platy-kurtic' to very 'lepto-kurtic' sediments. However, the majority of the sediments are 'leptokurtic' to 'very leptokurtic.'

Conclusion

The present study of the sedimentary parameters of the sands from the left bank in the downstream direction of the meandering river Ganga, SSW of Ramnagar Fort was undertaken following the work of Agrawal, Dixit and Pandey (1966–67) in the second meander from the point of view of studying the nature of the grain size distribution in the two meanders. In the present study various parameters were evaluated with the help of Phi Probability Graph paper and not on ordinary arithmetic ordinates used by Agrawal *et al.* (1966–67). Folk (1966), while reviewing the various methods of measuring the grain size parameters, has opined that the use of arithmetic ordinates for determining the values of skewness and kurtosis is utterly worthless. The two different methods used for the material obtained from the adjoining meanders has brought out the differences in values, and hence the results of the present study should be taken to be more accurate.

The present study shows that the Ganga sands mostly consist of medium to very fine size. Majority of the sediments are bimodal due to the presence of considerable amount of silt, particularly on the southernmost part of the deposit. They are from moderately to very well-sorted sediments possessing negative to very positive skewness and are platy-kurtic to very leptokurtic.

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REFERENCES

Agrawal, L., Dixit, P. C. and Pandey, A. R. (1966-67). A study of the grain size distribution in Ganga sands near Varanasi (India). *J. scient. Res. Banaras Hindu Univ.*, **17** (1), 234–245.

Cadigan, R. A. (1961). Geologic interpretation of grain-size distribution measurements of Colorado Plateau sedimentary rocks. *J. Geol.*, **69**, 121–144.

Folk, R. L. (1966). A review of grain size parameters. *Sedimentology*, **6**, 73–93.

Folk, R. L. and Ward, W. C. (1957). Brajos river bar, a study in the significance of grain-size parameters. *J. sedim. Petrol.*, **27**, 3–27.

Inman, D. L. (1952). Measures for describing the size distribution of sediments. *J. sedim. Petrol.*, **22**, 125–145.

Krumbein, W. C. and Pettijohn, F. J. (1938). Manual of Sedimentary Petrology. New York, Appleton-Century, 549.

Otto, G. H. (1939). A modified logrithmic probability graph for the interpretation of mechanical analysis of sediments. *J. sedim. Petrol.*, **9**, 62–76