

Comparative studies of moment, graphic and phi measures on the sands of the East Coast beaches, India

O.S. CHAUHAN and A.K. CHAUBEY

National Institute of Oceanography, Dona Paula, Goa 403 004 (India)

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Abstract

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A comparative study of moment, phi and graphic parameters, at $1/4-\phi$ class interval, has been undertaken on 120 representative samples, selected out of 2000 samples from four beaches along the East Coast of India. The results show very good correlations among graphic, phi and moment means (correlation coefficient = 0.99), and among inclusive graphic standard deviation, phi standard and moment standard deviations (correlation coefficient = 0.90). Thus, they may be computed by any of these methods without any significant differences. The linear correlation between inclusive graphic skewness and graphic skewness is found to be good (coefficient of correlation = 0.99) whereas the moment and graphic skewness (of Folk and Ward and Inman) show lower correlation (0.54). Coefficient of correlation between graphic and moment kurtosis is much less (0.42) and, therefore, these are not comparable.

Introduction

Moment and graphic parameters are widely used and the merits of these measures have been widely discussed (Inman, 1952; Friedman, 1962; 1967, 1979; Griffiths, 1967; Davis and Ehrlich, 1970; Jones, 1970; Ispording, 1972; Jaquet and Vernet, 1976; Emery, 1978; Swan et al., 1978). Opinions on the use of moment or graphic methods vary considerably because a complete distribution curve is taken into consideration for the computation of the moment measures. The graphic measures of Folk and Ward (1957) and Inman (1952), on the other hand, discard 5% at each end of a curve. The properties of the moment and graphic parameters may vary significantly due to discarding of this 5%. Koldijk (1968) felt that the moment mean is more accurate than the graphic mean because all grain size classes are involved in its calculations. He further observed that the

standard deviation is more exactly calculated based on the entire grain size distribution, and the graphic standard deviation reaches only up to 70% of the value. The skewness values, which depend upon the tails of the distribution, also usually fail to be indicative of the nature of the distribution in graphic measures particularly, when the coarse or fine classes exceed 5%.

Based upon either moment or graphic measures, the properties of the various measures calculated partially depend upon the grouping of the data. If longer class intervals are considered ($1-$ or $1/2-\phi$), the values of the continuous variate are compressed to the midpoint of the class interval and lead to erroneous results. Folk (1966) pointed out the possible error involved in making these computations, but it is generally ignored (Jones, 1970). The error gets amplified if the sample standard deviation is small compared to the sieving class interval.

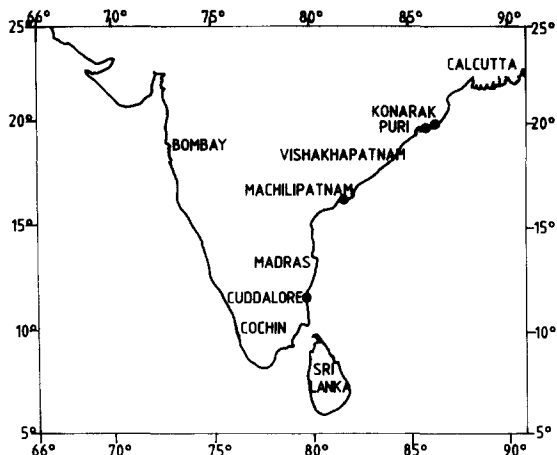


Fig. 1. Location map of the area of study.

Sevon (1968) compared the results of moment and graphic measures based on 1- and 1/2- ϕ class intervals and has shown that correlations among various parameters are better for 1/2- ϕ class interval.

The purpose of this paper is to establish a correlation between moment and graphic measures based on 1/4- ϕ class interval. The paper discusses and expresses the relationship between moment and graphic parameters of samples from

heterogeneous beach environments along the East Coast of India.

Area

The beaches selected for the collection of sediments were Konarak, Puri, Machillipattanam and Cuddalore (Fig. 1). All these beaches are open, more than 7 km long and are directly exposed to the Bay of Bengal. They are so selected that their physiographic setting and the environment of deposition vary considerably. The salient features of the above beaches are summarized in Table 1.

Materials and methods

A total of 2000 sediment samples were collected from these beaches during 1978 to 1982 under different environmental conditions, along and across five transit lines extending from berm/backshore to slightly below low tide level. Analysis of these samples provided variations in the sedimentological parameters along and across these beaches under different environmental conditions. Based on these observed variations, 120 samples have been selected, 30 from each area,

TABLE 1

Salient features of the beaches of the study area

Name of the beach	Nature	Beach slope ($^{\circ}$)		Type of sediments	Prevalent wave parameter					
		fair season	rough season		fair season			rough season		
					H (m)	T (s)	direction	H (m)	T (s)	direction
Konark	open, located close to the river source	3-4	6-8	medium to fine sand	1	5-6	NNE for < 80%	2-24	7-12	SW for < 60%
Puri	open, receives sediments from river source during fair season only	6	9-10	medium to fine sand	1	5-6	NNE for 80%	2-4	7-12	SW for < 60%
Machillipattanam	open, tremendous supply of the sediments from major river source	3	4-5	fine sand	1-2	6	NE, NNE	2-4.5	7-12	variable
Cuddalore	no river source	5.6	9	coarse sand	1-2	6	NE, NNE	1.5-2	8-10	variable

TABLE 2

Formulae used for computations of various size parameters

Parameters	Formulae of Friedman (1962)	Formulae of Folk and Ward (1957)	Formulae of Inman (1952)
Mean	$\hat{\mu} = \frac{1}{100} \sum f(m_\phi)$	$M_z = (\phi_{16} + \phi_{50} + \phi_{84})/3$	$M_\phi = (\phi_{16} + \phi_{84})/2$
Standard deviation	$\hat{\sigma} = (\sum f(m_\phi - \bar{x})^2/100)^{1/2}$	$\sigma_1 = \frac{(\phi_{84} - \phi_{16})}{4} + \frac{(\phi_{95} - \phi_5)}{6.6}$	$\sigma_\phi = (\phi_{84} - \phi_{16})/2$
Skewness	$\hat{\alpha}_3 = \frac{1}{100} \bar{\sigma}^3 \sum f(m_\phi - \bar{x})^3$	$Sk_I = (\phi_{16} + \phi_{84} - 2\phi_{50})/2(\phi_{84} - \phi_{16}) + (\phi_5 + \phi_{95} - 2\phi_{50})/2(\phi_{95} - \phi_5)$	$\alpha_\phi = \frac{(\phi_{84} + \phi_{16} - 2\phi_{50})}{(\phi_{84} - \phi_{16})}$
Kurtosis	$\hat{K} = \frac{1\bar{\sigma}^4}{100} \sum f(m_\phi - \bar{x})^4$	$K_G = \frac{(\phi_{95} - \phi_5)}{2.44(\phi_{75} - \phi_{25})}$	

along the transit lines, from each physiographic unit (berm/backshore, high tide, mid tide and low tide regions) during fair weather and monsoon season. The method of sample collection has been described by Chauhan (1986) and Chauhan et al. (1988).

The collected sediments were washed and oven-dried at 70 °C. The samples were reduced to 100 g by coning and quartering. Sieving was performed at 1/4-φ class interval using a Ro-Tap sieve shaker for 15 minutes. ASTM 20-cm-diameter sieves were used to avoid clogging of openings.

Various graphic and moment measures were computed using the formulae of Inman (1952), Folk and Ward (1957) and Friedman (1979) (Table 2) on a Norsk Data 500 computer. Statistical calculations such as correlation coefficients, standard error in correlation coefficients, regression coefficients, means of X and Y variables, statistical significance test for the coefficients of correlation and regression coefficients and standard error in the means of X and Y variables were also computed on the ND-500 computer based on the formulae given by Kenny and Keeping (1964) and Griffiths (1967).

Results and discussions

In the present work, the correlation among moment measures (Friedman, 1979), graphic measures (Folk and Ward, 1957) and phi measures (Inman, 1952) were determined on the basis of X

and Y plots. The following possible pairs have been taken for the correlation:

- (1) Moment mean vs. graphic mean.
- (2) Moment mean vs. phi mean.
- (3) Graphic mean vs. phi mean.
- (4) Moment standard deviation vs. inclusive graphic standard deviation.
- (5) Moment standard deviation vs. graphic standard deviation.
- (6) Inclusive graphic standard deviation vs. graphic standard deviation.
- (7) Moment skewness vs. inclusive graphic skewness.
- (8) Moment skewness vs. graphic skewness.

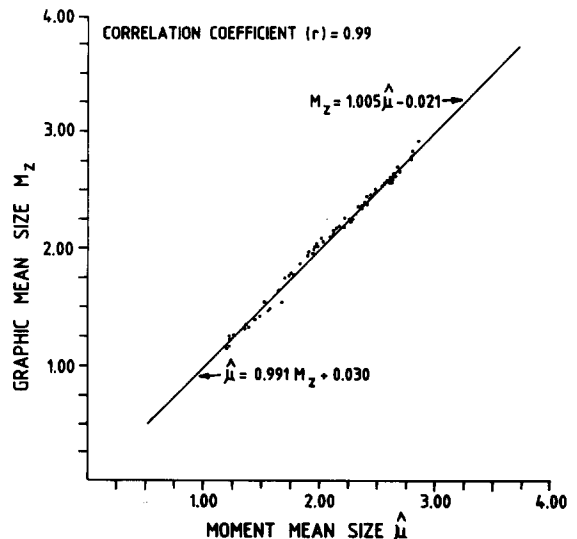


Fig. 2. Relationship between moment mean and graphic mean.

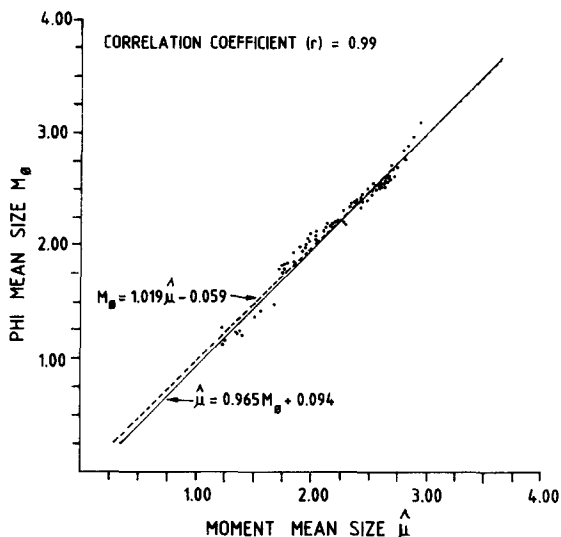


Fig. 3. Relationship between moment mean and phi mean.

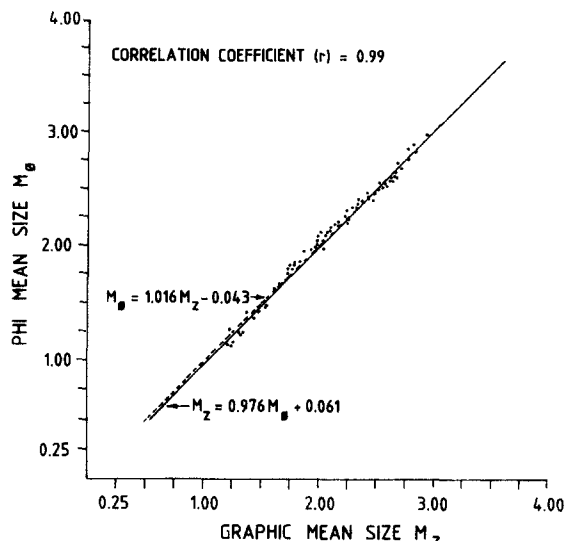


Fig. 4. Relationship between graphic mean and phi mean.

(9) Inclusive graphic skewness vs. graphic skewness.

(10) Moment kurtosis vs. graphic kurtosis.

Mean size

The correlation coefficient between graphic mean and moment mean is 0.99 with an standard error of 2.541×10^{-4} (Fig. 2). This coefficient between the phi mean and moment mean (Fig. 3) is 0.99 (standard error = 1.09×10^{-3}). The value of the correlation coefficient between graphic mean and phi mean (Fig. 4) is 0.99 (standard error = 5.149×10^{-4}). The probability (*P*) of these corre-

lations being accidental is 0.01 (Table 3). As it is possible to choose either of the variables as *X* and *Y*, it is worthwhile to obtain the equation of regression for different pairs. These are:

$$\begin{aligned} \hat{\mu} &= 0.991M_z + 0.31 \\ M_z &= 1.005\hat{\mu} - 0.21 \\ \hat{\mu} &= 0.965M_\phi + 0.94 \\ M_\phi &= 1.019\hat{\mu} - 0.059 \\ M_z &= 0.976M_\phi + 0.069 \\ M_\phi &= 1.016M_z - 0.049 \end{aligned}$$

An examination of Figs. 2,3 and 4 clearly shows that the lines of regression of *X* and *Y* and vice

TABLE 3

Statistical significance level of the coefficients of correlations and regression

Parameters	Level of significance of correlation coefficient ($V = N - 2$)	Level of significance of coefficient of regression ($V = N - 2$) ^a	
		X on Y	Y on X
1. Moment mean vs. graphic mean	0.01	0.01	0.01
2. Moment mean vs. phi mean	0.01	0.01	0.01
3. Graphic mean vs. phi mean	0.01	0.01	0.01
4. Moment standard deviation vs. inclusive graphic standard deviation	0.01	0.01	0.01
5. Moment standard deviation vs. graphic standard deviation	0.01	0.01	0.01
6. Inclusive graphic standard deviation vs. graphic standard deviation	0.01	0.01	0.01
7. Moment skewness vs. inclusive graphic skewness	0.01	0.01	0.01
8. Moment skewness vs. graphic skewness	0.01	0.01	0.01
9. Inclusive graphic skewness vs. graphic skewness	0.01	0.01	0.01
10. Moment kurtosis vs. graphic kurtosis	0.01	0.01	0.01

^a *X* denotes first measure of the pair; *Y* denotes second measure of the pair.

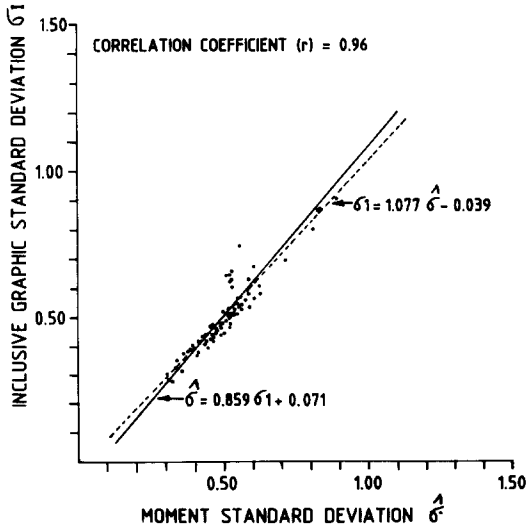


Fig. 5. Relationship between moment standard deviation and inclusive graphic standard deviation.

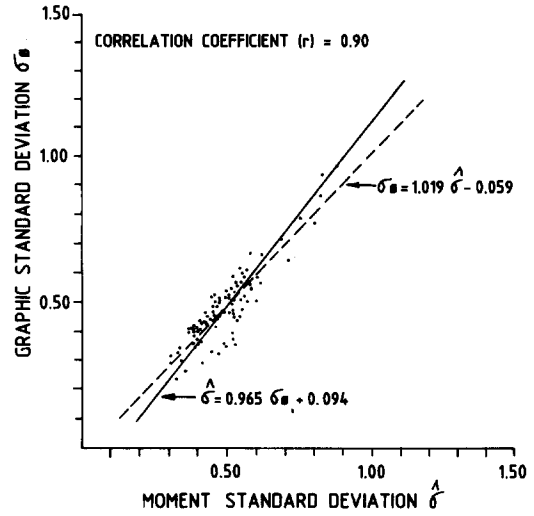


Fig. 6. Relationship between moment standard deviation and graphic standard deviation.

versa are similar for all the pairs and there exists a linear correlation between X and Y variables. The estimated values of X or Y variables computed based on regression equations are also very close. Therefore, the results of mean size computations, based on either moment or graphic measures, do not vary with the change of the method, and therefore, may be computed by any method.

Standard deviation measures

Figs. 5, 6 and 7 show the relationship among moment standard deviation and inclusive graphic standard deviation; moment standard deviation and graphic standard deviation and; between inclusive graphic standard deviation and graphic standard deviation, with the lines of regression. The values of the correlation coefficient for each of these pairs are also depicted in Figs. 5–7. Table 3 gives the statistical significance for the coefficients of the correlations and the regressions.

Study of X and Y plots together with the regression lines reveals that the moment standard deviation of Friedman (1979) and the graphic standard deviation measures of Inman (1952) and Folk and Ward (1957) in general have good linear correlations. The degree of linear correlation is, however, reduced for the sediments having higher standard deviation, skewness and kurtosis (sedi-

ments of berm, dunes and high tide level) and reflects the influence of higher skewness and kurtosis on the standard deviation of these sediments.

Skewness measures

The relationship based on the equations of regression for moment, graphic and inclusive graphic skewness for the different pairs along with the values of correlation coefficient are presented

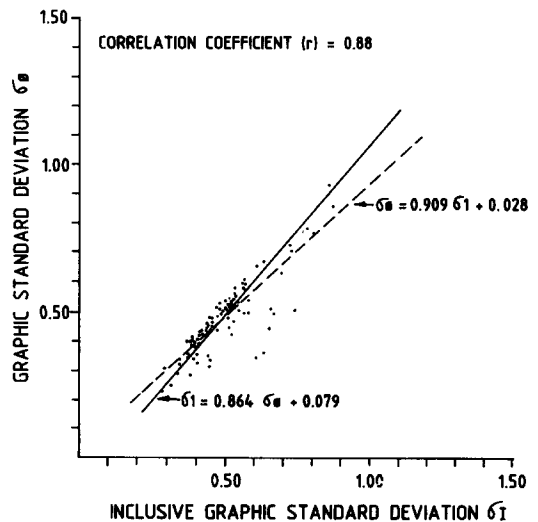
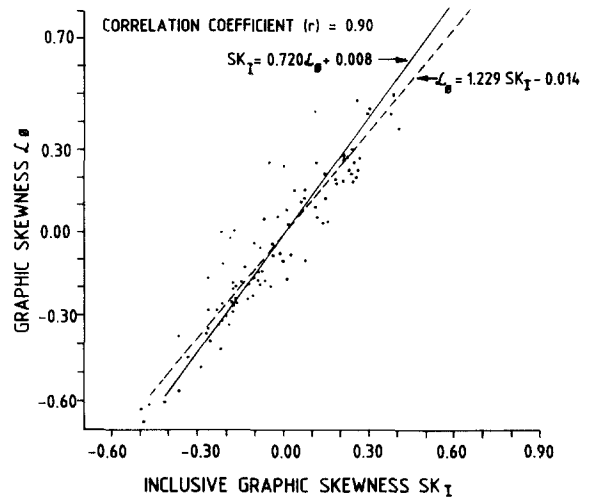
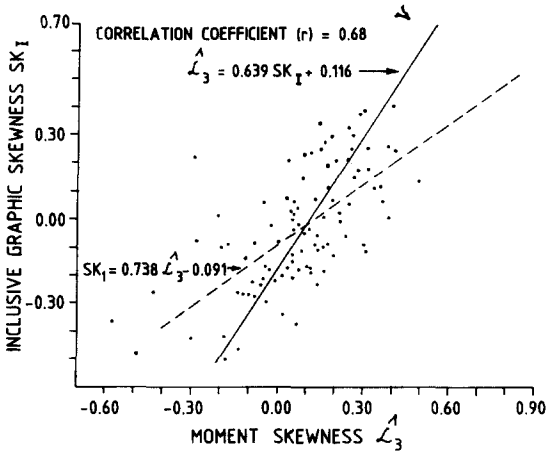


Fig. 7. Relationship between inclusive graphic standard deviation and graphic standard deviation.



in Figs. 8–10. The figures demonstrate good correlations between inclusive graphic and graphic skewness. The degree of linear correlation is reduced between moment and inclusive graphic skewness, and between moment and graphic skewness. However, the correlation between inclusive graphic skewness and moment skewness is better than between moment skewness and graphic skewness. The poor correlation between graphic skewness measures (of Folk and Ward and Inman) and moment skewness (of Friedman) is attributed to the fact that they measure different properties. Consideration of full distribution modifies the

moment skewness values. Thus, the skewed distribution having prominent tails record higher variations in the values of moment and graphic measures, disturbing the degree of correlation. The better correlation between inclusive graphic skewness and graphic skewness reflects the similar properties of these measures.

Kurtosis measures

The correlation coefficient between kurtosis is 0.42 (standard error 5.367×10^{-2} , $p = 0.01$) and the regression lines (Fig. 11) are far from identical. It is, thus, clear that the properties of moment and graphic kurtosis are different and not comparable (Jones, 1970; Jaquet and Vernet, 1976; Hashimi, 1981).

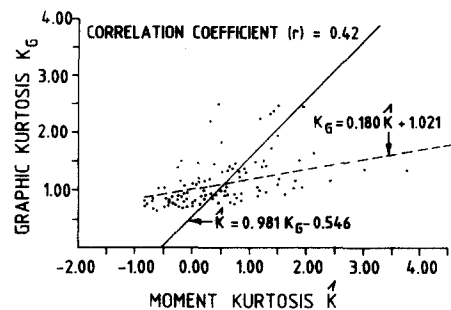
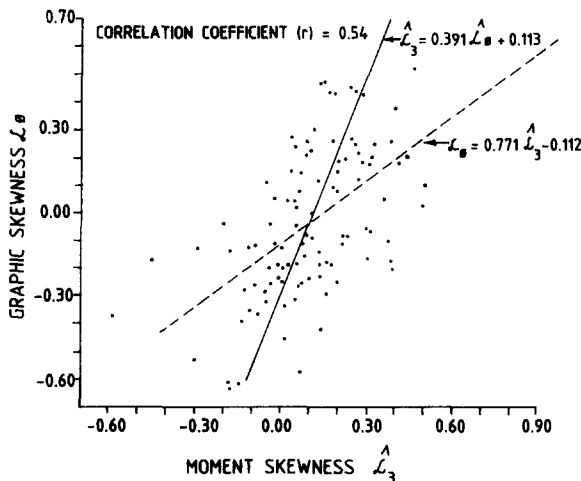


Fig. 9. Relationship between moment skewness and graphic skewness.

Fig. 11. Relationship between moment kurtosis and graphic kurtosis.

Conclusions

The results of the present study lead us to conclude:

(1) Mean size computations based on $1/4-\phi$ class intervals show very good linear correlations; hence, computation of the mean by any method gives a good estimate of population mean.

(2) Standard deviations based on $1/4-\phi$ class intervals also do not vary significantly irrespective of the method used and hence, may be computed by any method.

(3) The skewness measures show less comparability, particularly on the sediments having a skewed distribution (sediments of dunes and fore-shore region in the present study). The moment and inclusive graphic skewness is better correlated than moment and graphic skewness. A higher correlation between graphic and inclusive graphic skewness shows that there is no superiority of Folk and Ward measures over phi measures of Inman at $1/4-\phi$ class interval.

(4) The kurtosis measures do not show any comparability, due to the fact that they estimate different properties.

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References

- Chauhan, O.S., 1986. Beach cycles and associated sediment movements at Puri and Konarak, Orissa. Ph.D. Thesis, Garhwal University, 160 pp. (unpublished).
- Chauhan, O.S., Verma, V.K. and Prasad, C., 1988. Variations in the mean size as an indicator of the beach sediment movement at Puri and Konarak beaches, Orissa, India. *J. Coastal Res.*, 4: 27-35.
- Davis, M. and Ehrlich, R., 1970. Relationship between measure of sediment size frequency distribution and the nature of sediments. *Geol. Soc. Am. Bull.*, 80: 3537-3548.
- Emery, K.O., 1978. Grain size in laminae of beach sand. *J. Sediment. Petrol.*, 48: 1203-1212.
- Folk, R.L., 1966. A review of grain size parameters. *Sedimentology*, 6: 73-93.
- Folk, R.L. and Ward, W.C., 1957. Brazos river bar: a study in the significance of grain size parameter. *J. Sediment. Petrol.*, 27: 3-27.
- Friedman, G.M., 1962. On sorting, sorting coefficient and log normality of the grain size distribution of sandstone. *J. Geol.*, 70: 737-756.
- Friedman, G.M., 1967. Dynamic processes and statistical parameters compared for size frequency distribution of beach and river sand. *J. Sediment. Petrol.*, 37: 327-354.
- Friedman, G.M., 1979. Difference in size distribution of population of particles among sands of various origin: address of retiring president of the International Association of Sedimentologist., *Sedimentology*, 26: 3-32.
- Griffiths, J.C., 1967. Scientific methods in the analysis of sediments. McGraw Hill, New York, N.Y., 507 pp.
- Hashimi, N.H., 1981. Comparative study of moment and graphic size parameters of the sediments of the western continental shelf of India. *Math. Geol.*, 13: 291-301.
- Inman, D.L., 1952. Measures for describing the size distribution of the sediments. *J. Sediment. Petrol.*, 22: 125-145.
- Isphording, W.D., 1972. Analysis of variance applied to measures of central tendency and dispersion in sediments. *J. Sediment. Petrol.*, 42: 107-121.
- Jaquet, J.M. and Vernet, J.P., 1976. Moment and graphic size parameters in the sediments of Lake Geneva (Switzerland). *J. Sediment. Petrol.*, 46: 305-312.
- Jones, T.A., 1970. Comparison of descriptors of sediment grain size distribution. *J. Sediment. Petrol.*, 40: 1204-1215.
- Kenny, J.F. and Keeping, E.S., 1964. Mathematics of Statistics, Part 1. D. Van Nostrand, Princeton, N.J. 348 pp.
- Koldijk, W.S., 1968. On environment sensitive grain size parameters. *Sedimentology*, 10: 57-69.
- Sevon, W.D., 1968. First and second degree regression correlation of the size analysis statistical parameters of Trask, Inman, Fold and Ward and Friedman. *J. Sediment. Petrol.*, 38: 238-246.
- Swan, D., Clague, J.J. and Luternauer, J.L., 1978. Grain size statistics, I. Evaluation of the Folk and Ward graphic measures. *J. Sediment. Petrol.*, 48: 863-878.