Granulometric Analysis of the Exotic Sandstones in and around Moreh and Chandel, Chandel District, Manipur

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***Abstract*-**Chaotic assemblage of conglomerate, gritstone, sandstone, shale, limestone, chert and ophiolitic derivatives occurs along the western contact of Nagaland-Manipur ophiolite belt in N-S to NNE-SSW trending direction. This assemblage is known as sedimentary melange and extends for about 200 km from north-east of Chokla in Nagaland to the south of Moreh in Manipur. Sandstones being the dominant litho-unit among the sedimentary mélange have been selected for the present study. These sandstones occur as floating bodies intermingling with both Disangs and ophiolite, hence the term exotic sandstone is used. Analysis of grain size data of these exotic sandstones in and around Moreh and Chandel, Chandel district reveals that all the samples show unimodal distribution. Cumulative curves suggest saltation and suspension are the major mode of transportation of these sediments. Mean values ranging from 1.40 Φ to 3.29 Φ suggest medium to very fine sand size. Standard deviation values (0.20 to 1.10) suggest that these sediments are very well sorted to moderately sorted and indicate fluctuating energy conditions during the time of deposition. The values of skewness range from -0.88 to 0.19 and 76.31% of the samples are negatively skewed, indicating high energy condition during the time of deposition of the sediments. Bivariate plots suggest that sediments were deposited both in fluvial and near shore environments. Discriminant function analysis reveals that exotic sandstones of the present study area were deposited under diverse conditions

Key words-Grain size analysis, exotic sandstones, standard deviation, skewness, bivariate plots, discriminant function analysis

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I. Introduction

The study of grain size is very important as it is a fundamental descriptive measure of sediment and sedimentary rocks. It is helpful in understanding the mechanism operated during the process of transportation and deposition, as well as the distance of sediment transport and sensitive to the physical changes of the transporting media and the depositional basin. Systematic analysis and presentation of grain size data provide basis for the reconstruction of sedimentary processes. Various advance techniques of exploring the information on grain populations for the interpretation of sedimentary process experiences varying degree of success. Even the dedicated workers would agree that no universal solution exists as yet to enable the sedimentologists unequivocally to distinguish the depositional environment of ancient deposits with 100% certainty on the grain size criteria alone. However, an enormous amount of information about a sedimentary deposit can be obtained from systematic examination of the multiple sub-populations.

II. THE STUDY AREA

Present study area around Moreh and Chandel, Chandel District is situated in the southern part of Manipur, bordering Myanmar. The geological formation occurring in the area belongs to the Ophiolite suites of rocks, sedimentary mélange and Disangs, forming an integral part of the Indo-Myanmar Ranges. The N-S to NNE-SSW trending arcuate belt of ophiolite within the Indian Territory extends for about 200 km from northeast of Chokla to the south of Moreh in Manipur. A narrow zone of sedimentary mélange occurs within the Disangs along its contact with ophiolite. Sedimentary mélange is a chaotic assemblage of diverse types of rocks viz. conglomerate, gritstone, sandstone, shale, limestone, chert and ophiolitic derivatives.

Some aspects of ophiolite and associated rocks of Manipur have been studied by Mitra *et al.* [10], Ibotombi [7], Devala [1], Devala *et al.* [2, 3], Khuman [8], Khuman and Soibam, [9], Ranjitkumar [12] and others. Mitra *et al.* [10 have considered the sedimentary mélange units associated with Nagaland-Manipur Ophiolite belt as olistostrome. However, available published and unpublished literature reveals that no one has attempted sedimentological studies of the exotic sandstones exposed in the present study area. Accordingly the authors have made an attempt to interpret the depositional environment of the exotic sandstones exposed in and around Moreh and Chandel, Chandel district. In the study area sedimentary mélange consist of fine, medium to coarse-grained sandstones, cherts, serpentinites and ophiolitic derivatives. Sandstones being the dominant litho-unit have been selected for the present study. This sandstone unit occurs as floating bodies intermingling with both Disangs and ophiolite, hence the term exotic sandstone is used. A simplified stratigraphic succession of the study area is shown in Table-1.

Table-1 Stratigraphic succession of the study area

Lithounits and age	Description
Exotic sandstones (Eocene?)	Medium to Coarse-grained; massive to sometimes bedded huge blocks of sandstones
- - - - - - - - - - - - - - - - - - - Unconformity - - - - - - - - - - - - - - - - - -	
Disangs (Eocene to Cretaceous)	Dark grey to black colour shales, often brown to dirty white due to weathering
~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ Tectonic Contact ~ ~ ~ ~ ~ ~ ~ ~ ~ ~	
Ophiolite (Upper Createaceous)	Usually serpentinised ultramafics. Dykes of ultramafic and basics are found within the serpentinised ultramafics
~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ Unconformity~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~	
Basement complex (?)	

III. GRAIN SIZE ANALYSIS

Generally, size of a particle is not readily defined as it is a measure of the dimensions which best described a specific group of particles. The method used in determination of size vary widely from calipers on the coarsest fragments, through sieving and techniques dependent upon settling velocity, to those detecting changes in electrical resistance. So, no single technique of assessing particle size is applicable throughout the entire size spectrum. Each technique has certain specific advantages and usually a set of limiting conditions within which the technique operates. In the present study, the samples are hard and compact, so the method of thin section is used. 76 samples have been selected for grain size analysis.

A. Presentation of dats

Graphical or statistical techniques can be used for the presentation of data according to the purpose and aim of the study. In the present study both the techniques have been used for the presentation of data.

1). *Graphical presentation*: The grain size data generated through thin section technique is transformed into their phi equivalent. Then frequency percentage and cumulative frequency percentage are tabulated at one-phi class interval. For quick visual assessment and comparison, these data are graphically presented as frequency curves (Fig. 1) and cumulative frequency curve (Fig. 2). Frequency curves are plotted on arithmetic ordinate scale and cumulative curves are plotted on the probability ordinate scale. All the 76 samples collected from different localities, show unimodal distribution. Variability in the nature of frequency curves suggests fluctuation in the kinetic energy during deposition of these sediments. Analysis of the cumulative curves indicates that the present sediments were dominantly transported in saltation and traction modes and few in saltation, traction and suspension. Absence of sharp breaks between different modes of transportation suggests mixing of sediment population due to fluctuation in the energy condition or derived from different sources. Percentile values such as Φ_5, Φ_{16}, Φ_{25}, Φ_{50}, Φ_{75}, Φ_{84} and Φ_{95}, are determined from the cumulative curves The percentiles values obtained from thin sections are corrected and converted to their sieve equivalent using Friedman's [5] expression

$$\Phi = 0.3815 + 0.9027\ \Phi',$$

where φ is sieve equivalent and φ′, thin section value.prepare your paper before styling

1) *Statistical Parameters of Grain Size*: Statistical parameters viz. median, graphic mean, graphic standard deviation, graphic skewness, graphic kurtosis, are calculated from corrected percentile values based on Folk and Ward's [4] formulae and presented in Table 2.

i) *Median*: The median is that size for which half of the particles are coarser and half finer. So, median is the measure of central tendency and divides the whole population into two. It can be determined from the 50% line of the cumulative distribution curve. The median values for the present samples range between 1.40 Φ and 3.29 Φ.

ii) *Graphic Mean*: It is one of the graphic measures that determine the overall size of the population. Mean size indicates the central tendency or the average size of the sediment. It is computed from size of particles spread through a range of particle sizes and is related to the average kinetic energy of the transporting media and the depositional basin. Mean sizes ranges between 1.56 Φ to 3.30 Φ suggesting that these sediments fall under medium to very fine sand size category.

iii) *Graphic Standard Deviation*: It is a measure of sorting. It describes the dispersion or spread of data around the mean and indicates fluctuations in kinetic energy of the depositing agencies about its average velocity. It is one of the most useful graphic measures that indicate the effectiveness of the depositing media in separating grains of different size fractions. Sorting of sediment is determined by several factors such as source rocks, distance of transport, effectiveness of transporting agencies and size of sediment itself. A small value of standard deviation indicates that the observations are clustered tightly around a central value (mean). Conversely, a large standard deviation value indicates the values are scattered widely around the mean. In the present analysis the value of standard deviation ranges from 0.20 to 1.10. If the value of standard deviation is less than 0.35, then the sediment is very well sorted. Sample no 10 collected from Modi area is very well sorted. 9.21% of the whole samples are well sorted, 88.16% are moderately sorted except sample no. 56 and 36 which are poorly sorted. This indicates that the energy was fluctuating during the time of deposition of these sediments.

iv) *Graphic Skewness*: Skewness is the tendency of a distribution to lean to one side that is to deviate from normality and it leads to differences between the median and the mean values. Hence, it is a measure of symmetry of the frequency distribution. It indicates the position of the mean with respect to the median and is independent of sorting. The skewness value in present samples ranges between -0.88Φ to 0.19Φ. 76.31% of the whole samples show coarse tail distributions, 19.74% show near symmetrical distribution while only 3.95% belong to fine to very fine tail distribution i.e. the present samples are ranging between fine to coarse tail distribution suggesting that these sediments were deposited under fluctuating energy conditions.

v) *Graphic Kurtosis*: It is the measure of the ratio between the sorting in the tails and the central portion of the distribution. If the central portion is better sorted than the tails, the frequency curve is said to be excessively peaked or leptokurtic. If the tails are better sorted than the central portion, the curve is said to be platykurtic. Strongly platykurtic curves are often bimodal with sub-equal amount of two modes. In the present study, 48.68% of the samples are platykurtic, 40.79 % are mesokurtic and only 11.13% of the samples are leptokurtic.

Table 2: Statistical parameters calculated from percentile values.

Sample no.	Median	Mean	Standa Deviati	Skewness	Kurtosis
1	2.18	2.22	0.75	0.01	0.86
2	3.16	3.08	0.39	-0.42	1.92
3	1.80	1.76	0.76	-0.06	0.93
4	2.61	2.46	0.79	-0.33	0.89
5	2.44	2.26	0.90	-0.31	0.80
6	2.15	2.24	0.72	0.11	0.42
7	2.95	2.72	0.72	-0.56	1.18
8	2.30	2.26	0.47	-0.19	1.29
9	2.64	2.51	0.72	-0.29	0.90
10	3.29	3.30	0.20	0.03	1.10
11	2.30	2.25	0.87	-0.16	0.78
12	2.80	2.66	0.65	-0.39	1.00
13	2.90	2.66	0.73	-0.55	1.09
14	1.88	1.82	0.41	-0.09	0.88
15	2.78	2.57	0.75	-0.45	0.99
16	2.42	2.34	0.83	-0.20	0.78
17	2.44	2.38	0.71	-0.17	0.81
18	3.05	2.89	0.53	-0.51	1.06
19	2.70	2.58	0.64	-0.28	0.89
20	2.40	2.33	0.95	-0.29	1.06
21	2.31	2.33	0.69	-0.01	0.71

22	2.60	2.53	0.66	-0.19	0.80
23	2.03	2.18	0.79	0.18	0.68
24	2.38	2.35	0.78	-0.11	0.67
25	2.54	2.33	0.89	-0.33	0.89
26	2.72	2.54	0.74	-0.39	1.01
27	2.66	2.51	0.76	-0.34	0.97
28	2.52	2.40	0.79	-0.88	0.84
29	2.60	2.52	0.70	-0.22	0.84
30	3.06	2.79	0.57	-0.60	1.00
31	2.62	2.55	0.65	-0.19	0.80
32	3.00	2.74	0.64	-0.56	0.78
33	2.88	2.56	0.85	-0.58	0.98
34	3.10	2.94	0.55	-0.53	1.34
35	2.71	2.69	0.47	-0.09	0.90
36	1.40	1.56	1.00	0.19	0.84
37	2.93	2.75	0.71	-0.53	1.26
38	2.51	2.35	0.84	-0.34	1.11
39	2.22	2.12	0.90	-0.19	0.85
40	2.17	2.08	0.83	-0.21	1.06
41	2.49	2.36	0.86	-0.26	0.75
42	2.76	2.62	0.70	-0.38	1.01
43	2.23	2.23	0.84	-0.07	0.73
44	2.47	2.48	0.52	0.01	0.80
45	2.58	2.45	0.78	-0.33	1.09
46	2.71	2.61	0.64	-0.29	0.79
47	2.57	2.48	0.71	-0.24	0.85
48	2.43	2.42	0.58	-0.08	0.94
49	3.00	2.90	0.44	-0.35	0.95
50	2.90	2.76	0.59	-0.42	1.03
51	3.06	2.73	0.73	-0.64	0.90
52	2.46	2.43	0.66	-0.13	0.81
53	3.00	2.86	0.49	-0.42	0.95
54	3.08	2.91	0.70	-0.60	1.02
55	3.08	2.84	0.67	-0.63	1.44
56	2.30	2.08	1.10	-0.33	0.75
57	2.12	2.13	0.89	-0.06	0.71
58	2.86	2.63	0.76	-0.53	1.12
59	2.10	2.23	0.59	0.26	0.88
60	3.04	2.82	0.60	-0.55	1.08
61	2.57	2.45	0.76	-0.27	0.82
62	2.43	2.41	0.68	-0.07	0.72
63	3.02	2.81	0.60	-0.54	1.03
64	2.65	2.50	0.78	-0.37	1.04
65	3.00	2.70	0.73	-0.62	0.97
66	2.50	2.39	0.83	-0.24	0.77
67	3.00	2.73	0.67	-0.59	0.94
68	2.56	2.48	0.71	-0.24	0.93
69	2.83	2.65	0.71	-0.47	0.97
70	2.42	2.42	0.51	-0.05	1.06
71	2.36	2.30	0.79	-0.17	0.77
72	2.02	2.01	0.58	-0.03	1.02
73	2.87	2.73	0.58	-0.39	0.91
74	2.90	2.57	0.82	-0.59	1.03
75	2.25	2.26	0.65	-0.03	0.93
76	2.18	2.19	0.81	-0.04	0.78

IV. ENVIRONMENTAL INTERPRETATION FROM GRAIN SIZE DATA

1) *Bivariate plots:* Stewart [14] is the one who made earliest attempts to characterize depositional environment by means of bivariate scatter diagrams. He plotted median against skewness and standard deviation for sediments from rivers, wave dominant zones and quiet water environments, and defined envelopes within which his analysis occurred. Friedman [6] also used scattered diagrams of sorting and skewness to provide discrimination between beach and fluvial environments. Again various workers have used different diagrams of scatter plots to characterized the depositional environment. Moiola and Weiser [11] have plotted skewness against standard deviation and mean size; mean size against standard deviation to discriminate the beach and fluvial environments. In order to discriminate the depositional environments of the arenaceous rocks, the bivariate scatter plots as suggested by Stewart [14], Friedman [6] and Moiola and Weiser [11] have been used in the present analysis. Bivariate plots (Fig. 3: A and B) after Stewart [14] reveals that the present sandstones were deposited both in the fluvial and beach or near shore environments but dominantly in the beach environment. Bivariate plots (Fig. 3-C-F) after Friedman [6] and Moiola and Weiser [11] suggest that the samples are dominantly deposited in the fluvial environment rather than the beach environments.

1. *Dicriminant fucntion analysis:* Geological data can be analysed to interpret the depositional environment with the help of the discriminant functions. It is a multivariate procedure that provides an additional link between the univariate and multivariate statistics. Many workers have tried to differentiate the depositional environment using multivariate analysis on the basis of the various geological parametres. Sahu [13] used grain size parameters like mean size, standard deviation, skewness and kurtosis in the discriminant function analysis in order to differentiate the mechanism of transportation and depositional environment. He used the following discriminating parameters.

$$Y_{\text{aeolian: beach}} = -3.5688M_z + 3.701\sigma^2 - 2.0766S_k + 3.1135K_g$$
$$Y_{\text{beach: marine}} = 15.6534\,M_z + 65.7091\sigma^2 + 18.1071S_k + 18.5043K_g$$
$$Y_{\text{marine:fluvial}} = 0.2852\,M_z - 8.7604\sigma^2 - 4.8932S_k + 0.0482K_g$$
$$Y_{\text{fluvial: turbidite}} = 0.7215\,M_z - 0.4030\sigma^2 - 6.7322S_k + 5.2927K_g$$

The following classifications are used to distinguish the depositional environments on the basis of the result obtained from the discriminant function analysis.

1. $Y_{\text{aeolian: beach}}$ less than-2.741=Aeolian environment
2. $Y_{\text{aeolian: beach}}$ more than-2.7411=Beach environment
3. $Y_{\text{beach: marine}}$ less than 65.3650=Beach environment
4. $Y_{\text{beach: marine}}$ more than 65.3650=Shallow marine environment
5. $Y_{\text{marine:fluvial}}$ less than-7.4190=Fluvial environment
6. $Y_{\text{marine:fluvial}}$ more than-7.4190=Shallow marine environment
7. $Y_{\text{fluvial: turbidite}}$ less than 9.8433=Turbidity environment
8. $Y_{\text{fluvial: turbidite}}$ more than 9.8433=Fluvial environment

The depositional environment deduced for the present samples is shown in the Table-3.

Analysis of Table-3 reveals that the arenaceous rocks of the present study area were deposited under diverse conditions. Out of 76 samples, 56 samples show the combined effects of Marine-Turbidity-Aeolian environments. 18 samples show the combine effect of Beach-Marine- Turbidity environments. Only two samples (sample no. 36 and 56) show the combine effect of Fluvial-Beach-Marine-Turbidity environments.

Table-3: Depositional environments of the exotic sandstones of the study area

Sample no.	Fluvial	Beach	Marine	Turbidity	Aeolian
1	A	A	P	P	P
2	A	A	P	P	P
3	A	P	P	P	A
4	A	A	P	P	P
5	A	P	P	P	A
6	A	A	P	P	P

7	A	A	P	P	P
8	A	A	P	P	P
9	A	A	P	P	P
10	A	A	P	P	P
11	A	P	P	P	A
12	A	A	P	P	P
13	A	A	P	P	P
14	A	A	P	P	P
15	A	A	P	P	P
16	A	A	P	P	P
17	A	A	P	P	P
18	A	A	P	P	P
19	A	A	P	P	P
20	A	P	P	P	A
21	A	A	P	P	P
22	A	A	P	P	P
23	A	A	P	P	P
24	A	A	P	P	P
25	A	P	P	P	A
26	A	A	P	P	P
27	A	A	P	P	P
28	A	P	P	P	A
29	A	A	P	P	P
30	A	A	P	P	P
31	A	A	P	P	P
32	A	A	P	P	P
33	A	P	P	P	A
34	A	A	P	P	P
35	A	A	P	P	P
36	P	P	P	P	A
37	A	A	P	P	P
38	A	P	P	P	A
39	A	P	P	P	A
40	A	P	P	P	A
41	A	A	P	P	P
42	A	A	P	P	P
43	A	A	P	P	P
44	A	A	P	P	P
45	A	P	P	P	A
46	A	A	P	P	P
47	A	A	P	P	P
48	A	A	P	P	P
49	A	A	P	P	P
50	A	A	P	P	P
51	A	A	P	P	P
52	A	A	P	P	P
53	A	A	P	P	P
54	A	A	P	P	P
55	A	P	P	P	A
56	P	P	P	P	A
57	A	P	P	P	A
58	A	P	P	P	A
59	A	A	P	P	P
60	A	A	P	P	P
61	A	A	P	P	P
62	A	A	P	P	P
63	A	A	P	P	P
64	A	P	P	P	A
65	A	A	P	P	P
66	A	A	P	P	P
67	A	A	P	P	P
68	A	A	P	P	P
69	A	A	P	P	P
70	A	A	P	P	P
71	A	A	P	P	P
72	A	P	P	P	A
73	A	A	P	P	P
74	A	P	P	P	A
75	A	A	P	P	P
76	A	A	P	P	P

V. DISCUSSION AND CONCLUSION

Grain size distribution in clastic sedimentary rocks is a function of its initial size, distance and media of transport and depositional basin. Thus, its systematic analysis and presentation provide a useful tool for the interpretation of the sedimentary processes. Distribution of grain size in the study area is more or less uniform. All the 76 samples collected from different localities, show unimodal distribution. Variability in the nature of frequency curves suggests fluctuation in the kinetic energy during deposition of these sediments. Analysis of the cumulative curves indicates that the present sediments were dominantly transported in saltation and traction modes and few in saltation, traction and suspension. Absence of sharp breaks between different modes of transportation suggests mixing of sediment population due to fluctuation in the energy condition or derived from different sources.

Graphic measures like median, mode, standard deviation, skewness and kurtosis shows more or less uniformity. The median value ranges from 1.40 to 3.29Φ. Mean size ranges from 1.56 to 3.30Φ and is directly related to the average kinetic energy of the depositional basin. Variability in the values of mean size indicates fluctuation in the kinetic energy.

Standard deviation is a measure of sorting and describes the effectiveness of the transporting and depositing media in separating grains into different size fractions. In the present analysis, the value ranges from 0.20 to 1.10Φ. Out of the total samples, 9.21% are well sorted, 88.61% are moderately sorted and only 2.6% are poorly sorted. Thus it indicates fluctuation in the energy condition during their transportation and deposition.

Skewness is a measure of symmetry of the frequency distribution and related to the kinetic energy. Out of the total 76 samples, 76.31% show coarse skewness, 19.74% show near symmetrical skewness and only 3.95% are fine to very fine skewed. Coarse tail distributions are more common and suggest relatively high kinetic energy condition.

In the present study, out of the total samples, kurtosis value of 11 samples are unity or very close to unity, 20 samples have value greater than unity and the remaining 45 samples show kurtosis value less than unity which justify the fluctuation in the energy condition.

Bivariate plots suggest that these samples were deposited both in the fluvial and beach or near shore environments Discriminant function analysis reveals that these sandstones were deposited under diverse environmental conditions. Most of the samples show the combined effect of more than two environments. However, marine and turbidity are the most dominant environments.

From the above analyses it may be concluded that the sediments were deposited under diverse conditions in shallow environment where the energy was high and fluctuating nature..

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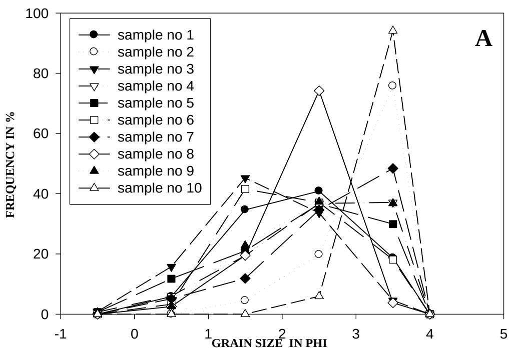

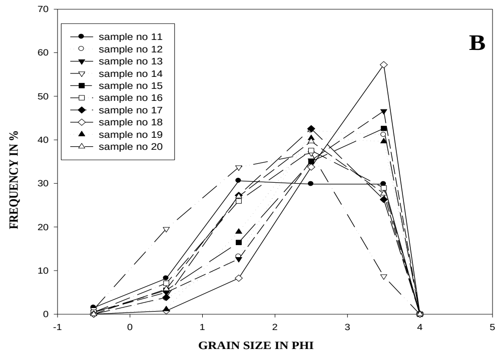

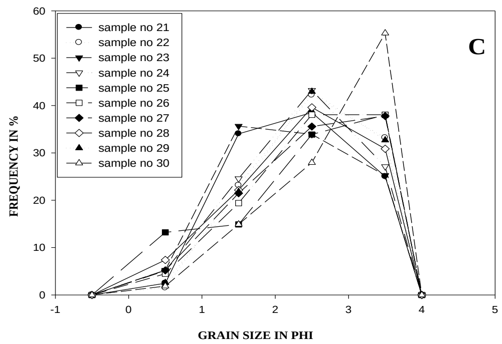

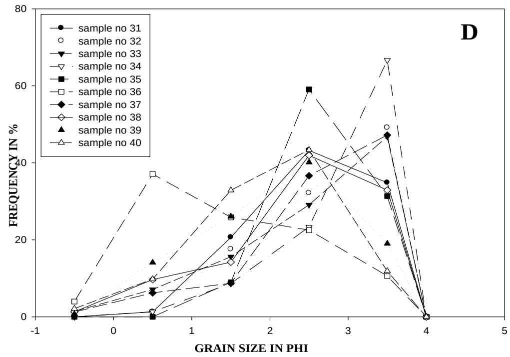

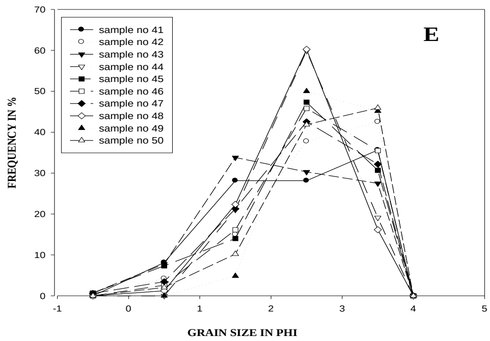

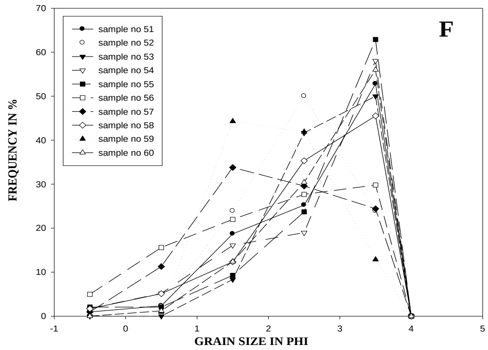

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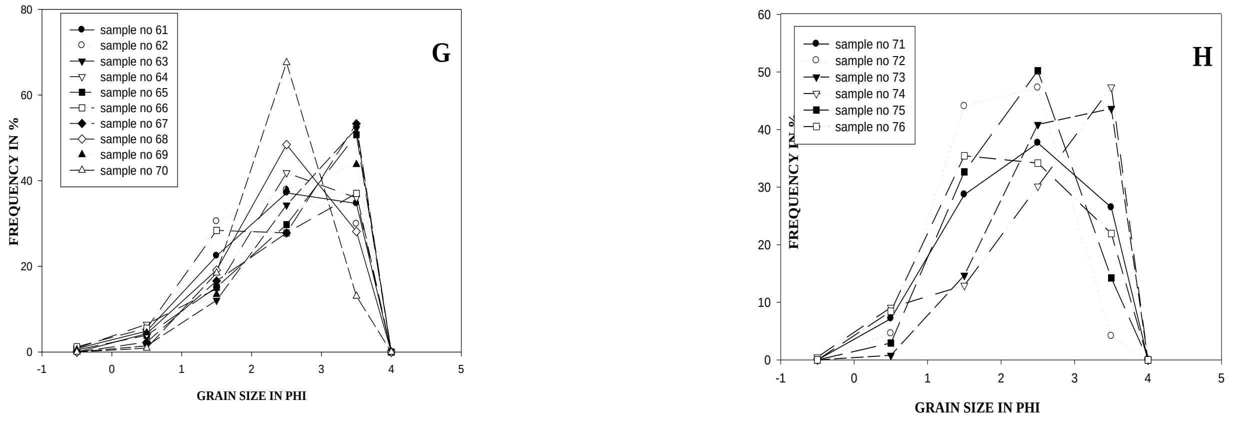
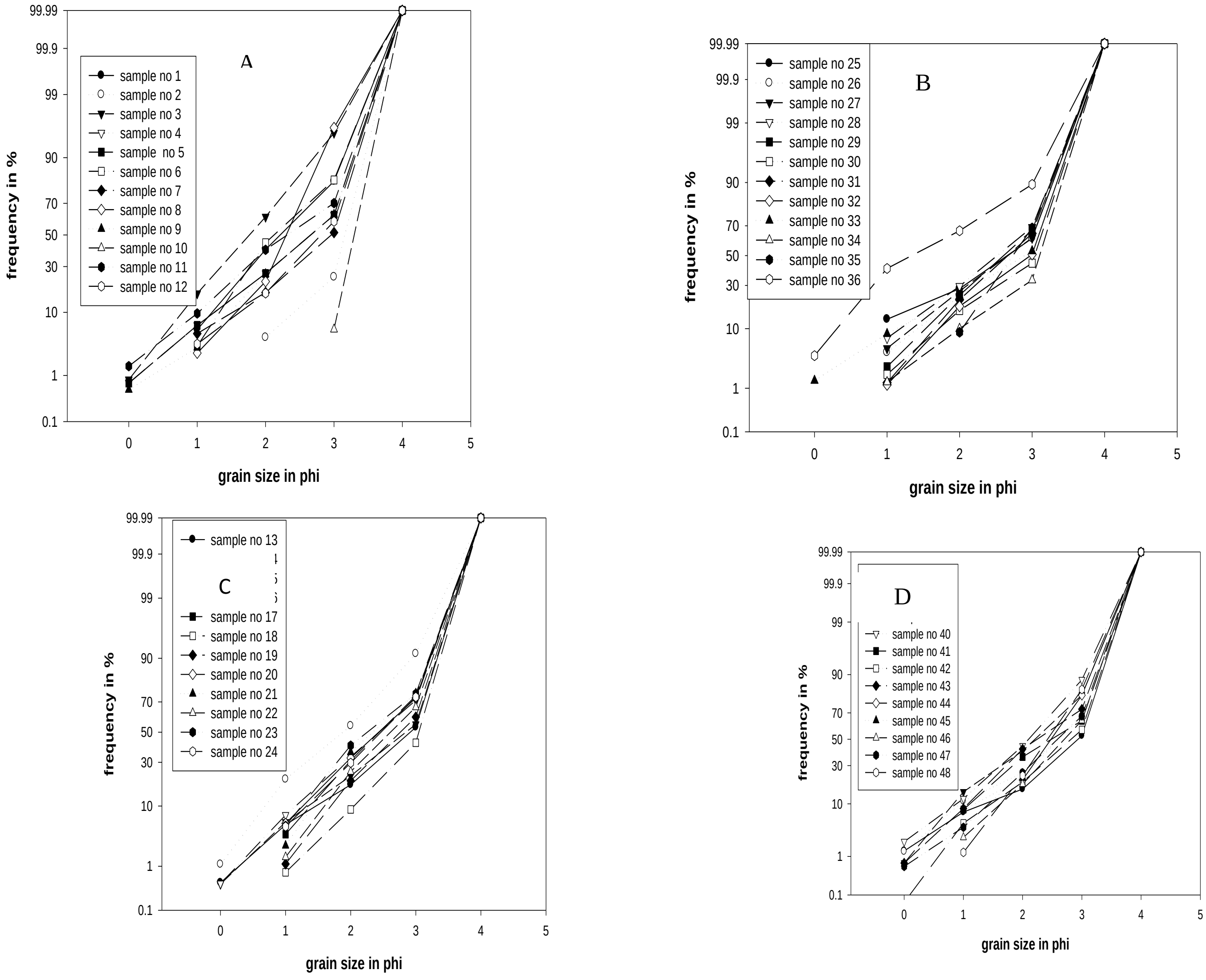


-H).

Fig. 1: Frequency curves (A-H).



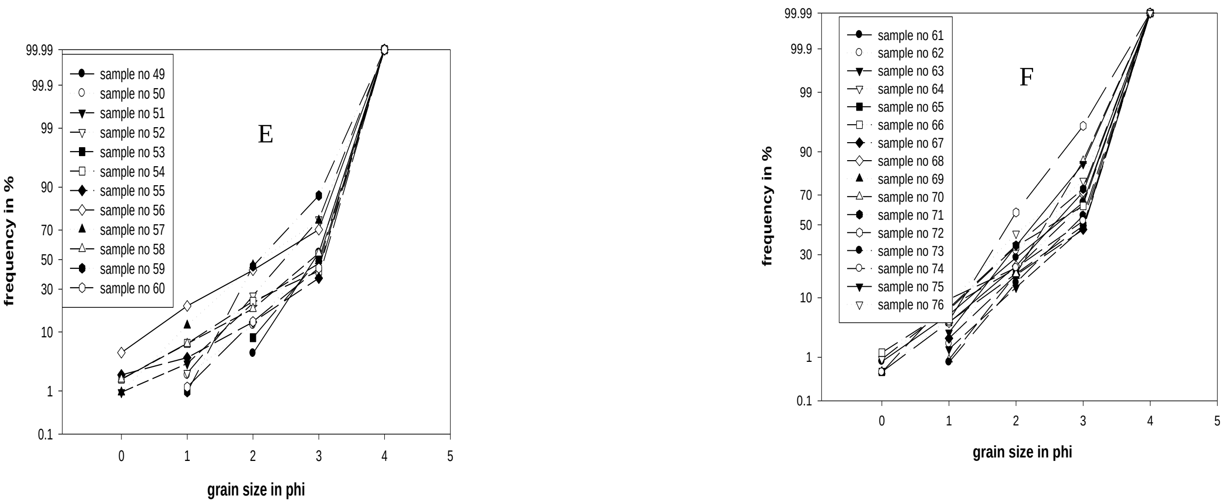


Fig. 2: Cumulative frequency curves (A-F).

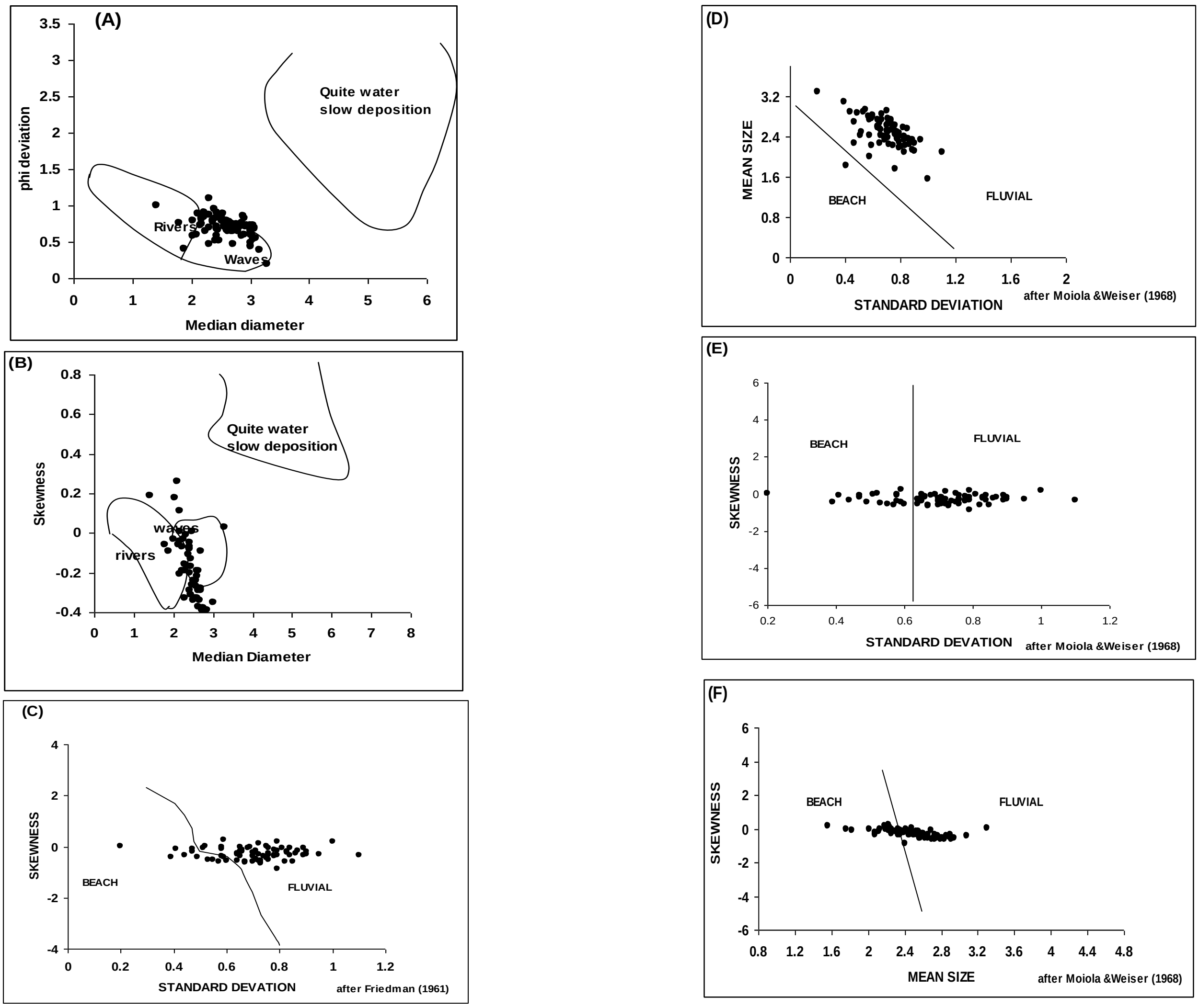


Fig. 3: Bivariate plots giving environmental significance-A and B after Stewart [14]; C-F after Moiola, R .J. and Weiser, D.[11]