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Grain size and texture of the sandstones occurring in and around Mawsinram, Meghalaya

P. BARTHAKUR[1] and P. K. DAS[2]

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Abstract

The grain size analyses and textural studies have been made from four types of sandstones occurring in and around Mawsinram, Meghalaya. For this purpose, statistical parameters of the grain size distribution have been determined. The nature of cumulative and frequency curves shows mostly bimodality in nature. It indicates mixing of the sediments mostly under sand and silt modes. Moreover, it shows the variation in the kinetic energy of the depositing agents which reflect the diversity in the grain size of source materials and different modes of transportation of sediments.

The univariant plots of size parameters reflect the distance of provenance, fluctuation in the velocity of the depositing media and higher hydrodynamic energy conditions of the transporting medium.

The bivariant plots of the samples of sandstones indicate sedimentation processes took place both under river and marine conditions. Log probability plots show dominance of saltation followed by suspension and rolling. The C-M patterns of four types of sandstones show that the sediments were carried dominantly by graded suspension alongwith rolling. The sandstones are of sand and silty sand under textural classification.

Key words : Grain size, Texture, Sandstones, Mawsinram, Meghalaya.

Introduction

"Size analysis" is defined as the quantitative expression of the size frequency distribution of particles in granular, fragmental or powdered materials. It can be also expressed as a process by which the relative proportions of the particles of various sizes in the sediments can be determined.

Grain size distribution is a very important property of the clastic sediments, and it has a fundamental relationship with the physical forces involving the mechanism of transportation and deposition of sediments. Various methods of grain size analysis have been developed by various sedimentary petrologists. The result of the statistical data are now applied for the study if the tectonic framework of sedimentation and depositional environment. A grain size frequency distribution is taken to be environment sensitive. Sedimentologists have for long time tried to obtain clues to the environment of deposition from analysis of grain size sediments. Thus, the geologic significance of grain size analysis of clastic sediments has greatly been emphasized in the recent years towards the evaluation of depositional environment and transportation history of sediments[11,15,21,24,25,26,28,30]. Krumbein and Pettijhon[13] suggested the use of graphic representation and statistical analysis of sedimentary data. Inman (1952) used various measurements for describing the size of the distribution of the sediments. Folk and Ward[7] studied the significance of grain size parameters and discussed the possible geological significance. Sahu[26] suggested a new measure *i.e.*, “modality index” to determine the bimodal and polygonal nature of size distribution curves. Friedman (1967, Spencer, 1963) demonstrated that correlation exists between size frequency distribution and depositional process.

Later work by Visher[32] on the applicable of log-probability plots to size distribution data has opened a potential valuable investigation that related mechanism of deposition to specific environment. The evaluation of grain size and sorting gives the clues to the condition of formation of sediments grain depends on the nature of the source rock and transporting agent. Hence the sediments size is mainly a function of the agent of erosion, the distance of transportation and transporting media.

A study of grain size distribution thus reveals the physical effect of the depositing environment and hydrodynamic conditions existing at the time of deposition. There have been repeated attempt to use grain size parameters to establish and differentiate environments of deposition by many workers like Folk and Ward[7], Passega[19,20], Friedman[3,4,5], Sahu[26,27], Moiola and Weiser[17], Pettijhon[23] Folk[8] and others.

The relationship between grain size distribution and depositional environment have been widely used to study and interpret clastic sediments although, there are conflicting opinions regarding environmental sensitive of the textural parameters.

Sediments are products of inherence and environment. The decipherment of environment of sedimentation, the prevailing energy conditions, turbulence of water, velocity of currents, relief of the areas and gradient of basin of sedimentation which are very well reflected by textural parameters of sediments.

Geology of the area :

The Mawsinram area is covered by a thick pile of sediments ranging in age from Precambrian to Tertiary period. The Phanerozoic sediments are lying above the Shillong Group of rocks of Precambrian age. The area is bounded by 25°17′ N - 25°22′N and 91°31′ E - 91°32′ E Topsheet No. 780/11) (Fig. 1).

Based on field observations, the different lithounits are shown below (Table 1).

Table 1

Age	Group	Formation/ Member	Lithounit
Eocene (Tertiary)	Jaintia	Lakadong Sandstone	Coal bearing Sandstone
		Lakadong Limestone	Fossil bearing Limestone
Eocene to Cretaceous		Langpar Sandstone	Calcareous Sandstone
Cretaceous	Khasi	Upper Mahadek Sandstone	Green coloured Sandstone
		Lower Mahadek Sandstone	Purple coloured Sandstone
		Bottom Conglomerate	Conglomerate with pebbles
- - - - - - - - - - - - - - - - - - Angular Unconformity - - - - - - - - - - - - - - - - - -			
Pre-cambrian	Shillong	Upper Shillong	Phyllite and slate

Methodology :

For size analysis, the samples were collected from the field. Loose samples of the sandstones were used by conventional Sieve and Pipitte method described by Krumbein and Pettijhon[13]. The data obtained from mechanical analysis was used in drawing of cumulative curves on probability graph paper. Various size parameters were calculated from the cumulative curves using the formulae of Folk and Ward[7]. Frequency curves were also drawn on graph paper. C-M pattern were made followed by Passega and Byramjee[21]. Log-probability plots were done followed the methods of Visher[32]. Textural classification were made following the methods of Folk[6].

Results

Frequency Curves :

Frequency curve is a belt shaped curve and is generated from a histogram increasing the number of size classes to infinity, which correspondingly reduces the class interval to zero[16].

The general patterns of cumulative curves are mostly bimodal in nature in all four types of sandstones. The two modes consists of one primary and the other is secondary. The two modes are of sand and silt mode.

The frequency curves show dominantly bimodal nature in purple coloured and green coloured sandstones, whereas in calcareous sandstones, curves show almost polymodal and in coal bearing sandstones, curves show mostly unimodal nature (Fig. 2a,b,c & d).

Cumulative Curves :

The cumulative curves are constructed to show the percent of grains coarser or finer than any given grain size of an individual sample. It is conventional to plot grain size on the abscissa with smaller grain size to the right and to cumulative percentage on the ordinate. (Fig. 3a,b,c & d)

Grain size parameters :

Grain size frequency distribution of four types of sandstone samples have been studied as this type of study reflects the provenance, mode, energy, tectonic framework, sorting deviations, symmetry of distribution, peakedness etc. For this purpose, graphic mean-size (Mz) inclusive graphic standard deviation (σ_i), inclusive graphic skewness (Ski) and graphic kutrosis (K_G) were studied using the formulae e.g. P1, P5, P16, P25, P50, P75, P84 and P95 were counted the cumulative curves. (Tables - 2a,b,c & d ; 3a,b,c & d).

Univariant and Bivariant Plots :

The univariant plots of graphic mean size, inclusive standard graphic standard deviation, inclusive graphic skewness and graphic kutrosis were done (Figs. 4a,b,c & d) to know the mode, energy condition, sorting deviation, symmetry of distribution, peakedness etc. from all sandstone types.

In the present study, an attempt has also been made to study the interrelationship between the four size parameters using scatter plots. These bivariant scatter plots were made after Folk and Ward[7], Sahu[26], Friedman[4], Moiola and Weiser[17], Thomas *et. al*.[31] and Glaister and Nelson[9], (Figs. - 5a,b,c & d ; 6a,b,c & d ; 7a,b,c & d ; 8a,b,c & d ; 9a,b,c & d ; 10a,b,c & d).

C-M Pattern :

An important bivariant plot in sedimentary studies for analysis of sedimentary environments is C-M diagram. It is diagram meant to illustrate the sedimentary environments of deposition, with respect to size, range and energy level of transportation, also determining the process characteristic agents that the responsible for the formation of clastic deposit.

The C-M pattern of Passega[19,20] and Passega and Byramjee[21] are followed to study the characteristic of the depositional agents and environments of the present area. According to Pettijohn[23], a sedimentary rock is not only a product of specific provenance and transport history but is also a product of its environment of deposition. The process of deposition and texture of sediments are intimately associated with another.

Passega[19,20] had established that precise relationship exists between texture and mechanism of transport and these relations are tremendous helpful during geological investigation.

Clastic sedimentary rocks are formed by sediments transported in a variety of ways. Depending upon the grain size these are three distinct modes of sediment transport as follows - rolling, saltation and suspension. The coarser particles are transported by rolling, grain size of lower range are carried by jumping and sliding, while finest particles are considered to be product of graded suspension[20]. Suspension may be subdivided as - uniform or pelagic type. Tractive current and turbidity current are the two types of bottom currents which are capable of transporting sediments. Traction currents are capable of transporting sediments. Traction currents are capable of transporting their load either rolling or in suspension and turbidity current which is a rapid process, carries the entire load in suspension.

According to Passega[19] C-M pattern on a logarithmic diagram are characterized by depositional agent. In the present study the two parameters of grain size distribution of individual samples are considered for representations in C-M diagram. The two parameters used in these plots from grain size distribution are particularly significant and are closely related to transportation and deposition mechanism and as a consequence, the grain size images give fairly precise information of hydraulic condition.

In the present study, the data for C-M pattern diagrams taken from cumulative curves directly as suggested by Passega[19,20]. C-indicates value of one percentile and M indicates value of median (50%) percentile. Thus in the C-M diagram values were calculated and converted for the samples using the table compiled by Page[18]. The complete C-M pattern diagrams were dawn followed by Passega[19,20] and Passega and Byramjee [21] (Fig. 11a,b,c & d).

Log-probability plots :

The log-probability plots were proposed by Visher[32] to establish a relationship between grain size distribution and depositional processes. Later on, several workers such as Glaister and Nelson[9]. Amarlal and Pryor[1] and Moshrif (1980) used Visher's approach in the recognition of ancient depositional environments.

Approaches to use grain size to determines sedimentary environment have been made for years and a number of outstanding contribution have been forwarded in this regard. Each providing new insight into nature and significance on grain size distribution. Extension textural study of both recent and ancients sediments has provided the basis for a genetic interpretation of sand texture. e.g. rolling or surface creep, saltation and suspension.

Visher[32] related the shape of grain size curves to the mode of transport. He published typical curves from various modern as well as ancient environments. The main idea behind this analysis is the recognition of sub populations within as individual grain size distribution.

A plot of grain size curves on logprobability paper gives straight line curve segments, each segment denoting a single sub population. Each sub-population shows a long normal distribution generated by different modes of sediments transport and deposition and differs from other subpopulations in median and in standard distribution. Visher[32] believed that characteristics of individual grain size distribution curves do provide a basis for environment identification.

In case of transportation, true suspension is caused by turbulence when there is no vertical change in grain size. The size of a sediment particle that may be held in suspension is dependent upon turbulence. The break or truncation between suspension and bedded transport may be highly variable and reflect physical conditions at the time of deposition. Very little information is available regarding the maximum grain size which moves in saltation transport. Various hydrodynamic factors, such a current velocities, water depth and nature of the bed seem to be control the maximum size transported by saltation. Grains of 0.71-1.00 mm sizes which moves in saltation transport various hydrodynamics factors, such as current velocities, water depth, and nature of the bed seem to control the maximum size transported by saltation. Grains of 0.7-1.00 mm size move part of saltation process and are deposited due to the interaction between the traction current and graded suspension.

In the present study, the cumulative percentage obtained from the size analysis of the four sandstone samples were plotted on log-probability paper. For each sample straight lines were drawn through common points in order to obtain three (or four) segments, which were demarcated by the coarse truncation (C.T.) and fine truncation (F.T.) points. Percentage by weight of each segment was noted down from graph the total percentage of the curve thus obtained was taken as 100% and different sub-population were calculated from the percentages of respective segments (Fig. 12a,b,c & d).

Since sorting is directly proportional to the steepness of the curves of the log-probability plots[8], arbitrary angular limits of the curves were considered to evaluate classes like well sorted (>70°), moderately well sorted (70° - 60°), moderately sorted (60° - 50°) and poorly sorted (<50°).

Textural classification :

The textural classification for a clastic sediment is of considerable importance. Particle size is an important textural element because, it is related to the dynamic conditions of transportation and deposition. Terrigenous sedimentary rocks are characterised by extreme variations in composition and grain size; and within certain limits, any mineral composition can occur with any grain size[6].

The scheme attempted in the present case is after Folk[6]. In this triangular classification, the three apices of the triangle represent sand (100%), silt (100%) and clay (100%) respectively. The triangle is divided to give ten textural classes. Four categories are represented by tries on the triangle for a gravel free sediments, more than 90%, 50-90%, 10-50% and less than 10% sand. Next to the sand the silt to clay ratio is used. Boundaries at 2:1 and 1:2 silt to clay ratio subdivided each of the three tires of the triangle into three classes.

The triangular plots of the sand, silt and clay percentage of the four sandstone types are sand and silty sand (Fig. 13a,b,c & d).

Discussion and Interpretation

The character of sediments is determined both by the intensity of the formative processes operating upon it and the time till which these processes continue to act and it reflects the energy conditions of a depositing medium, the nature of the source rock, the distance it travelled, fluctuation of kinetic energy and the number of cycle it had undergone.

In the present case, four distributions are considered, namely purple coloured sandstone, green coloured sandstone, calcareous sandstone and coal bearing sandstone and efforts have been given to compare and contrast between these four from the inherent statistical characteristics and the depositional environment point of view.

Firstly, we consider the frequency distribution curves of the purple coloured sandstones which show bimodal nature with peaks around 2.5ϕ and 1ϕ. The sandstones indicate unimodality and reflect lower energy condition of roughly uniform nature but addition of finer particles or gradual lessening of the energy condition which subsequently leads to distortion of sorting has been observed. The calcareous sandstones show almost bimodal nature and the coal bearing sandstones show unimodal nature with a sharp peak around 2ϕ and also reflect lower energy condition. It has been observed that the bimodality in case of purple coloured sandstone and calcareous sandstones is due to addition of coarser material in the main mode and it is more in case of calcareous sandstone resulting distortion of sorting. This bimodality according to Sahu[26] may be result of extreme variation in the velocity of the depositing agent and/or the lack of certain particle size ranges in the source materials, thus indicating heterogenity of the deposits. The bimodal nature of the sediments also implies that the sediments were carried by different modes of transportation such as rolling or sliding, saltation and suspension processes. The characteristics that come out from the cumulative curves are also similar to that frequency curves but it can be said that the features comes out sharp in the former case than the later.

The graphic mean size of the sediments indicate average size of the sediments which is influenced by the source of supply, environment and the average kinetic energy (velocity) of the depositing agent[26]. Fine sand nature of the green coloured sandstones indicate less velocity variation of the medium and a lower energy range of the same. But in case of purple coloured sandstones and calcareous sandstones, extreme velocity variations in the nature of the depositing media, its graded nature or a source control affect may be cited. In case of both the sandstone types if the coarser clasts are considered, their deposition basically needs a higher energy level, but at the same time the amount of finer clasts which are in considerable amount contradicts the settings. A higher energy would not feasibly transport such finer modes. Hence an extremely graded situation may be cited for these two lithounits which might have been in the line of a turbid current. In case of coal bearing sandstones, it indicates equal velocity of the media.

The inclusive standard deviation of the studied samples show poor sorting in case of purple coloured sandstones, green coloured sandstones and moderately to poor sorting in case of calcareous sandstones. In case of green coloured sandstones it is probably due

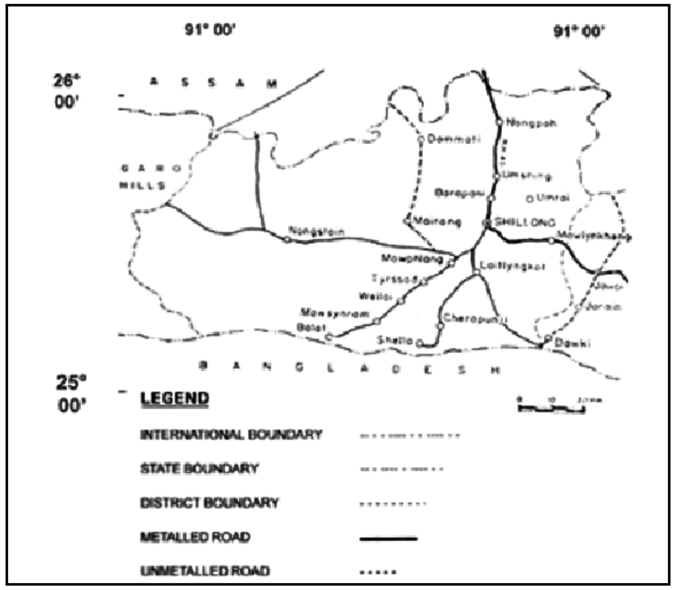
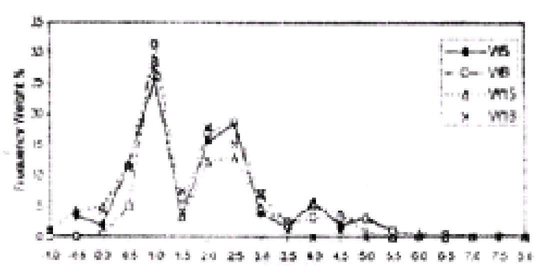
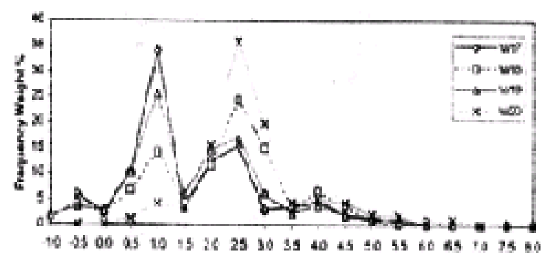


Fig. 1. Map of the Khasi Hills of Meghalaya showing the location of the Study Area



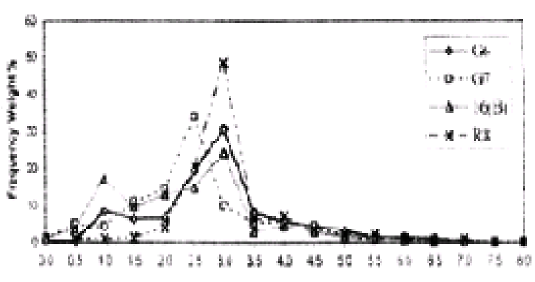
Grain Size (in phi)

Fig. 2a. Frequency curves of weight precentage of grain size data of Purple Sandstones



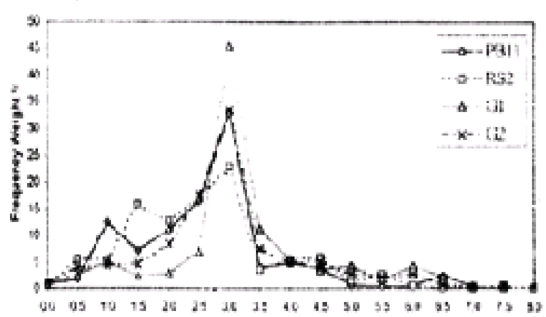
Grain Size (in phi)

Fig. 2c. Frequency curves of weight precentage of grain size data of Calcareous Sandstones



Grain Size (in phi)

Fig. 2b. Frequency curves of weight precentage of grain size data of Green Sandstones



Grain Size (in phi)

Fig. 2d. Frequency curves of weight precentage of grain size data of Coal bearing Sandstones

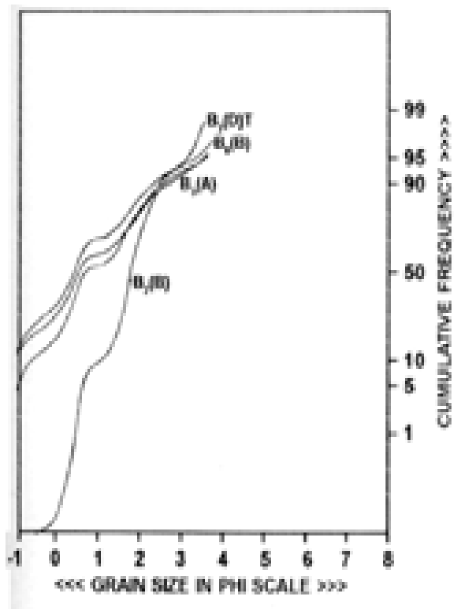


FIG. 3 a : CUMULATIVE FREQUENCY CURVES OF PURPLE SANDSTONE.

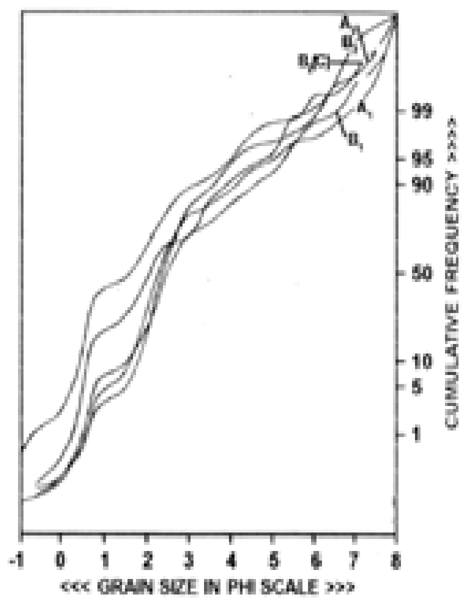


FIG. 3 c : CUMULATIVE FREQUENCY CURVES OF CALCAREOUS SANDSTONE.

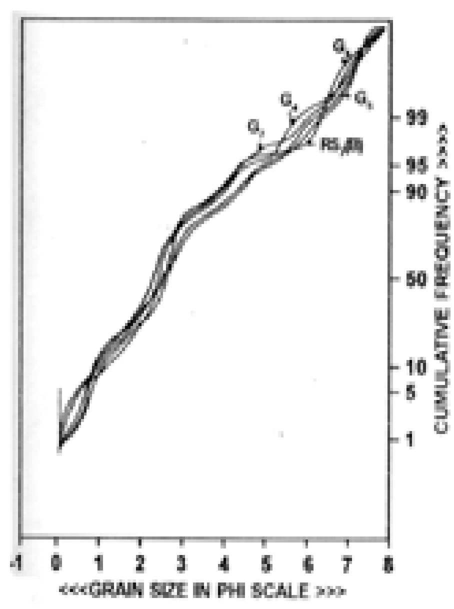


FIG. 3 b : CUMULATIVE FREQUENCY CURVES OF GREEN SANDSTONE

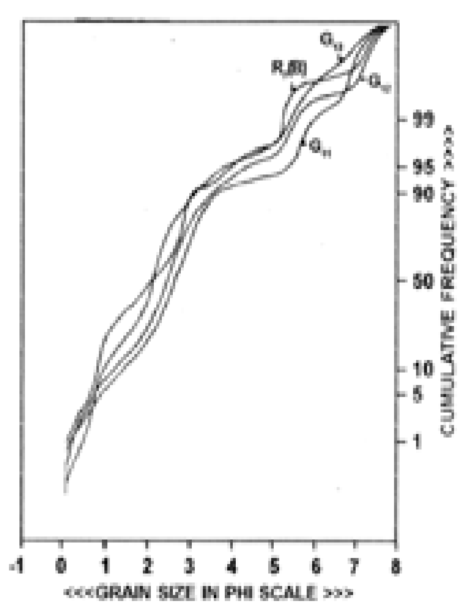


FIG. 3 d : CUMULATIVE FREQUENCY CURVES OF COAL BEARING SANDSTONE

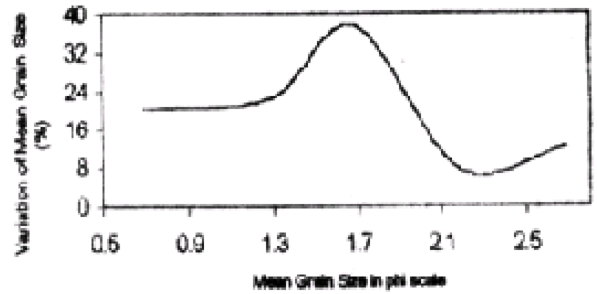


Fig. 4 a : Purple Sandstone

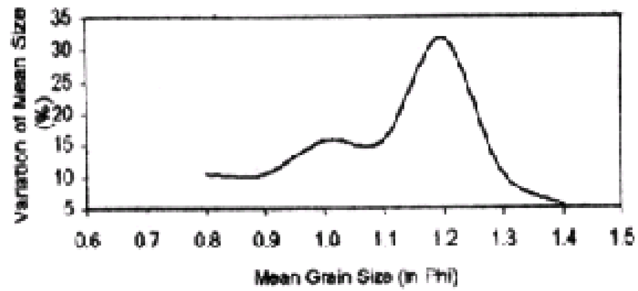


Fig. 4b : Green Sandstone

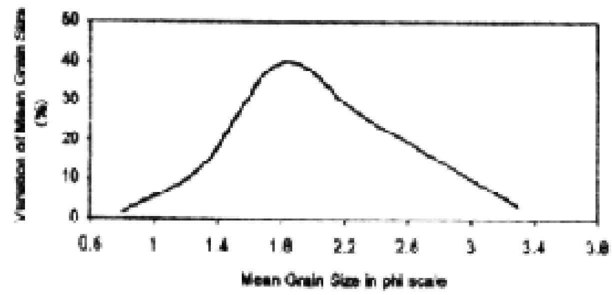


Fig. 4c : Calcareous Sandstone

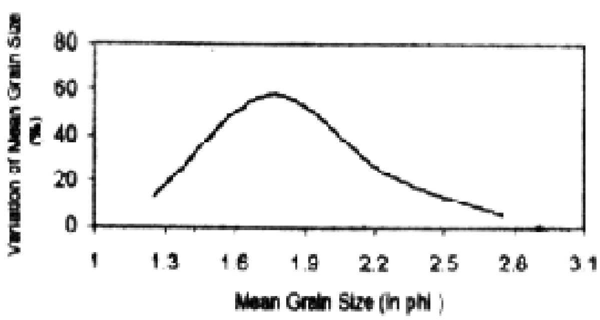


Fig. 4d : Coal bearing Sandstone

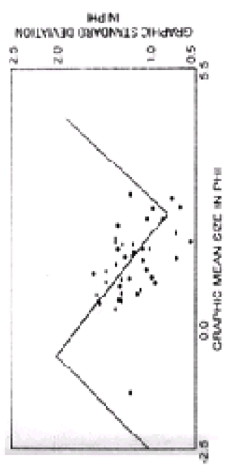


Fig. 5 a : Graphic Mean Size vs. Graphic Standard Deviation of the Purple Sandstone. (after Folk and Ward, 1957).

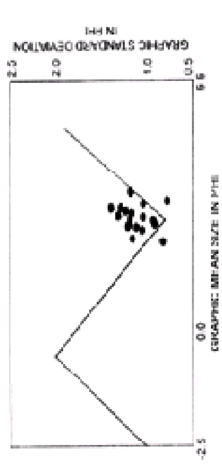


Fig. 5 b : Graphic Mean Size vs. Graphic Standard Deviation of the Green Sandstone. (after Folk and Ward, 1957).

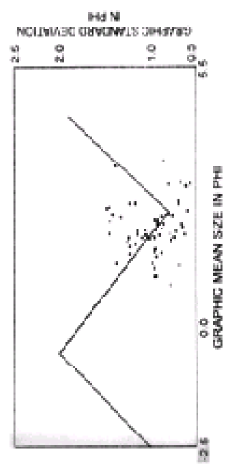


Fig. 5c : Graphic Mean Size vs. Graphic Standard Deviation of the Calcareous Sandstone. (after Folk and Ward, 1957).

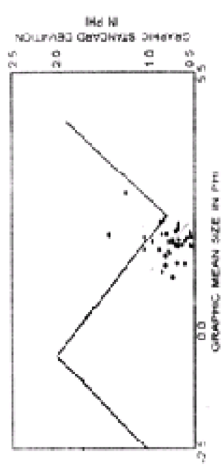


Fig. 5d : Graphic Mean Size vs. Graphic Standard Deviation of the Coal bearing Sandstone. (after Folk and Ward, 1957).

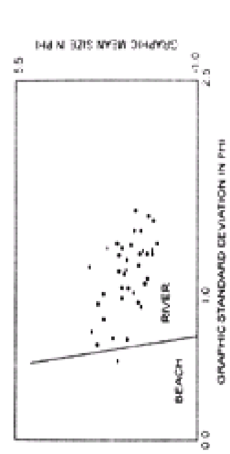


Fig. 6a : Graphic Mean Size vs. Graphic Standard Deviation of the Purple Sandstone. (after Moiola and Weiser, 1968).

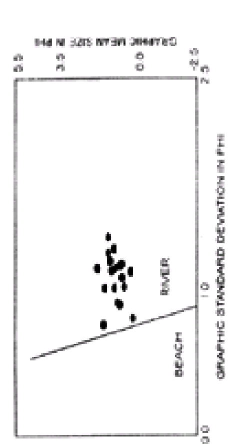


Fig. 6 b : Graphic Mean Size vs. Graphic Standard Deviation of the Green Sandstone. (after Moiola and Weiser, 1968).

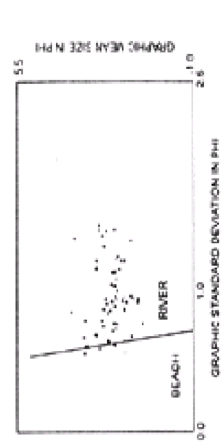


Fig. 6c : Graphic Mean Size vs. Graphic Standard Deviation of the Calcareous Sandstone. (after Moiola and Weiser, 1968).

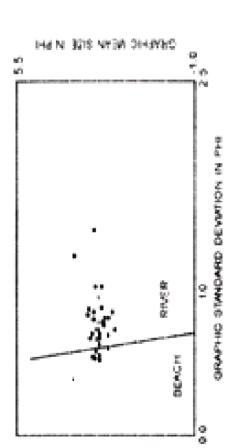


Fig. 6d : Graphic Mean Size vs. Graphic Standard Deviation of the Coal bearing Sandstone. (after Moiola and Weiser, 1968).

to addition of finer sizes of the particles available at the provenance and may also result due to gradual lessening of energy condition in the depositing agent but in case of purple coloured and calcareous sandstones poor sorting either clasts are later additives or, vice versa. In case of coal bearing sandstones the sorting is better than the other three types may result due to low energy fluctuation of the depositing agent. The sorting nature does not reflect a long transportation.

The inclusive graphic skewness values indicates that the sediments of all four types viz. purple coloured, green coloured, calcareous and coal bearing sandstones possess mainly near symmetrical to positive distribution. However, percentage of sample having negative skewness value is relatively high in calcareous sandstones and coal bearing sandstones. Friedman[3] found that the dune sands, irrespective of whether the dune sands-coastal, lake or river are generally positively skewed while beach sands are negatively skewed. Positive values are indicative of cool calm and sheltered environment[2,4]. According to Martins[14] positive

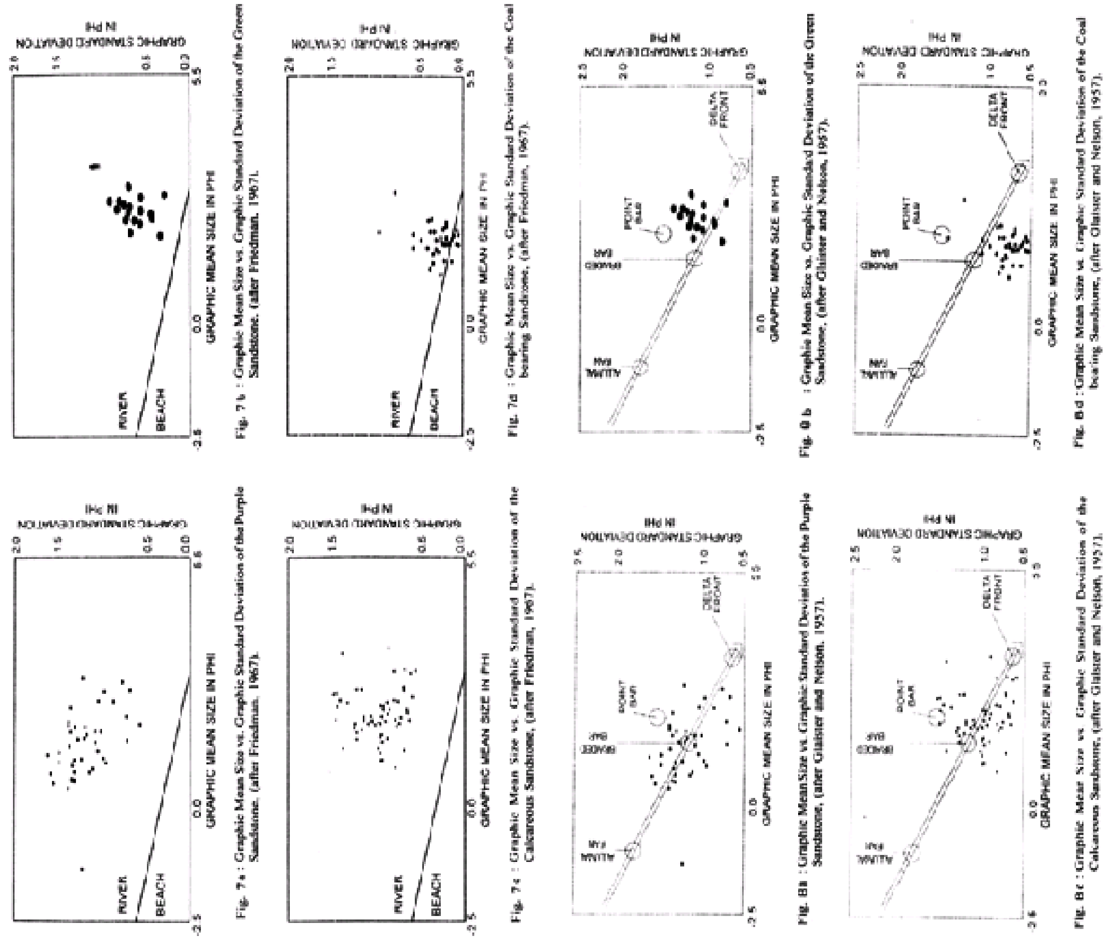


Fig. 7a : Graphic Mean Size vs. Graphic Standard Deviation of the Purple Sandstone. (after Friedman, 1967).

Fig. 7b : Graphic Mean Size vs. Graphic Standard Deviation of the Green Sandstone. (after Friedman, 1967).

Fig. 7c : Graphic Mean Size vs. Graphic Standard Deviation of the Calcareous Sandstone, (after Friedman, 1967).

Fig. 7d : Graphic Mean Size vs. Graphic Standard Deviation of the Coal bearing Sandstone, (after Friedman, 1967).

Fig. 8a : Graphic Mean Size vs. Graphic Standard Deviation of the Purple Sandstone, (after Glaister and Nelson, 1957).

Fig. 8b : Graphic Mean Size vs. Graphic Standard Deviation of the Green Sandstone, (after Glaister and Nelson, 1957).

Fig. 8c : Graphic Mean Size vs. Graphic Standard Deviation of the Calcareous Sandstone, (after Glaister and Nelson, 1957).

Fig. 8d : Graphic Mean Size vs. Graphic Standard Deviation of the Coal bearing Sandstone, (after Glaister and Nelson, 1957).

skewness results from unidirectional sediment transport. Higher percentage of negative skewness values probably indicate the fluctuation of energy condition is relatively less in case of calcaerous and coal bearing sandstones. Though the mixing of two populations occur but the finer fraction governs the status of skewness in this case by their dominance in the distribution.

The value of kutrosis for normal distribution is a vital parameter which points any abnormality in the distribution. In the present case, sorting of all the four distribution is found to better in the central portion compared to the tails which further indicate a constancy in the impact of the energy of the media irrespective of its level. Although energy fluctuations were there towards the tails in all the cases, the finer/coarser fraction could not disrupt the internal sorting of the distributions. Since the sediments are characteristically leptokurtic and positively skewed, the sediments are near the source of the sands because the

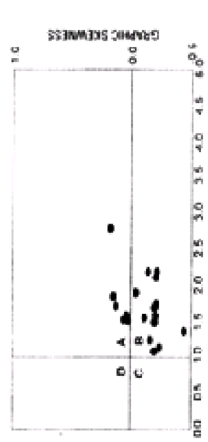


Fig. 9b : Graphic Kurtosis vs. Graphic Skewness of the Green Sandstone, (after Thomas et al., 1972).

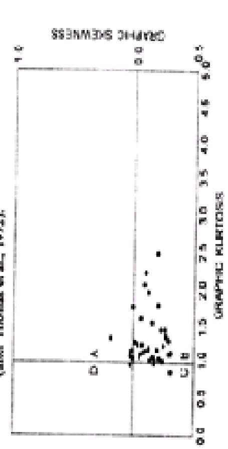


Fig. 9d : Graphic Kurtosis vs. Graphic Skewness of the Coal bearing Sandstone, (after Thomas et al., 1972).

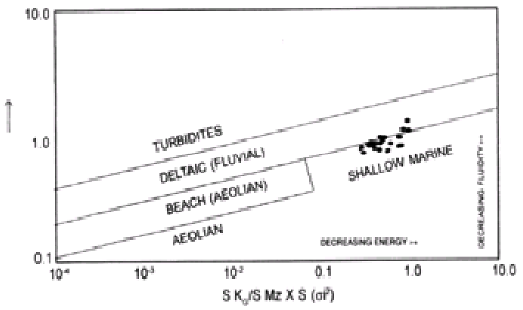


Fig.10b : BIVARIANT LOG-LOG PLOT BETWEEN $\sqrt{\sigma i^2}$ AND S K_G/S Mz X S (σi^2) (*after* SAHU, 1964) OF THE GREEN SANDSTONES.

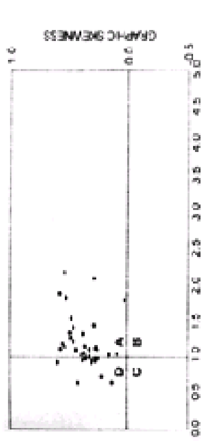


Fig. 9a : Graphic Kurtosis vs. Graphic Skewness of the Purple Sandstone, (after Thomas et al., 1972).

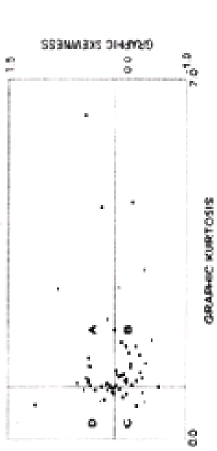


Fig. 9c : Graphic Kurtosis vs. Graphic Skewness of the Calcareous Sandstone, (after Thomas et al., 1972).

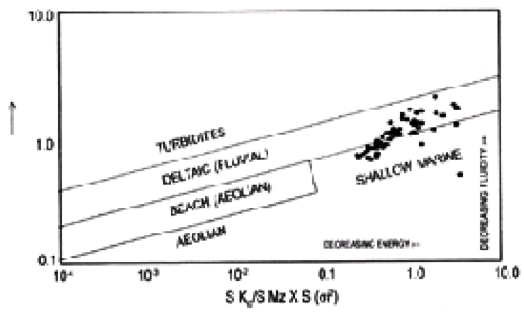


Fig.10c : BIVARIANT LOG-LOG PLOT BETWEEN $\sqrt{\sigma i^2}$ AND S K_G/S Mz X S (σi^2) (*after* SAHU, 1964) OF THE CALCAREOUS SANDSTONES.

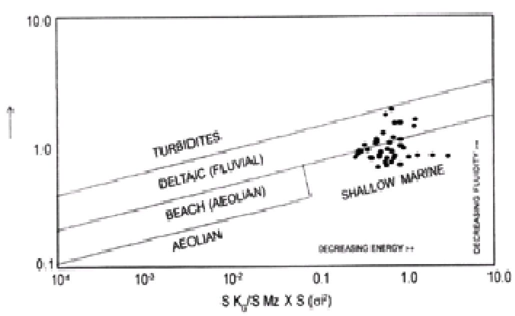


Fig.10a : BIVARIANT LOG-LOG PLOT BETWEEN $\sqrt{\sigma i^2}$ AND S K_G/S Mz X S (σi^2) (*after* SAHU, 1964) OF THE PURPLE SANDSTONES.

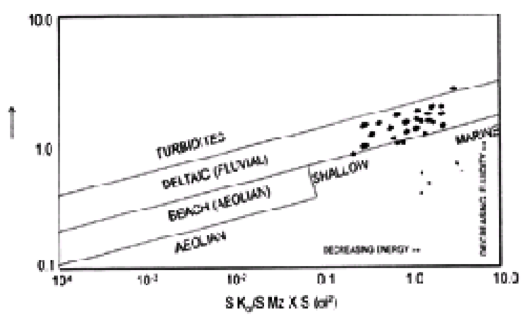


Fig.10d : BIVARIANT LOG-LOG PLOT BETWEEN $\sqrt{\sigma i^2}$ AND S K_G/S Mz X S (σi^2) (*after* SAHU, 1964) OF THE COAL BEARING SANDSTONES.

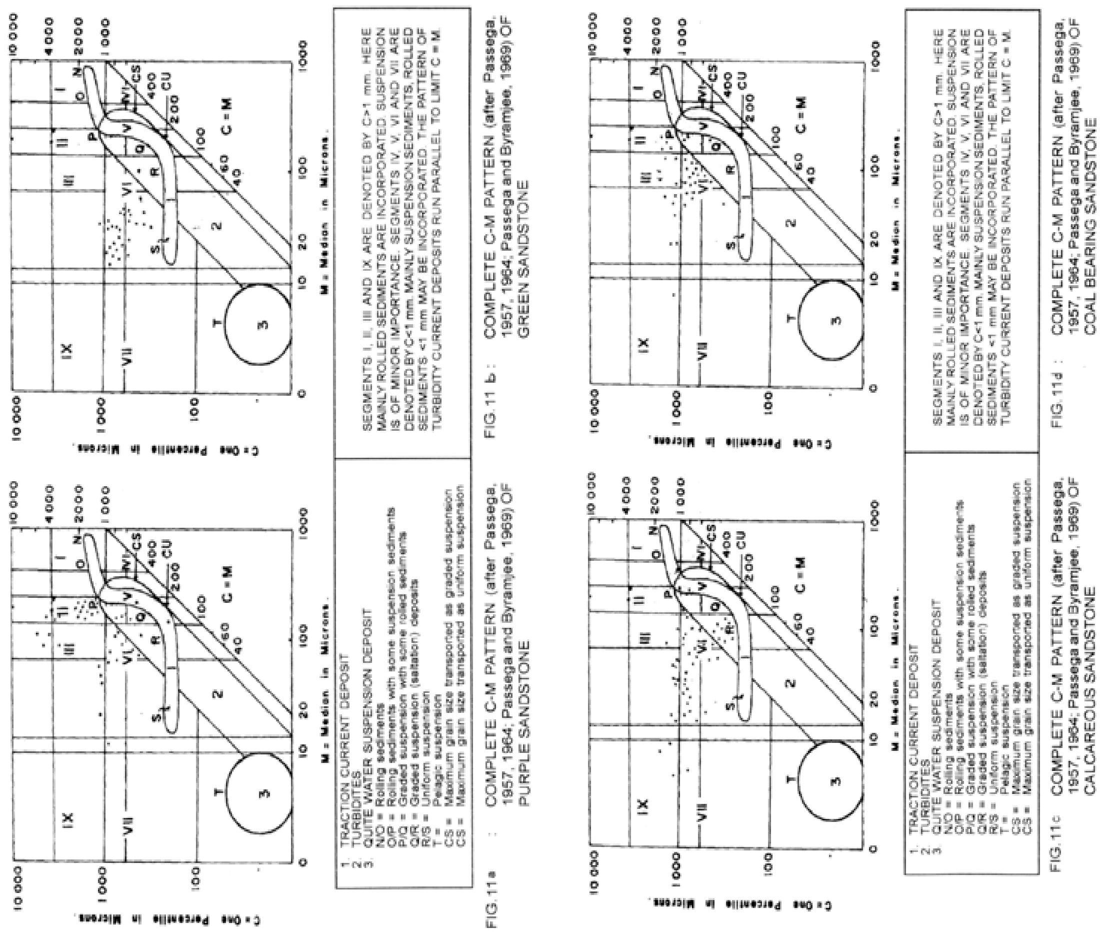


FIG. 11a : COMPLETE C-M PATTERN (after Passega, 1957, 1964; Passega and Byramjee, 1969) OF PURPLE SANDSTONE

FIG. 11 b : COMPLETE C-M PATTERN (after Passega, 1957, 1964; Passega and Byramjee, 1969) OF GREEN SANDSTONE

FIG. 11c : COMPLETE C-M PATTERN (after Passega, 1957, 1964; Passega and Byramjee, 1969) OF CALCAREOUS SANDSTONE

FIG. 11d : COMPLETE C-M PATTERN (after Passega, 1957, 1964; Passega and Byramjee, 1969) OF COAL BEARING SANDSTONE

sands are in excess[7].

Bivariant scatter plots were made following Folk and Ward[7], Friedman[3,4]; Moiola and Weiser[17]; Thomas *et al*. (1992) and Glaister and Nelson[9] for they give clue to mode of deposition and may be one of the criteria for identifying environment. All the statistically biased bivariant plots indicate following :

In case of purple coloured sandstones, addition of finer materials with the coarse results poor sorting and positive skewness. Moderate energy condition of the depositing media is seen and it is observed that the central portion is effected and sorting is also effected. The environmentally biased plots shows concentration in river mostly but few in beach field and a transitional environment can also be interpreted. Since concentration is around the braided bar zone so the sandstone is not yet matured where energy condition is a little high than the green coloured sandstone.

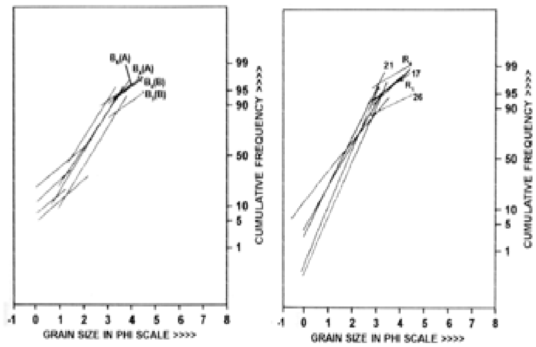


FIG.12 a : LOG PROBABILITY CURVES OF PURPLE SANDSTONE.

FIG.12 c : LOG PROBABILITY CURVES OF CALCAREOUS SANDSTONE.

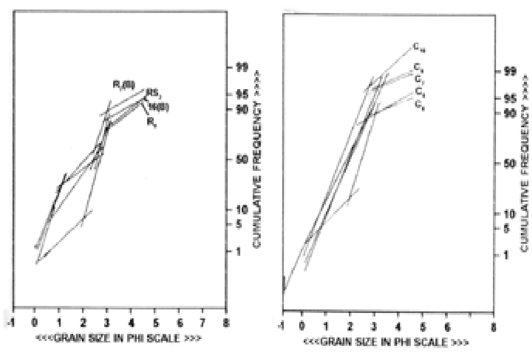


FIG.12 b : LOG PROBABILITY CURVES OF GREEN SANDSTONE

FIG.12 d : LOG PROBABILITY CURVES OF COAL BEARING SANDSTONE

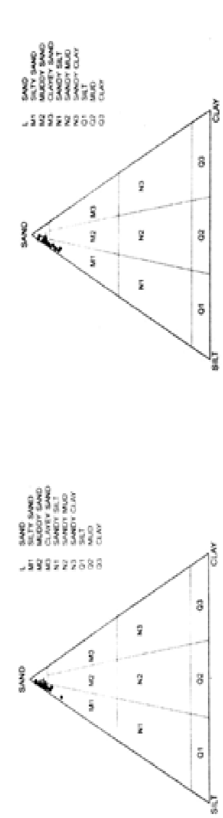


Fig. 13 a : Textural Classification of the Purple Sandstone, (after Folk, 1954).

Fig. 13 b : Textural Classification of the Green Sandstone, (after Folk, 1954).

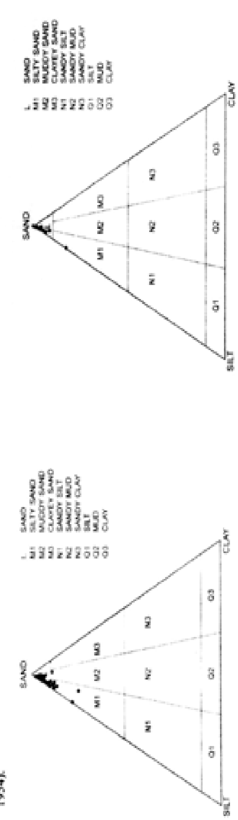


Fig. 13 c : Textural Classification of the Calcareous Sandstone, (after Folk, 1954).

Fig. 13 d : Textural Classification of the Coal bearing Sandstone, (after Folk, 1954).

In case of green coloured sandstones, addition of more finer materials is well reflected and results poor sorting and positive skeweness values. The energy level of the media responsible for deposition of the sandstone is moderately to low and is more uniform in the central portion and as a result sorting is better in the central portion. The environmentally biased plots show concentration of the points mainly in the river field but few shows in the beach field also can suggest a transitional environment. The sandstone is matured one.

In case of calcareous sandstones, presence of both coarser and finer materials result poor sorting and result both positive and negative skewness values. It has been observed, wide variation of energy condition for depositing media results poor sorting and the central portion is much effected. The environmentally biased plots shows concentration in both river and beach field suggests a transitional environment. Concentration around braided bar and deviation towards delta suggests decreasing of energy from higher side to lower.

In case of coal bearing sandstones, sorting is better than other three types and also mixing is good resulting symmetrical skewness

Table 2a. Tabulated Data of Percentile Values in Phi (Φ) and C-M Values (in microns) of the Purple Sandstone

Sample No.	P_1	P_5	P_{16}	P_{25}	P_{54}	P_{75}	P_{84}	P_{95}	C	M
W_{17}	-1.09	-0.65	0.46	0.62	0.96	2.20	2.50	4.06	2128.7	514.1
W_{18}	-1.02	-0.60	0.51	0.83	2.14	2.68	3.10	4.17	2027.9	226.9
W_{19}	-1.12	-0.52	0.42	0.63	1.56	2.30	2.63	4.13	2173.5	339.2
W_{20}	0.49	1.00	1.89	2.02	2.33	2.84	3.51	4.69	712.0	198.9
B_2(B)	0.59	0.75	1.52	1.75	2.05	2.34	2.53	3.80	664.3	241.5
B_2(D)T	-1.41	-0.98	-0.03	0.38	0.83	2.03	2.43	3.54	2657.4	562.5
B_3(A)	-2.41	-1.52	-0.86	-0.15	0.78	1.95	2.36	3.58	4314.7	582.4
B_3(B)	-1.49	-0.85	0.12	0.44	0.86	1.90	2.33	3.59	2808.9	551.0
B_4(A)	-2.21	-1.54	-1.10	-0.75	0.53	1.51	1.89	2.59	4626.8	692.6
B_4(B)	-1.78	-1.15	-0.14	0.36	0.81	1.70	1.96	2.63	3434.3	570.4
B_4(A)	-2.18	-1.52	-0.75	-0.03	0.61	1.69	2.04	2.65	4531.5	655.2
B_4(B)	-2.55	-1.69	-0.91	-0.46	0.52	1.65	2.06	3.56	5856.3	697.4
W_7	-1.35	-0.97	-0.54	0.13	0.76	1.85	2.19	3.14	2549.1	590.5
W_8	0.49	0.74	1.30	1.68	1.99	2.16	2.28	2.86	712.0	251.7
W9	-1.72	-1.49	-0.20	0.17	0.73	1.98	2.34	3.06	3294.4	602.9
W_{10}	-1.20	-0.72	0.23	0.43	0.78	1.85	2.02	2.59	2297.4	582.4
W_{11}	0.52	0.57	0.68	0.72	1.66	2.03	2.20	2.72	697.4	316.4
W_{12}	-1.34	-1.20	0.62	0.04	0.71	1.81	2.03	2.88	2531.5	611.3
W_{13}	-1.36	-1.21	-0.80	0.63	0.59	1.73	2.05	2.69	2566.9	664.3
W_{14}	-1.04	-0.87	-0.36	0.21	0.74	1.72	2.01	2.73	2056.2	597.7

Sample No.	P_1	P_5	P_{16}	P_{25}	P_{54}	P_{75}	P_{84}	P_{95}	C	M
A_1	0.75	1.32	1.87	2.08	2.38	2.93	3.65	5.17	5.94.6	192.1
A_1	0.79	1.70	2.06	2.19	2.50	2.86	3.22	4.23	578.3	176.8
B_1	0.61	0.89	1.93	2.17	2.57	3.51	4.09	5.30	655.2	168.4
B_2	0.39	0.61	0.89	1.60	2.19	3.29	3.57	5.04	763.1	219.2
B_2(C)	-0.49	0.43	0.64	0.73	1.78	2.33	2.70	4.09	1404.4	291.2
B_2	0.17	0.55	0.70	0.85	1.82	2.30	2.60	3.96	889.0	283.2
B_4(C)	0.68	0.88	1.79	1.93	2.13	2.57	3.13	4.32	624.2	228.5
B_5(A)	1.59	1.92	2.11	2.19	2.58	3.08	3.65	4.39	332.2	167.2
C_2(M)	-1.83	-1.31	0.09	0.52	1.10	2.25	2.58	4.33	3555.4	466.5
C_2(T)	-1.42	-1.05	-0.14	0.43	0.89	2.21	2.85	4.62	2675.9	539.6
D_1	-1.10	-0.59	0.52	0.73	2.00	2.67	3.00	4.36	2143.5	250.0
D_2	-1.00	-0.40	0.46	0.69	1.60	2.25	2.62	3.90	2000.0	329.9
W_1	-1.12	-0.57	0.51	0.74	2.05	2.56	2.85	4.14	2173.5	241.5
W_2	-1.10	-0.20	0.45	0.61	1.52	2.16	2.44	3.56	2143.5	348.7
W_3	-1.19	-1.11	-0.13	0.46	0.82	2.06	2.42	4.44	2281.5	566.4
W_4	-0.76	-0.09	0.61	0.75	1.63	2.30	2.67	4.19	1693.5	323.1
W_5	-1.12	-0.11	0.49	0.65	1.67	2.33	2.95	4.72	2173.5	314.3
W_6	0.14	0.51	0.70	0.80	1.79	2.44	2.91	4.67	907.5	289.2
W_{15}	-1.00	-0.62	0.30	0.55	1.02	2.55	2.84	4.22	2000.0	493.1
W_{16}	-1.01	-0.57	0.36	0.59	1.11	2.03	2.39	2.91	2013.9	463.3

Table 2b. Tabulated Data of Percentile Values in Phi (Φ) and C-M Values (in microns) of the Green Sandstone

Sample No.	P_1	P_5	P_{16}	P_{25}	P_{50}	P_{75}	P_{84}	P_{95}	C	M
PB_{11}	0.01	0.79	2.16	2.53	2.74	3.55	4.12	5.35	993.09	149.69
RS_2	0.13	0.38	1.19	1.48	2.33	2.84	3.49	4.46	613.83	198.88
G_1	0.05	0.67	2.34	2.60	2.79	3.34	4.01	5.69	965.94	144.59
G_2	0.06	0.51	1.64	2.01	2.61	3.06	3.85	5.33	959.26	163.80
G_3	0.08	0.49	1.53	1.95	2.54	3.27	4.03	5.54	946.06	171.94
RS_1(B)	0.15	0.66	1.09	1.65	2.49	2.76	3.07	4.31	901.25	178.01
G_4	0.02	0.62	1.62	1.96	2.45	3.17	3.84	5.05	986.23	183.01
G_5	0.05	0.49	1.36	1.83	2.50	2.84	3.56	4.64	965.94	176.78
G_6	1.80	0.78	1.47	1.93	2.59	3.04	3.73	4.92	287.17	166.09
G_7	0.01	0.42	1.25	1.69	2.32	2.80	3.28	4.40	993.09	200.27
16(B)	-0.19	0.55	0.86	1.18	2.19	2.76	3.00	4.63	1140.76	219.15
R_8	0.54	1.58	2.29	2.45	2.73	3.20	3.50	4.70	687.77	150.73
G_8	0.21	0.85	1.94	2.21	2.60	3.23	3.85	4.56	864.54	164.94
G_9	0.15	0.70	1.68	2.05	2.47	2.75	3.13	4.42	901.25	180.49
G_{10}	0.11	0.50	1.18	1.42	2.35	3.00	3.35	4.87	926.59	196.15
R_7(B)	0.03	0.83	1.06	1.99	2.65	2.78	3.87	4.87	979.42	159.32
G_{11}	0.07	0.80	1.75	2.10	2.56	2.95	3.19	5.34	952.64	169.58
G_{12}	0.15	0.68	1.57	1.95	2.38	2.79	3.08	4.24	901.25	192.11
G_{13}	0.37	0.66	1.20	1.55	2.02	2.35	2.64	3.71	773.78	246.56
G_{15}	0.11	0.54	1.14	1.53	2.40	2.89	3.50	4.48	926.59	189.46
G_{16}	0.07	0.53	1.43	1.87	2.55	3.13	3.74	5.18	952.64	170.81
G_{18}	0.01	0.51	1.62	2.03	2.62	3.20	3.85	5.83	993.09	162.68
G_{19}	0.12	0.68	1.44	2.06	2.71	3.03	3.55	5.50	920.28	152.80
G_{21}	0.05	0.62	1.72	2.13	2.75	3.30	3.95	5.72	965.94	148.71
G_{22}	0.39	0.76	1.49	1.90	2.30	3.05	3.71	5.10	763.15	203.16
G_{23}	0.12	0.69	1.39	1.85	2.50	2.96	3.59	4.80	920.28	176.72
G_{24}	0.06	0.62	1.05	1.56	2.48	2.92	3.33	4.78	959.26	172.92
G_{25}	0.09	0.58	1.12	1.65	2.43	2.85	3.99	5.55	939.53	185.91
G_{26}	0.22	0.67	1.38	1.84	2.56	3.11	3.59	5.00	858.65	169.58
G_{30}	0.17	0.66	1.35	1.86	2.54	3.03	3.36	5.20	889.01	171.94

Table 2c. Tabulated Data of Percentile Values in Phi (Φ) and C-M Values (in microns) of the Calcareous Sandstone

Sample No.	P_1	P_5	P_{16}	P_{25}	P_{54}	P_{75}	P_{84}	P_{95}	C	M
8(E)	-0.02	0.30	1.13	1.31	2.12	2.59	2.87	4.45	1014.0	230.0
11(A)	-0.20	0.05	0.46	1.11	2.23	2.70	2.92	4.20	1148.7	213.2
15(up)	-0.25	0.24	1.49	2.17	2.68	3.15	3.68	4.78	1189.2	156.0
8(A)	0.09	0.37	1.40	2.13	2.78	3.30	3.70	4.33	939.5	145.6
1(A)	-0.10	0.14	1.05	1.34	2.43	2.95	3.50	4.94	1071.8	185.6
R_4	0.48	1.13	1.54	2.11	2.59	2.82	3.04	4.06	717.0	166.1
8(C)	-0.17	0.12	1.39	2.15	2.73	2.50	3.71	4.08	1125.1	150.7
2	0.05	1.30	2.75	3.10	3.67	3.98	4.11	4.85	965.9	978.6
16(B)	-0.18	0.05	0.43	1.08	1.82	2.71	2.82	4.23	1132.9	283.2
19(C)	-0.03	0.24	1.00	1.25	2.03	2.57	2.75	4.31	1021.0	244.9
7	-0.02	0.11	0.69	1.31	2.32	2.74	2.86	4.12	1014.0	200.3
20	0.93	1.15	1.59	2.00	2.55	2.79	2.94	3.95	524.9	170.8
10	0.08	0.52	1.19	1.30	1.89	2.62	2.72	4.00	946.1	269.8
13	2.41	2.77	2.68	2.73	2.79	3.00	3.72	4.70	188.2	144.6
PB_1	1.46	2.20	2.46	2.53	2.72	3.28	3.73	4.22	363.5	151.8
PB_2	1.22	1.41	2.07	2.31	2.58	2.80	3.15	4.23	429.3	167.2
14	-0.12	0.05	0.31	0.60	1.42	2.75	2.89	3.94	1086.7	372.9
R_9	-0.30	0.05	0.54	1.17	1.93	2.50	2.78	4.10	1231.1	262.4
PB_9	0.12	0.33	0.92	1.13	1.38	2.01	2.40	3.75	920.2	384.2
PB_0	1.12	1.40	2.05	2.55	2.53	2.63	2.80	4.15	460.1	173.1
PB_9	0.45	1.06	1.35	1.44	1.97	2.34	2.53	3.28	732.1	255.3
R_4	1.20	1.83	2.55	2.66	2.81	3.56	3.79	4.28	435.3	142.6
19(A)	-0.18	0.02	0.22	0.40	1.17	1.90	2.36	2.94	1132.9	444.4
PB_2	-0.19	-0.04	0.18	0.29	0.76	1.53	2.27	2.90	1140.8	590.5
15(low)	-0.25	-0.13	0.08	0.17	1.14	1.40	2.02	2.93	1189.2	453.8
1(B)	-0.04	0.38	1.32	1.65	2.52	2.75	2.94	3.85	1028.5	174.3
25	-0.03	0.46	1.27	1.50	2.32	2.73	3.00	3.80	1021.0	200.3
6	0.24	0.78	1.20	1.45	2.12	2.42	2.57	3.78	846.8	230.0
9(A)	-0.15	0.05	0.56	1.14	2.27	2.73	2.80	3.62	1109.6	207.3
10(B)	0.30	1.28	1.53	2.00	2.36	2.55	2.70	3.72	812.3	194.3
R1	-0.14	0.11	0.73	1.16	1.60	2.40	2.61	3.34	1101.9	329.9
17	0.20	0.63	1.19	1.28	1.86	2.43	2.59	3.23	870.5	275.5
23	0.09	0.40	1.12	1.32	2.15	2.77	2.82	3.84	939.5	225.3
21	0.30	1.12	1.44	1.62	2.28	2.53	2.66	3.42	812.3	205.9
11(B)	-0.09	0.13	1.17	1.55	2.32	2.64	2.77	3.30	1064.4	200.3
PB10	-0.13	0.29	1.33	1.95	2.52	2.67	2.72	3.68	1094.3	174.3
3	0.08	0.45	1.30	1.41	1.98	2.61	2.74	2.89	946.1	253.5
R4	-0.12	0.10	0.72	1.00	1.56	2.32	2.49	3.65	1086.7	339.2
24(A)	-0.54	0.19	0.80	1.35	2.45	2.73	2.82	4.22	1454.0	183.0
16(A)	-0.23	0.32	0.72	0.90	1.29	1.88	2.45	3.68	1172.8	409.0
9(B)	-0.50	0.57	1.54	2.23	2.65	2.70	2.83	4.36	1414.2	159.3
9(C)	-0.67	-0.18	0.50	0.71	2.05	2.75	2.84	4.30	1591.1	241.5
4	-1.23	-0.82	0.28	0.69	2.73	2.81	2.88	4.55	2345.7	150.7
11(C)	0.06	1.451	2.60	2.71	2.81	2.95	3.62	5.15	959.3	142.6
5(A)	-0.05	0.57	1.18	1.90	2.65	2.83	2.98	3.94	1035.5	159.3
5(B)	-0.49	0.73	2.20	2.73	3.58	3.98	4.41	6.29	1404.4	083.5
12	0.04	0.56	0.85	1.07	2.01	2.50	2.61	2.81	971.8	248.3
18(A)	0.34	0.63	0.88	1.17	2.05	2.59	2.69	4.04	790.0	241.5
18(C)	-0.95	-0.42	0.91	2.20	2.81	3.35	3.82	4.65	1931.9	142.6
22	-0.52	0.65	0.86	1.25	2.57	2.90	3.73	5.26	1434.0	168.4
24	0.78	1.20	2.35	2.46	2.62	2.78	3.02	4.75	582.4	162.7
26	-0.85	-0.50	0.24	0.46	1.65	2.46	2.77	4.48	1802.3	848.1
27	-1.02	-0.36	0.86	1.17	2.48	3.03	3.42	5.03	2027.9	179.2
28(A)	-0.59	0.13	1.24	1.85	2.58	2.90	3.77	5.56	1505.2	167.2
28(B)	0.04	0.43	0.75	0.89	1.18	1.61	2.02	2.89	971.8	441.4
29	-0.53	-0.22	0.23	0.46	0.89	2.36	1.58	2.76	1443.9	539.6
30	0.16	0.78	1.10	1.25	1.73	2.52	2.88	4.36	895.0	301.5
31	0.02	0.26	0.47	0.63	1.25	2.06	2.34	3.66	986.2	420.4
32	0.20	0.61	0.88	1.22	1.96	2.78	2.81	4.05	870.5	257.0
18(B)	-0.63	0.15	0.66	0.85	2.32	2.74	2.83	3.52	1547.6	260.3

Table 2d. Tabulated Data of Percentile Values in Phi (Φ) and C-M Values (in microns) of the Coal bearing Sandstone

Sample No.	P_1	P_5	P_{16}	P_{25}	P_{50}	P_{75}	P_{84}	P_{95}	C	M
C_{31}	-0.52	-0.07	0.40	0.65	1.24	1.73	2.05	3.00	1434.0	423.40
C_{32}	-0.69	0.02	0.46	0.68	1.13	1.55	1.77	2.72	1613.30	456.90
C_{33}	-0.81	0.54	1.31	1.46	1.74	2.10	2.28	2.70	1753.20	299.40
C_{34}	0.36	1.09	1.35	1.42	1.63	2.01	2.29	3.04	779.20	323.10
C_{35}	-0.75	0.03	0.56	0.86	1.38	1.94	2.14	2.80	1681.80	384.20
C_{36}	-0.63	0.25	0.87	1.14	1.68	2.19	2.41	2.93	1547.60	312.10
C_{37}	-0.07	0.71	1.12	1.30	1.69	2.22	2.50	3.14	1049.8	309.90
C_{38}	0.00	0.12	1.41	1.65	1.82	2.25	2.53	3.16	1000.0	283.20
C_{39}	-0.33	0.62	1.26	1.50	1.93	2.31	2.50	2.99	1257.0	262.40
C_{40}	-0.60	0.25	0.90	1.16	1.61	2.08	2.31	3.00	1515.70	327.60
C_{41}	-0.82	0.06	0.82	1.14	1.69	2.26	2.57	3.06	1765.40	309.90
C_{42}	-0.57	0.09	1.18	1.45	1.92	2.28	2.46	2.98	1484.50	264.30
C_{43}	-0.42	0.17	0.83	1.06	1.51	2.07	2.39	3.01	1337.90	351.10
C_{44}	-0.45	1.02	1.54	1.69	2.11	2.42	2.59	2.93	1366.00	231.60
C_{45}	-0.13	0.45	1.02	1.42	2.01	2.36	2.56	3.10	1094.3	248.30
C_{46}	0.01	0.54	1.22	1.47	1.99	2.32	2.50	2.89	993.10	251.70
C_{47}	-0.15	0.70	1.58	1.82	2.21	2.54	2.73	3.29	1035.50	216.61
C_{48}	-0.01	1.15	1.66	1.83	2.20	2.63	2.88	3.63	993.10	217.60
C_{49}	-0.02	0.87	1.21	1.38	1.73	2.15	2.42	3.11	1014.00	301.50

Sample No.	P_1	P_5	P_{16}	P_{25}	P_{54}	P_{75}	P_{84}	P_{95}	C	M
C_{31}	-0.52	-0.07	0.40	0.65	1.24	1.73	2.05	3.00	1434.0	423.40
C_{32}	-0.69	0.02	0.46	0.68	1.13	1.55	1.77	2.72	1613.30	456.90
C_{33}	-0.81	0.54	1.31	1.46	1.74	2.10	2.28	2.70	1753.20	299.40
C_{34}	0.36	1.09	1.35	1.42	1.63	2.01	2.29	3.04	779.20	323.10
C_{35}	-0.75	0.03	0.56	0.86	1.38	1.94	2.14	2.80	1681.80	384.20
C_{36}	-0.63	0.25	0.87	1.14	1.68	2.19	2.41	2.93	1547.60	312.10
C_{37}	-0.07	0.71	1.12	1.30	1.69	2.22	2.50	3.14	1049.8	309.90
C_{38}	0.00	0.12	1.41	1.65	1.82	2.25	2.53	3.16	1000.0	283.20
C_{39}	-0.33	0.62	1.26	1.50	1.93	2.31	2.50	2.99	1257.0	262.40
C_{40}	-0.60	0.25	0.90	1.16	1.61	2.08	2.31	3.00	1515.70	327.60
C_{41}	-0.82	0.06	0.82	1.4	1.69	2.26	2.57	3.06	1765.40	309.90
C_{42}	-0.57	0.09	1.18	1.45	1.92	2.28	2.46	2.98	1484.50	264.30
C_{43}	-0.42	0.17	0.83	1.06	1.51	2.07	2.39	3.01	1337.90	351.10
C_{44}	-0.45	1.02	1.54	1.69	2.11	2.42	2.59	2.93	1366.00	231.60
C_{45}	-0.13	0.45	1.02	1.42	2.01	2.36	2.56	3.10	1094.3	248.30
C_{46}	0.01	0.54	1.22	1.47	1.99	2.32	2.50	2.89	993.10	251.70
C_{47}	-0.15	0.70	1.58	1.82	2.21	2.54	2.73	3.29	1035.50	216.61
C_{48}	-0.01	1.15	1.66	1.83	2.20	2.63	2.88	3.63	993.10	217.60
C_{49}	-0.02	0.87	1.21	1.38	1.73	2.15	2.42	3.11	1014.00	301.50

Table 3a. Statistical Parameters of the Grain Size Analysis of the Purple Sandstone

Sample No.	M_s	Grain Size	σ_1	Standard Deviation	Sk_i	Skewness	KG	Kurtosis	X*	Y
A_1	2.63	Fine Sand	1.028	Poorly Sorted	0.438	Very Finely Skewed	1.900	Very Leptokurtic	0.68	0.98
A_3	2.59	Fine Sand	0.670	Moderately Well Sorted	0.304	Very Finely Skewed	1.547	Very Leptokurtic	1.33	1.22
B_1	2.86	Fine Sand	1.210	Poorly Sorted	0.322	Very Finely Skewed	1.350	Leptokurtic	0.32	0.91
B_2	2.22	Medium Sand	1.340	Poorly Sorted	0.158	Finely Skewed	1.070	Mesokurtic	0.27	0.86
B_2(C)	1.71	Medium Sand	1.069	Poorly Sorted	0.077	Nearly Symmetrical	0.937	Mesokurtic	0.48	0.97
B_3	1.71	Medium Sand	0.999	Moderately Sorted	0.038	Nearly Symmetrical	0.963	Mesokurtic	0.57	1.00
B_4(C)	2.35	Fine Sand	0.856	Moderately Sorted	0.382	Very Finely Skewed	2.202	Very Leptokurtic	1.28	1.08
B_5(A)	2.78	Fine Sand	0.759	Moderately Sorted	0.427	Very Finely Skewed	1.137	Leptokurtic	0.71	1.15
C_2(M)	1.25	Medium Sand	1.470	Poorly Sorted	0.167	Finely Skewed	1.336	Leptokurtic	0.49	0.82
C_2(T)	1.20	Coarse Sand	1.606	Poorly Sorted	0.313	Very Finely Skewed	1.283	Leptokurtic	0.42	0.79
D_1	1.84	Medium Sand	1.370	Poorly Sorted	-0.120	Coarsely Skewed	1.045	Mesokurtic	0.30	0.85
D_2	1.56	Medium Sand	1.190	Poorly Sorted	0.007	Nearly Symmetrical	1.129	Leptokurtic	0.51	0.92
W_1	1.80	Medium Sand	1.290	Poorly Sorted	-0.210	Coarsely Skewed	1.060	Mesokurtic	0.35	0.88
W_2	1.47	Medium Sand	1.067	Poorly Sorted	0.004	Nearly Symmetrical	0.994	Mesokurtic	0.60	0.97
W_3	1.03	Coarse Sand	1.470	Poorly Sorted	0.279	Finely Skewed	1.420	Leptokurtic	0.64	0.82
W_4	1.64	Medium Sand	1.163	Poorly Sorted	0.103	Finely Skewed	1.130	Leptokurtic	0.51	0.93
W_5	1.70	Medium Sand	1.340	Poorly Sorted	0.150	Finely Skewed	1.170	Leptokurtic	0.38	0.86
W_6	1.80	Medium Sand	1.180	Poorly Sorted	0.190	Finely Skewed	1.039	Mesokurtic	0.41	0.92
W_{15}	1.38	Medium Sand	1.360	Poorly Sorted	0.377	Very Finely Skewed	1.166	Leptokurtic	0.46	0.86
W_{16}	1.28	Medium Sand	1.034	Poorly Sorted	0.147	Finely Skewed	0.990	Mesokurtic	0.72	0.98
W_{17}	-1.30	Medium Sand	1.210	Poorly Sorted	0.408	Very Finely Skewed	1.206	Leptokurtic	-0.63	0.91

Table 3b. Statistical Parameters of the Grain Size Analysis of the Green Sandstone

Sample No.	M_s	Grain Size	Σ_1	Standard Deviation	Sk_i	Skewness	KG	Kurtosis	X*	Y
PB_{11}	3.016	Fine Sand	1.173	Poorly Sorted	0.287	Positive Skewed	1.832	Very Leptokurtic	0.85	0.44
RS_2	2.336	Fine Sand	1.193	Poorly Sorted	0.026	Nearly Symmetrical	1.229	Leptokurtic	0.36	0.84
G_1	3.046	Fine Sand	1.178	Poorly Sorted	0.308	Very Positive Skewed	2.780	Very Leptokurtic	0.65	0.85
G_2	2.700	Fine Sand	1.282	Poorly Sorted	0.125	Positive Skewed	1.880	Very Leptokurtic	0.42	0.78
G_3	2.700	Fine Sand	1.390	Poorly Sorted	0.190	Positive Skewed	1.567	Very Leptokurtic	0.32	0.72
RS_1(B)	2.210	Medium Sand	1.048	Poorly Sorted	-0.208	Negative Skewed	1.347	Leptokurtic	0.55	0.95
G_4	2.630	Fine Sand	1.226	Poorly Sorted	0.213	Positive Skewed	1.500	Very Leptokurtic	0.37	0.82
G_5	2.470	Fine Sand	1.178	Poorly Sorted	-0.0025	Nearly Symmetrical	1.680	Very Leptokurtic	0.49	0.85
G_6	2.590	Fine Sand	1.190	Poorly Sorted	0.067	Nearly Symmetrical	1.528	Very Leptokurtic	0.42	0.84
G_7	2.280	Fine Sand	1.110	Poorly Sorted	-0.0044	Nearly Symmetrical	1.469	Leptokurtic	0.52	0.90
16(B)	2.016	Fine Sand	1.153	Poorly Sorted	-0.0023	Nearly Symmetrical	1.058	Mesokurtic	0.39	0.87
R_8	2.840	Fine Sand	0.775	Moderately Sorted	0.267	Positive Skewed	1.704	Very Leptokurtic	0.99	1.29
G_8	2.790	Fine Sand	1.039	Poorly Sorted	0.182	Positive Skewed	1.490	Leptokurtic	0.49	0.96
G_9	2.426	Fine Sand	0.926	Moderately Sorted	-0.0206	Nearly Symmetrical	2.177	Very Leptokurtic	1.02	1.08
G_{10}	2.290	Fine Sand	1.204	Poorly Sorted	-0.037	Nearly Symmetrical	1.333	Leptokurtic	0.40	0.83
R_7(B)	2.530	Fine Sand	1.310	Poorly Sorted	-0.012	Nearly Symmetrical	2.095	Very Leptokurtic	0.48	0.76
G_{11}	2.500	Fine Sand	1.040	Poorly Sorted	0.040	Nearly Symmetrical	2.180	Very Leptokurtic	0.81	0.96
G_{12}	2.340	Fine Sand	0.910	Moderately Sorted	-0.013	Nearly Symmetrical	1.730	Very Leptokurtic	0.89	1.10
G_{13}	1.950	Medium Sand	0.820	Moderately Sorted	-0.010	Nearly Symmetrical	1.560	Very Leptokurtic	1.19	1.22
G_{15}	2.346	Fine Sand	1.186	Poorly Sorted	-0.042	Nearly Symmetrical	1.187	Leptokurtic	0.36	0.84
G_{16}	2.573	Fine Sand	1.283	Poorly Sorted	0.085	Nearly Symmetrical	1.513	Very Leptokurtic	0.36	0.77
G_{18}	2.696	Fine Sand	1.364	Poorly Sorted	0.155	Positive Skewed	1.867	Very Leptokurtic	0.37	0.73
G_{19}	2.566	Fine Sand	1.258	Poorly Sorted	-0.023	Nearly Symmetrical	2.036	Very Leptokurtic	0.50	0.79
G_{21}	2.806	Fine Sand	1.331	Poorly Sorted	0.120	Positive Skewed	1.786	Very Leptokurtic	0.36	0.75
G_{22}	2.500	Fine Sand	1.213	Poorly Sorted	0.280	Positive Skewed	1.547	Very Leptokurtic	0.42	0.82
G_{23}	2.493	Fine Sand	1.173	Poorly Sorted	0.055	Nearly Symmetrical	1.518	Very Leptokurtic	0.44	0.85
G_{24}	2.286	Fine Sand	1.200	Poorly Sorted	-0.074	Nearly Symmetrical	1.254	Leptokurtic	0.38	0.83
G_{25}	2.513	Fine Sand	1.471	Poorly Sorted	0.172	Positive Skewed	1.697	Very Leptokurtic	0.31	0.68
G_{26}	2.510	Fine Sand	1.209	Poorly Sorted	0.030	Nearly Symmetrical	1.398	Leptokurtic	0.38	0.83
G_{30}	2.416	Fine Sand	1.191	Poorly Sorted	0.046	Nearly Symmetrical	1.591	Very Leptokurtic	0.46	0.84

Table 3c. Statistical Parameters of the Grain Size Analysis of the Calcareous Sandstone

Sample No.	M_s	Grain Size	σ_1	Standard Deviation	Sk_i	Skewness	KG	Kurtosis	X*	Y
19(B)	2.19	Medium Sand	0.660	Moderately Well Sorted	-0.152	Coarsely Skewed	1.810	Very Leptokurtic	1.230	1.910
R_1	1.64	Medium Sand	0.950	Moderately Sorted	0.075	Nearly Symmetrical	1.060	Mesokurtic	1.030	0.720
17	1.88	Medium Sand	0.744	Moderately Sorted	0.480	Nearly Symmetrical	0.927	Mesokurtic	1.160	0.890
23	2.03	Medium Sand	0.946	Moderately Sorted	0.115	Coarsely Skewed	0.972	Mesokurtic	1.030	0.530
21	2.127	Medium Sand	0.653	Moderately Well Sorted	0.193	Coarsely Skewed	1.036	Mesokurtic	1.240	1.140
11(B)	2.087	Medium Sand	0.880	Moderately Sorted	0.409	Very Coarsely Skewed	1.192	Leptokurtic	1.070	0.740
PB_{10}	2.190	Medium Sand	0.561	Moderately Sorted	-0.514	Very Coarsely Skewed	1.929	Very Leptokurtic	1.080	1.190
3	2.007	Medium Sand	0.729	Moderately Sorted	-0.099	Nearly Symmetrical	0.833	Platikurtic	1.170	0.780
R_8	1.590	Medium Sand	0.970	Moderately Sorted	0.120	Finely Symmetrical	1.100	Mesokurtic	1.020	0.740
24(A)	2.020	Medium Sand	1.150	Poorly Sorted	-0.270	Very Coarsely Skewed	1.190	Leptokurtic	0.930	0.450
16(A)	1.480	Medium Sand	0.941	Moderately Sorted	0.381	Very Finely Skewed	1.410	Leptokurtic	1.030	1.080
9(B)	2.340	Medium Sand	0.890	Moderately Sorted	-0.400	Very Coarsely Skewed	3.300	Extremely Leptokurtic	1.060	1.780
9(C)	1.790	Medium Sand	1.260	Poorly Sorted	-0.160	Coarsely Skewed	0.900	Mesokurtic	0.890	0.320
4	1.960	Medium Sand	1.460	Poorly Sorted	-0.600	V. Coarsely Skewed	1.030	Mesokurtic	0.850	0.250
11(C)	3.010	Fine Sand	0.810	Moderately Sorted	0.420	V. Finely Skewed	6.310	Extremely Leptokurtic	1.110	3.200
5(A)	2.270	Fine Sand	0.960	Moderately Sorted	-0.430	V. Coarsely Skewed	1.48	Leptokurtic	1.020	0.710
5(B)	3.390	Very Fine Sand	1.390	Poorly Sorted	-0.137	Coarsely Skewed	1.820	Very Leptokurtic	0.850	0.280
12	1.820	Medium Sand	0.780	Moderately Sorted	-0.304	V. Coarsely Skewed	0.640	Very Leptokurtic	1.130	0.580
18(A)	1.870	Medium Sand	0.960	Moderately Sorted	-0.060	Nearly Symmetrical	0.980	Mesokurtic	1.020	0.570
18(C)	2.510	Medium Sand	1.490	Poorly Sorted	-0.290	Coarsely Skewed	1.810	Very Leptokurtic	0.820	0.520
22	2.38	Fine Sand	1.416	Poorly Sorted	-0.120	Nearly Symmetrical	1.140	Leptokurtic	0.840	0.240
24	2.66	Fine Sand	0.700	Moderately Well Sorted	0.190	Finely Skewed	4.540	Extremely Leptokurtic	1.200	3.490
26	1.35	Medium Sand	1.380	Poorly Sorted	0.360	Very Finely Skewed	1.050	Mesokurtic	0.850	0.410
27	2.250	Fine Sand	1.450	Poorly Sorted	-0.159	Coarsely Skewed	1.180	Leptokurtic	0.830	0.250
28(A)	2.530	Fine Sand	1.455	Poorly Sorted	0.019	Nearly Symmetrical	2.119	Very Leptokurtic	0.830	0.4000
28(B)	1.310	Medium Sand	0.690	Moderately Well Sorted	0.350	Very Finely Skewed	1.400	Leptokurtic	1.200	2.260
29	0.900	Coarse Sand	0.789	Moderately Sorted	1.130	Finely Skewed	0.660	Very Platikurtic	1.130	1.180
30	1.900	Medium Sand	0.980	Moderately Sorted	0.380	Very Finely Skewed	1.150	Leptokurtic	1.010	0.630
31	1.350	Medium Sand	0.982	Moderately Sorted	0.290	Finely Skewed	0.970	Mesokurtic	1.010	0.750
32	1.850	Medium Sand	1.020	Poorly Sorted	0.030	Nearly Symmetrical	0.904	Mesokurtic	0.990	0.470
18(B)	1.936	Medium Sand	1.053	Poorly Sorted	-0.41	Very Coarsely Skewed	0.731	Platikurtic	0.970	0.340

Table 3d. Statistical Parameters of the Grain Size Analysis of the Coal bearing Sandstone

Sample No.	M_s	Grain Size	σ_1	Standard Deviation	Sk_i	Skewness	KG	Kurtosis	X*	Y
C_1	1.403	Medium Sand	0.610	Moderately Well Sorted	0.048	Nearly Symmetrical	1.179	Leptokurtic	2.26	1.64
C_2	1.79	Medium Sand	0.711	Moderately Well Sorted	0.088	Nearly Symmetrical	1.616	Very Leptokurtic	1.79	1.39
C_3	2.90	Fine Sand	1.260	Poorly Sorted	0.209	Positively Skewed	0.991	Mesokurtic	0.20	0.79
C_4	1.86	Medium Sand	0.957	Moderately Sorted	0.109	Positively Skewed	1.097	Mesokurtic	0.64	1.04
C_5	1.99	Medium Sand	1.046	Poorly Sorted	0.178	Positively Skewed	1.787	Very Leptokurtic	0.82	0.96
C_6	2.29	Fine Sand	0.877	Moderately Sorted	-0.090	Nearly Symmetrical	2.510	Very Leptokurtic	1.43	1.14
C_7	1.88	Medium Sand	0.612	Moderately Well Sorted	-0.140	Coarsely Skewed	1.039	Mesokurtic	1.55	1.63
C_8	1.69	Medium Sand	1.050		0.163	Positively Skewed	1.310	Leptokurtic	0.70	0.95
C_9	1.91	Medium Sand	0.679	Moderately Well Sorted	-0.052	Nearly Symmetrical	1.010	Mesokurtic	1.15	1.47
C_{10}	1.41	Medium Sand	0.703	Moderately Well Sorted	0.210	Positively Skewed	1.110	Leptokurtic	1.58	1.43
C_{11}	2.98	Fine Sand	0.390	Well Sorted	-0.180	Coarsely Skewed	1.370	Leptokurtic	3.00	2.58
C_{12}	2.33	Fine Sand	0.837	Moderately Sorted	-0.180	Coarsely Skewed	1.470	Leptokurtic	0.90	1.19
C_{15}	1.98	Medium Sand	0.538	Moderately Well Sorted	-0.160	Coarsely Skewed	1.260	Leptokurtic	2.21	1.86
C_{19}	2.11	Medium Sand	0.706	Moderately Well Sorted	-0.103	Coarsely Skewed	1.810	Very Leptokurtic	1.31	1.42
C_{25}	2.05	Medium Sand	0.856	Moderately Sorted	-0.207	Coarsely Skewed	1.325	Leptokurtic	0.88	1.17
C_{26}	2.03	Medium Sand	1.441	Poorly Sorted	-0.227	Coarsely Skewed	0.904	Mesokurtic	0.21	0.69
C_{27}	1.77	Medium Sand	0.675	Moderately Well Sorted	0.014	Nearly Symmetrical	1.209	Leptokurtic	1.49	1.47
C_{29}	1.96	Medium Sand	0.588	Moderately Well Sorted	-0.031	Nearly Symmetrical	1.564	Very Leptokurtic	2.33	1.69
C_{30}	2.05	Medium Sand	0.808	Moderately I Sorted	0.042	Nearly Symmetrical	2.263	Very Leptokurtic	1.69	1.24

values. The energy level of the media responsible for deposition is low and more uniform in the central portion results better sorting. Low energy condition is also supported by the concentration around delta front. A transitional environment is also well reflected by the environmentally biased plots.

Multivariant plots have been considered to be superior than the bivariant plots as they consider all the size parameters in a combination, and hence their sensitivity is much higher. In the present case, the same following Sahu[26] however shows deltaic fluvial and shallow marine *i.e.*, a transitional environment for purple coloured, green coloured and calcareous sandstones and a deltaic fluvial environment for coal bearing sandstones.

The textural classification indicates both 'sand' and 'silty sand' type for purple coloured, green coloured and calcareous sandstones. They are not pure sand but a mixture of sand and silt. Thus this bimodal nature reflects poor sorting of the sediments and reflected variation in kinetic energy and also indicative of diversity in size range of source materials and derivation of sediments from two or more sources. The coal bearing sandstones are mostly 'sand' type indicating better sorting than the other three types of sandstones.

The C-M Pattern diagram indicates influence of beach and river tractive current environment by basic C-M diagram which is supported by the complete C-M Pattern shows the influence of rolling with suspension is the mechanism for the development of purple coloured sandstones. In case of green coloured sandstones influence of beach and turbidity environment and influence of suspension with rolling are the mechanism leading to the generation of this sandstone. In case of calcareous sandstones wide distribution of the plots indicate of the influence of more than one environment setting (*i.e.*, turbidity, river tractive, beach) and is supported by the plots of complete C-M diagram which shows the dominance of both rolling and graded suspension. In case of coal bearing sandstones influence of turbidity current is more and it is supported by the complete C-M diagram. So this type of sandstone shows better sorting than the other three types. The log-probability curves of the four types of sandstones indicate presence of all three sub populations saltation, suspension and rolling populations with two inflection points. In all the four types of sandstone sorting is good in saltation population and poor in suspension and rolling population. The shape of the curves reflects type II distributions indicating the character of continental to shallow marine.

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