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Textural Characteristics and Depositional Environment of Olistostromal Sandstone of Ukhrul, Manipur

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***Abstract*-- Grain size analysis of olistostromal sandstone samples associated with Nagaland-Manipur Ophiolite Belt in and around Ukhrul Town which lies between 24º25´-25º10´N latitude and 94º10´-94º30´E longitudes has been carried out to find out textural characteristics and depositional environment. These sandstones are highly variable in size and shape; texturally and mineralogical immature. Most of these sandstones have unimodal distribution. Median values vary between 0.3ϕ-3.75ϕ and mean size varies from 0.86ϕ-3.81ϕ. They are positively, negatively as well as nearly symmetrically skewed. Bivariate and multivariate analysis indicates diversity in the depositional environment. However marine and turbidity is the most dominant environment.**

***Keyword*-- Grain size analysis, depositional environment, Nagaland-Manipur Ophiolite Belt, olistostromal sandstone.**

I. INTRODUCTION

Sediment texture refers to the shape, size and three-dimensional arrangement of the particles that make up sediment or a sedimentary rock. Particle size distribution in a clastic sedimentary rock is sensitive to the physical changes of the transporting media and the depositional basin. Systematic presentation and analysis of grain size data provide basis for the reconstruction of sedimentary processes including identification of depositional environment.

Since nineties sedimentologists are using grain size data for the interpretation of sedimentary processes. An earliest effort for the systematic analysis of grain size data was made by Udden (1898, 1914), Wentworth (1922).

Oseen (1913) and Rubey (1933) developed equations to extend the limit of settling velocity techniques to measure the size of coarse silt. Trask (1932), Krumbein (1934), Krumbein and Pettijohn (1938), Otto (1939), Twenhofel and Tyler (1941), Inman (1952), Spencer (1952) and others advocated the application of statistical techniques to characterise the frequency distribution of clastic sediments. Application of granulometric analysis in hydrodynamics and environmental interpretation was emphasised by Hjulstorm (1939), Doeglas (1946), Inman (1949), Bagnold (1946, 1956), Passega (1957, 1964), Folk and Ward (1957), Mason and Folk (1958), Harris (1958a), Roger and Head (1961), Moss (1963), Sahu (1964), Krinsley and Funnell (1965), Klovan (1966), Friedman (1967), Koldijk (1968), Chappell (1967), Moiola and Weiser (1968), Hails and Hoyt (1969), Visher (1969), Buller and Mc Manus (1972), Qidwai and Cassyap (1978), Swan et al. (1978); and others. Recent works by different researchers, viz. Mahendar (1996), Joshep et al (1997), Hanamgond and Chavadi (1998) Majumdar and Ganapati (1998), Murkute (2001a, 2001b) Raman and Reddy (2001), Bhat et al (2002), Rao et al (2005), Burhanuddin (2007), Rabindra et al (2008), Ashok and Rupesh (2009a, 2009b), Ashok and Neloy Khare (2009) and others amply testify the significance of the grain size study. Present paper is an attempt to investigate the grain size distribution, statistical parameters and their interelationship of olistostromal sandstones associated with Nagaland - Manipur Ophiolite belt in and around Ukhrul, Manipur which lies between 24º25´-25º10´N latitude and 94 º 10´-94 º 30´E longitudes (Fig. 1).

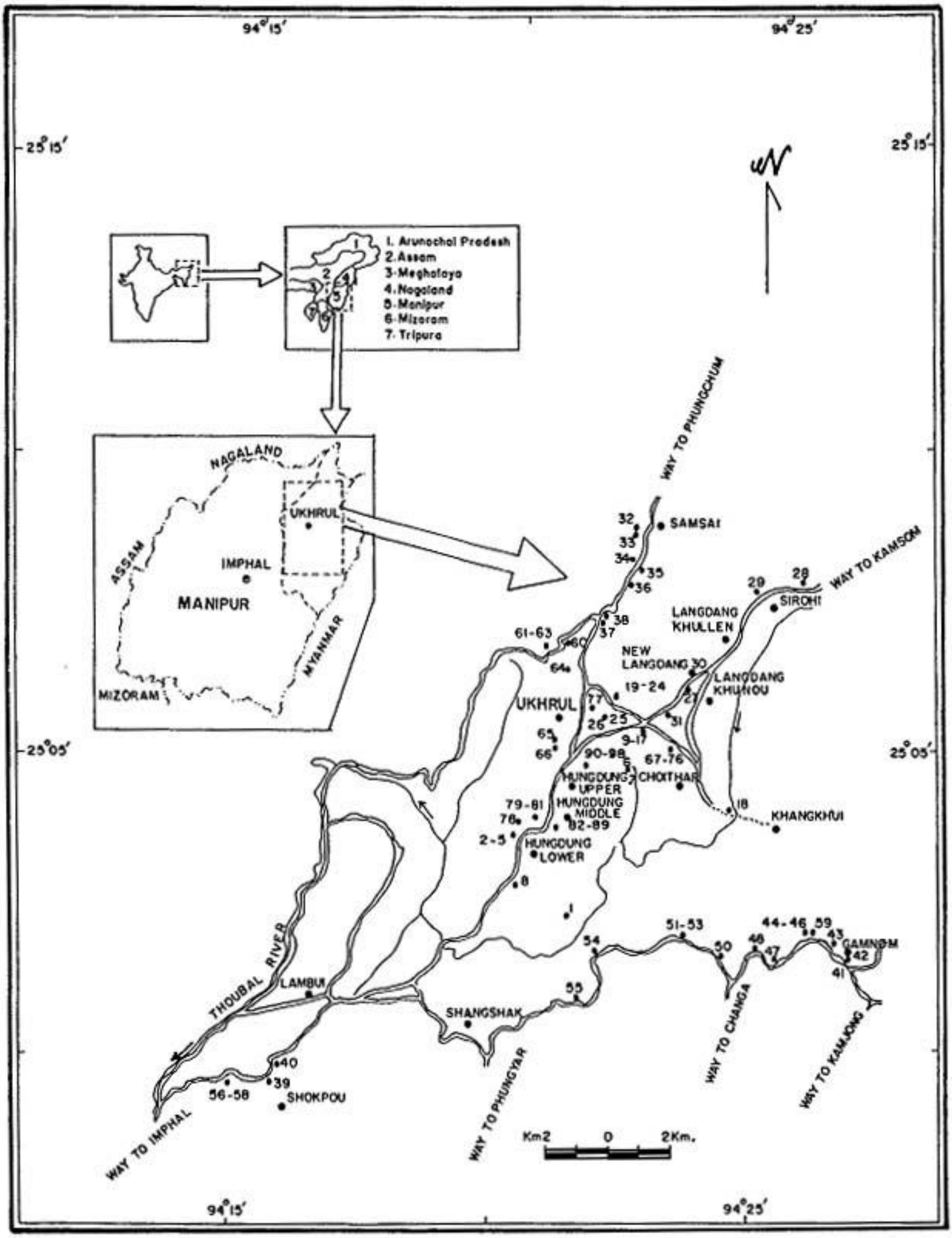

Figure 1: Location map of the study area.

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II. Geology Of The Area

Oldham (1883) was the pioneer worker who gave a geological picture of Manipur State. Evan (1932) described the rocks occurring in the east of Imphal valley as mainly Disangs and those in west as Barails. Vandemmlen (1949) gave first tectonic picture of the north-eastern region of India. Dayal and Duara (1963) and Daura and Debadhikari (1968) carried out systematic geological mapping in several parts of the state. Hill ranges of Manipur and the adjoining states belong to Indo-Myanmar Ranges (IMR) and have been correlated with the Alpine Orogeny (Brunnschweiler 1966). These ranges pass northward into a belt of NW-SE trending structures linking them with the Himalayan-Indonesian Orogenic Belt (Khin and Win, 1969). In this belt, dismembered Late Mesozoic-Eocene Ophiolitic rocks are juxtaposed towards west against a folded sequence of shelf-turbiditic Palaeogene Sediments (Acharyya 1991). In and around Ukhrul metamorphic complex is considered as the oldest formation. It is exposed in the eastern most part of the area and lies unconformably under the N-S to NNE-SSE trending arcuate belt of Ophiolite-Melange Suite. Chaotic assemblages of basic and ultrabasic intrusive and extrusive of peridotite, gabbro, serpentinite, chert, limestone, shale, sandstone, conglomerate etc. form this ophiolite-melange suite.

Disangs and Barails lies above this suite. A generalised geological succession is presented in Table 1. In the study area, arenaceous exotic blocks occur at Ukhrul town, Hungdung, Samsai, Gamnom, Shangching and Khangkhui. In Middle Hungdung the exotic sandstone blocks are earthy in colour, thickly bedded, coarse grained and highly friable. At places these sandstones are overlain by conglomerate. In lower Hungdung they are hard and compact, light-brown in colour. At places thin bands of clay occurs along the bedding planes of the sandstone blocks. A huge body of exotic sandstone is exposed along the road section, near Hungdung cement bus stop. They are thickly bedded medium to coarse grained, very hard and compact, highly jointed and fractured. Samples collected from the border area between Hungdung and Ukhrul town is quartzitic in nature, dark grey in colour, very hard compact and moderately coarse grained. Samples from Khangkhui, Samsai are course grained, reddish colour, hard and compact. Sample from Gamnom is medium grained, very hard and compact whitish in colour having calcareous cement. Dimension of these exotic bodies range from 150m×100m to about 500m×200m.

Table 1
Geological succession around Ukhrul, Manipur (Modified after Mitra *et al.*, 1986)

Age	Unit	Lithology
Upper Eocene to Oligocene	Barail Group	Massive sandstone, alternation of shale and sandstone, and bedded structure.
- - - - - - - Gradational contact - - - - - - -		
Cretaceous to Upper Eocene	Disang Group	Fine grained grey coloured sandstones, dark grey, splintery shales interbedded with sandy-shale and siltstone in upper part. Argillaceous grey shales interbedded with mudstones and minor amount of siltstone and argillaceous sandstone in lower part.
- - - - - - - Tectonic contact - - - - - - -		
Upper Cretaceous to Mid- Eocene	Ophiolite-Melange Suite	Basic and ultrabasic intrusive and extrusive of peridotite, gabbro, serpentinite, chert, limestone, shale, sandstone, gritstone conglomerate, etc.
~~ Unconformity ~~~~~~~		
Pre-Mesozoic or older	Metamorphic Complex	Low to medium grade metamorphic rocks of various compositions, phyllitic schists, quartzites, micaceous-quartzite, quartz-chlorite-mica schists, and marble, etc.
~~ Unconformity ~~~~~~		
Basement Complex Unseen		

III. Methodology

Depending upon the nature, grain size from seventy two sandstone samples collected from different locations are measured thin section, sieving and pipetting techniques.

Most of these samples area are hard and compact, as a result thin section method is adopted on sixty-six samples for detail grain size analysis, while only six samples which are friable and easily disaggregated undergo sieving and pipetting method.

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Grain size data of 72 samples are presented graphically in the form of histograms, frequency curves and cumulative frequency curves. The inflection points and percentage of sediment loads in different modes of transportation were determined from cumulative frequency curves prepared after sieving and pipetting data. Various statistical parameters were computed using the formulae of Folk and Ward (1957), Folk (1980), Reinick and Singh (1980), Pettijohn (1984), Lindholmn (1987) and Sengupta (1996). The depositional processes and environments of the olistostromal sandstones associated with Nagaland-Manipur Ophiolite belt in and around Ukhrul, Manipur were found out from different bivariate plots of Moiola and Weiser (1968) Friedman (1961), Stewart (1958), and Passega (1957, 1964) and discriminant function proposed by Sahu (1964).

IV. Result And Discussion

Histograms: Analysis of histogram reveals that only few samples show bimodal distribution while others show uni-modality. Bimodality may be due to the mixing of the sediments from different provenance or sub-populations. In most of the cases modal class lies in 1-2ф (0.25 to 0.50mm).

Frequency curves: Frequency curves show positive, negative as well as nearly symmetrical distribution. Such highly variable nature of the frequency curves indicates fluctuation in the energy condition at the time of deposition of these sediments.

Cumulative curves: Cumulative curves plotted on the probability ordinate scale do not form continuous straight line (Fig. 2). Excepting few samples curves plotted for the present data show two, three or more straight line segments. Each segment has different slope that indicates the presence of more than one population of grains. Each of this population is related to different mode of transportation-traction, saltation and suspension (Doeglas, 1946; Visher, 1969 and Moss, 1962 and 1963). Cumulative curves of the present study indicate that saltation is the major process of transport though traction and suspension have also played some role during deposition of these sediments. Slope angles of line segments in saltation mode vary from 16° to 55°, indicating poor sorting (Qidwai and Cassyap, 1978). In most of the curves, the breaks are not sharp enough, which suggest the mixing of detritus carried by currents with different energy (Sharda and Verma 1977) or they may be the products of different provenance. The percentages of materials carried in different modes of transportations and inflection points for those data derived from sieving and pippeting were presented in Table 2 and 3. Loads on traction, saltation and suspension show wide variation. This indicates the highly variability in competency of the transporting agency.

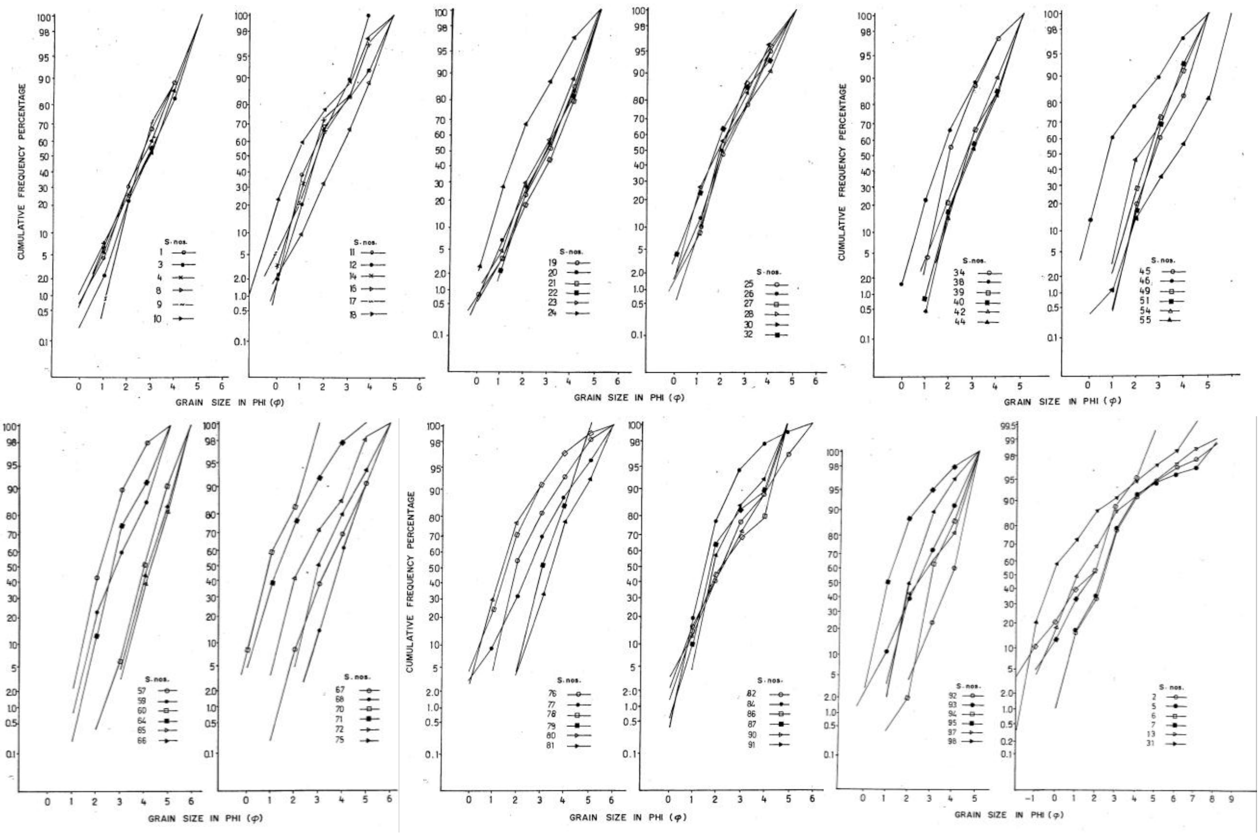

Figure 2: Arithmetic probability curves.

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Table 2
Percentage Of Sediments Carried In Different Modes Of Transportation.

Sample no	Traction	Saltation	Suspension
2	15.1000	75.9673	7.7076
5	16.2044	77.8826	4.7644
6	56.3300	38.8196	4.2220
7	52.2500	43.4746	3.8850
13	48.8044	38.0936	7.6568
31	20.7367	76.2064	2.6768

Table 3
Number And Position Of Inflection Points In Cumulative Frequency Curves

Sample no	Number of inflection points	Position of inflection points in phi-scale
2	03	1, 2, 3
5	04	0, 1, 2, 3
6	03	0, 3, 5
7	03	1, 2, 3
13	02	0, 2
31	05	-1, 0, 2, 5, 6

Statistical parameters: The data presented in histograms, frequency curves and cumulative frequency curves have pictoral value and gives crude general idea about the sediment. To get detail comparisons various statistical methods have been suggested out of which graphical method is relatively simple and widely used. In the present study graphical method is used. Graphic measures like median, mean, standard deviation, skewness and kurtosis indicate high variability (Table 4). The median value ranges from 0.3ф to 3.75ф. Mean size of the study are ranges between 0.86ф and 3.81ф. This highly variation in grain size indicates the variation in the kinetic energy at the time of deposition. In case of skewness, out of total samples 31 are fine skewed, 23 are very fine skewed and 14 are nearly symmetrical and only four samples are coarse skewed. Fine tail distribution is more common that suggest high kinetic energy of the depositional basin. Standard deviation values range from 0.34 to 1.75 and suggest that except one sample which is well sorted sandstone, others were deposited in the fluvial environment (Friedman, 1961).

In order to discriminate the depositional environments of the arenecuous rocks, the bivariate scatter plots as suggested by Moiola and Weiser (1968) and Friedman (1961) have been used in the present analysis. Bivariate plots of the study area indicate that most of the samples were deposited in the fluvial environment whereas few are in near shore environment. Mean size vs standard deviation (Fig.3A) and skewness vs mean size plots (Fig. 3C) reveals that few samples were deposited in beach and rest in the fluvial environment. Skewness vs standard deviation plot (Fig.3B) after Moiola and Weiser (1968) indicates that only five samples falls in the field of beach while others within the field of fluvial environment.

Skewness vs standard deviation plot (Fig.3D) after Friedman (1961) indicates that only one sample falls in the field of beach environment and others within the field of fluvial environment. Analysis of the C-M diagram (Fig 3E) reveals that these arenacous rocks were deposited under diverse conditions by different process.

The statistical parameters are also used to discriminate the depositional environment following discriminant function analysis after Sahu (1964).

The following classifications are used in order to distinguish the different depositional environments:

$Y_{aeolian:beach}$ > -2.7411---beach environment
$Y_{aeolian:beach}$ < -2.7411---aeolian environment
$Y_{beach:marine}$ < 65.3650---beach environment
$Y_{beach:marine}$ > 65.3650---shallow marine environment
$Y_{marine:fluvial}$ < -7.4190---fluvial environment
$Y_{marine:fluvial}$ > -7.4190---shallow marine environment
$Y_{fluvial:turbidite}$ < 9.8433---turbidity environment
$Y_{fluvial:turbidite}$ > 9.8433---fluvial environment

Analysis of data generated from the discriminant functions (table 5) reveals that arenaceous rocks of the study were deposited under diverse conditions. Maximum numbers of samples show combine effect of fluvial, beach, marine, and turbidity environment. However marine and turbidity is the most dominant environment.

Table 4
Size Parameters And Characteristics Of Olistostromal SandstoneS

Sample No	Median	Mean	Standard Deviation	Skewness	Kurtosis
1	1.89	2.22	0.89	0.29	0.89
2	2.3	2.26	1.36	0.07	1.63
3	2.35	2.52	0.95	-0.17	0.87
4	2.27	2.43	1.08	-0.01	0.97
5	2.3	2.21	1.45	0.13	2.45
6	1.8	1.3	1.74	-0.17	0.83
7	1.6	1.6	1.38	-0.2	1.04
8	2.19	2.41	1	0.05	0.87
9	2.1	2.42	0.76	0.26	1.09
10	0.89	1.41	1.1	0.36	1.01
11	2.35	2.45	1	-0.15	0.85
12	1.12	1.47	0.83	0.13	1.06
13	1.05	1.25	1.64	0.28	1.25
14	0.81	1.38	1.04	0.34	1.12
16	2.1	2.26	1.06	-0.04	0.96
17	1.15	1.55	1.14	0.19	1.13
18	0.3	0.87	1.15	0.31	0.96
19	2.42	2.52	0.92	-0.03	0.9
20	2.35	2.45	1.03	-0.06	0.95
21	2.65	2.7	0.95	-0.1	0.84
22	2.35	2.54	0.95	0.05	0.8
23	2.35	2.43	0.97	-0.17	0.87
24	1.04	1.45	0.96	0.22	1.02
25	1.5	1.89	0.88	0.24	0.98
26	1.5	1.87	0.98	0.2	1.12
27	0.55	0.9	0.78	0.12	1.2

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347 - 6435 (Online) Volume 2, Issue 1, January 2014)

28	1.35	1.73	1.19	0.19	0.85
30	1.42	1.75	0.77	0.14	0.72
31	0.8	1.13	1.75	0.41	1.15
32	1.19	1.52	1.05	0.15	1.13
34	1.42	1.78	0.67	0.27	0.96
38	1.1	1.46	0.87	0.19	0.53
39	2.2	2.48	0.94	0.15	0.37
40	2.35	2.56	0.86	0.1	0.91
42	2.25	2.39	0.34	0.02	1.13
44	2.35	2.57	0.82	0.12	0.86
45	2.25	2.54	0.88	0.19	0.83
46	0.3	0.89	1.06	0.55	1.13
49	2	2.27	0.81	0.18	1.02
51	2.2	2.39	0.72	0.12	1.03
54	1.65	2.08	0.87	0.33	0.84
55	3.15	3.16	1.19	-0.07	0.78
57	1.6	1.87	0.59	0.17	1.1
59	2.25	2.48	0.87	0.12	0.81
60	3.45	3.55	0.64	0.13	1.03
64	2.15	2.41	0.67	0.26	1.42
65	3.75	3.81	0.67	0.09	0.93
66	3.6	3.7	0.68	0.15	0.95
67	2.75	2.99	0.98	0.18	0.92
68	3.3	3.29	0.82	0	1.05
70	0.35	0.86	0.75	0.27	0.94
71	0.75	1.17	0.88	0.23	1.09
72	1.75	2.18	0.97	0.32	1.11
75	2.5	2.83	0.83	0.36	1
76	1.45	1.9	0.85	0.41	1.1
77	2	2.23	1.13	0.05	1.2
78	1.1	1.38	0.78	0.25	1
79	2.5	2.75	0.69	0.21	0.95
80	0.95	1.19	0.92	0.09	1.3
81	2.85	3.04	0.82	0.18	1.43
82	1.75	2.06	1.11	0.15	1.24
84	1.05	1.35	0.66	0.14	1.22
86	1.7	2.15	1.24	0.21	0.72
87	1.3	1.81	0.96	0.41	1.31
90	1.8	2.08	1.14	0.05	1
91	1.4	1.82	0.79	0.42	1.24
92	3.25	3.19	0.7	-0.27	0.9
93	1.85	1.97	1.1	-0.03	0.97
94	2.35	2.68	0.63	0.41	1.04
95	0.5	0.93	0.72	0.31	1.32
97	1.85	2.32	1.05	0.3	0.73
98	1.5	1.82	0.63	0.29	1.13

Table 5
Result Of The Discriminant Function Analysis.

Sample No	$Y_{aeolian:beach}$	$Y_{beach:marine}$	$Y_{marine:fluvial}$	$Y_{fluvial:turbidite}$
1	-2.77	109.48	-7.8	7.97
2	3.73	189.21	-15.91	10.06
3	-2.58	107.04	-6.28	4.87
4	-1.26	132.61	-9.41	6.3
5	7.26	220.93	-18.33	15.49
6	9.64	233.68	-25.54	2.94
7	5.06	166.73	-15.29	4.55
8	-2.2	121.9	-8.44	6.31
9	-3.63	101.56	-5.67	7.33
10	1.84	127.29	-11.97	8.33
11	-2.04	117.45	-7.29	4.8
12	0.11	90.51	-6.24	7.33
13	8.9	226.18	-24.79	8.22
14	1.91	121.21	-10.88	8.86
16	-0.76	126.77	-8.97	5.97
17	2.4	131.89	-11.86	7.93
18	4.17	125.39	-12.99	7.27
19	-2.94	111.98	-6.6	6.01
20	-1.69	125.23	-8.31	4.92
21	-3.42	116.03	-6.66	5.31
22	-3.34	115.43	-7.45	6.12
23	-2.07	113.82	-6.77	4.84
24	0.91	106.48	-8.73	7.61
25	-1.31	103.91	-7.48	7.9
26	-0.02	117.15	-8.83	8.3
27	2.54	79.42	-5.7	7.67
28	1.34	125.05	-12.89	6.48
30	-2.08	82.97	-5.41	5.84
31	10.13	58.12	-28.74	8.49
32	1.91	121.13	-10.05	6.01
34	-2.2	71.18	-4.89	8.02
38	-1.14	86.42	-7.18	4.87
39	-4.73	106.69	-7.73	4.39
40	-3.77	107.57	-6.21	7.04
42	-4.62	66.66	-0.39	7.85
44	-4.21	103.89	-5.87	7
45	-3.98	110.79	-7.12	7.26
46	3.77	109.58	-11.47	8.68
49	-2.84	101.72	-6.03	8.56
51	-3.63	93.16	-4.42	7.77
54	-2.65	98.42	-7.72	7.93
55	-3.41	156.74	-11.23	5.44
57	-2.25	76.25	-3.35	8.21
59	-3.77	106.49	-6.55	6.68
60	-8.2	104.51	-3.22	8.78
64	-3.05	98.41	-4.47	10.83
65	-11.71	108.83	-3.33	8.12
66	-8.82	109.29	-3.75	8.57
67	-4.6	131.38	-8.53	7.91
68	-5.94	115.86	-4.98	7.68

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International Journal of Recent Development in Engineering and Technology
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70	1.4	73.74	-6.1	7.27
71	1.64	94.67	-7.63	7.9
72	-1.51	123.01	-9.22	9.3
75	-5.17	115.23	-7.02	9.5
76	-1.51	105.4	-7.78	9.76
77	0.4	153.53	-10.8	7.82
78	-0.59	85.64	-6.22	7.78
79	-5.52	96.65	-4.47	8.31
80	2.76	100.23	-7.46	8.04
81	-4.19	123.61	-6.11	10.76
82	0.75	139.29	-10.91	8.59

84	0.31	78.26	-4.12	8.27
86	-0.12	153.29	-14.02	6.24
87	0.26	121.82	-9.64	10.66
90	0.4	137.95	-11.07	6.64
91	-1.14	101.25	-7.07	10.51
92	-6.14	95	-2.12	5.08
93	0.57	128.53	-9.9	5.88
94	-5.69	94.92	-4.67	10.07
95	2.05	79.17	-5.77	9.54
97	-2.54	128.14	10.48	7.16
98	-2.09	81.51	-4.4	9.16

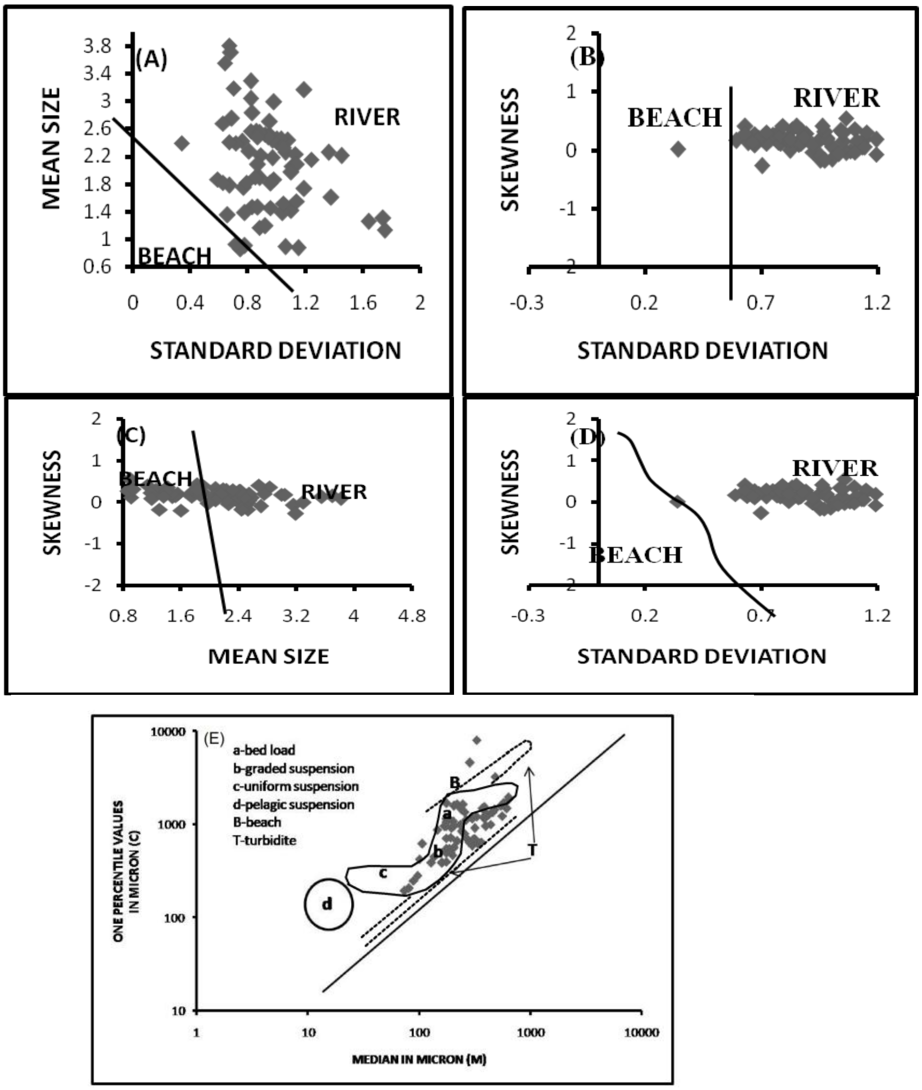

Figure 3: (A-C) bivariate plots- after Moiola and Weiser (1968), (D) bivariate plots after Friedman (1961) and (E) C-M plot after Passega (1957, 1964).

International Journal of Recent Development in Engineering and Technology
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V. CONCLUSION

Interpretation of grain size analysis indicates that:

i. Most samples have unimodal distribution.
ii. The modal class lies between 1-2ϕ (0.25 to 0.50mm) in most samples.
iii. Samples are positively, negatively as well as nearly symmetrical.
iv. The sediments were transported in all three modes - traction, saltation and suspension. However saltation remains the major process of transportation.
v. Slope of line segments in arithmetic probability curves varies from 16° to 55°, indicating poor sorting.
vi. Loads on traction, saltation and suspension show wide variation. This indicates the highly variability in competency of the transporting agency
vii. Due to fluctuation in the kinetic energy there was mixing of sediments of various sub-populations transported in different modes.
viii. The median value ranges from 0.3ϕ to 3.75ϕ. Mean size of the study are ranges between 0.86ϕ and 3.81ϕ. This highly variation in grain size indicates the variation in the kinetic energy at the time of deposition.
ix. Bivariate and multivariate analysis indicates diversity in the depositional environment. However marine and turbidity is the most dominant environment.

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