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Grain size analysis of the Renji Formation (Barail) and Bhuban Formation (Surma) sandstones in the Barak basin, Manipur, India: Implication for nature of transport and depositional environment

Angom Sangeeta, Oinam Kingson, N. Pandey, Ajano Khalo, P. Borgohain

Abstract - The grain-size analysis in the sandstones of the Renji Formation (Barail Group) and Bhuban Formation (Surma Group) in parts of the Barak Basin, western Manipur, India was carried to determine the grain size distributions, modes of sediment transportation and depositional environment. The grain size of the Barail sandstone ranges from 2.3ϕ to 3ϕ and their grains show well sorted to moderately well sorted, symmetrical to coarse - skewed as well as nearly very fine – skewed and mesokurtic nature whereas the grain size of the Surma sandstone varies from 2.7ϕ to 3.4ϕand these grainsdisplay moderately well sorted to moderately sorted, coarse - and symmetrical skewed, mesokurtic to very leptokurtic nature. The Kurtosis analysis shows that the Barail siliciclastic sediments have been sorted in normal energy condition, whereas the Surma siliciclastic sediments likely have been sorted in normal to low as well as high energy conditions. Generally, the Barail and Surma sandstones show unimodal distribution. A shallow marine environment has been envisaged for the deposition of sediments of both the Barail and the Surma sandstone, dominated by saltation process.

Keywords: Grain size analysis, sandstone, Barak basin, western Manipur, transportation, depositional environment

I. INTRODUCTION

Amidst controversies regarding effectiveness of grain-size analysis in sedimentological studies, workers like [5], [6], [7], [8], [13], [14], [15], [16] and [17] have successfully accomplished the task of classifying and discriminating the sedimentary environments using grain-size characteristics. Although for a long time, the significance of grain size distribution in siliciclastic sediments were recognized as an important tool in understanding the provenance and hydrualics of depositional environments [1], [2], the past few decades have seen a declining trend in use of Grain-size techniques in environmental discrimination.

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Nevertheless, the basic concept of grain-size analysis still holds well in interpreting the depositional processes. Grain size analysis plays an important role for classifying unconsolidated materials and sediments, sedimentary rocks and sedimentary environments [23] and [24]).

In view of this context, we made an effort to study the characteristics of grain size using thin-section technique in the silisiclastic sediments of the Barak Basin, western Manipur, India. In this study, our aims are to provide a better understanding of the nature of transportation and depositional environment of the sediments in the Barak Basin.

II. STUDY AREA

The study area is a part of the Indo-Burma Ranges, covering in and around Nungba, Noney district (National Highway-37), western Manipur, India (Fig. 1a and b). It also belongs to the Inner Fold Belt of Naga-Manipur Hills, which comprises of two synclinoria: Kohima synclinorium and Patkai synclinorium. The study area is part of Kohima synclinorium possessing spectacularly developed Oligocene Barail Group (Renji Formation) which, in turn, is overlain by Miocene Surma Group of rocks (Bhuban Formation). The study area lies between 24°45′-24°50′ N latitudes and 93°20′- 93°30′E longitudes of the topographic sheet Nos. 83H/5, 83H/6 and 83H/9 of the Survey of India, covering an area of nearly 50 km^2 (Fig- 1).The Oligocene Barail and Miocene Surma Group of rocks constitute the main lithologies in the study area where these were juxtaposed along a thrust named Rengpang Thrust (see Table I).

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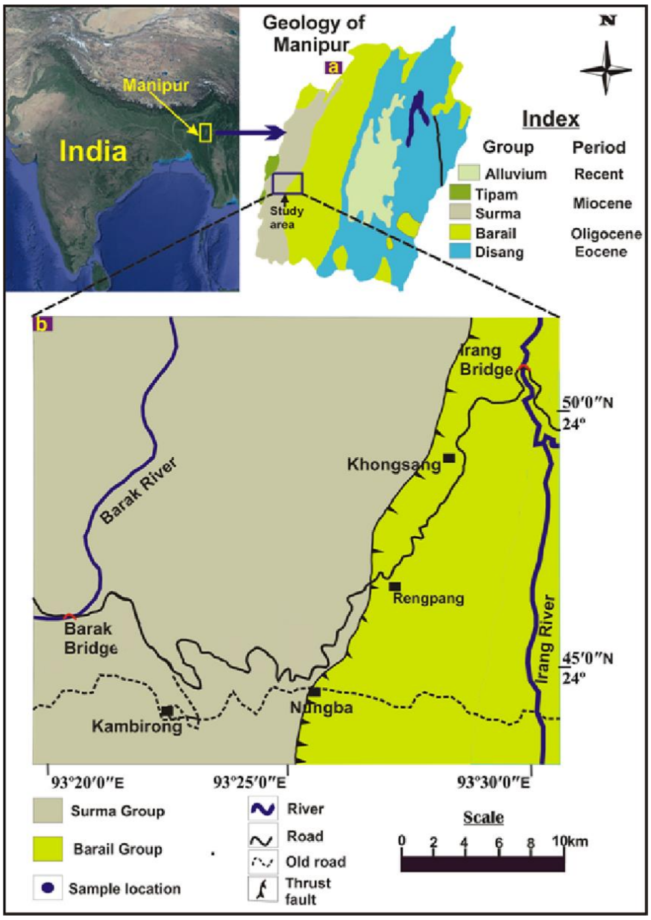

Fig-1. (a)Map showing Geology of Manipur and location of the study area, and (b) Map showing Geologyl of the study area "modified after [19]".

TABLE I: Table showing the stratigraphic succession of the study area

Group (Formation)	Lithology	Age
Surma Group (Bhuban Formation)	Alternating succession of shale, sand, siltstone and massive to cross - bedded ferruginous sandstones. Presence of flaser& lenticular beddings, tabular and herringbone cross stratification is characteristic of sandstones. Occasional fossils, coal streaks and intraformational conglomerate are also not very uncommon.	Miocene
----------------------------------Thrusted boundary--------- ----------------------------		
Barail Group (Renji Formation)	Thick to medium ripple and cross-bedded fine to medium grained sandstone – minor shale alterations with carbonized plant remains and coal streaks. Sporadic occurrence of granule layers & clay intraclasts as well as trace fossils are also not very uncommon.	Oligocene
Based not exposed		

III. METHODOLOGY

In order to have an idea about the grain-size distributions in Renji Formation (Barail) and Bhuban Formation (Surma) sediments; a total of 20 samples (10 each from Barail and Surma rocks) were studied in thin-section following the technique suggested by [3]. The size measurement was carried out with the help of graduated eye piece in the Leica DMLP Petrological microscope at the Department of Earth Science, Assam University. The size was obtained in millimeter and further it was converted into phi units [1]. The number frequencies obtained against every phi intervals were recalculated to 100% for the graphical treatment of grain size data. Following [5], obtained recalculated number frequencies were used to prepare cumulative frequency curves using the lognormal probability scale. From the prepared cumulative curves phi-values for different percentiles were obtained in order to compute the various graphic measures. Following the formulae suggested by [3] the statistical parameters of size distribution were calculated and further correlated with the sieve data following techniques suggested by [4], [6] and [1]. Environmental discriminations were attempted using V1 and V2 plot (Fig- 4) after [17].

IV. RESULT AND DISCUSSIONS

Cumulative frequency curves (CM)

Visher (1969) describes the correlation of the distribution of grains in consolidated or unconsolidated siliciclastics with their transport processes and depositional environments by using the plot log-phi graphs/ log-probability plots. Following cumulative frequency curve analysis technique proposed by [7], [10], [16], the cumulative percentage achieved from the grain size analysis of the studied sandstones were plotted on the log-phi graphs / log probability plots. CM diagram defines the rolling, saltation and suspension process for the deposition of sediments [25]. Almost all the studied Barail and Surma sandstones show a single line segment or straight line on log-phi graphs indicating predominance of saltation sedimentation with minor suspension processes (Figs – 2 and

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3). The details of the statistical parameters of grain size distribution are shown in Tables- II and III.

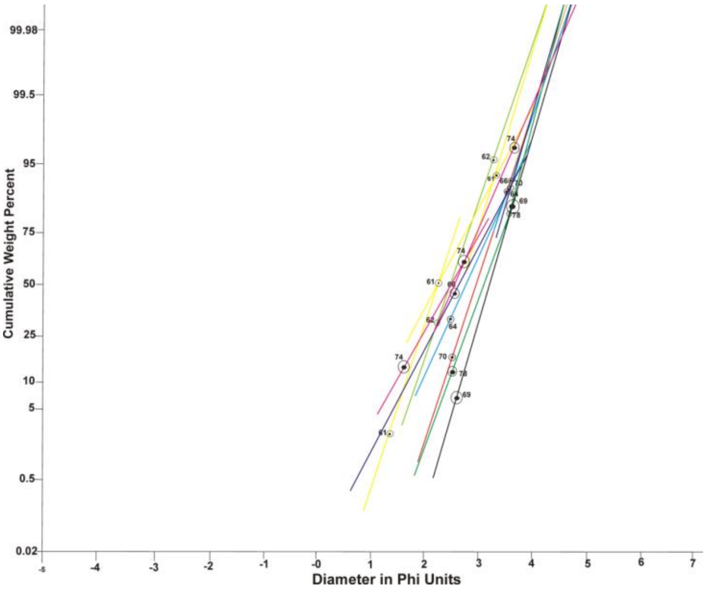

Fig-2: Cumulative curves of sediments for Renji Formation (Barail Group) of the study area “modified after [7]”.

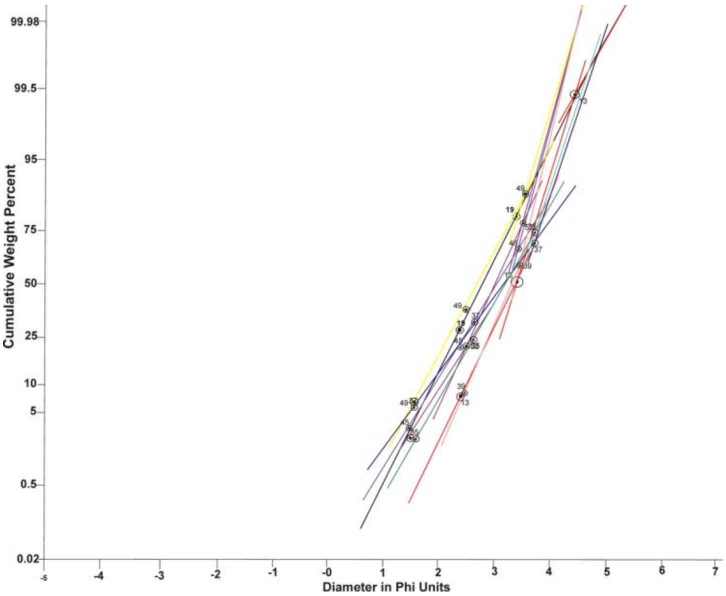

Fig-3: Cumulative curves of sediments for Bhuban Formation (Surma Group) of the study area “modified after [7]”.

Graphic mean size (Mz)

Graphic mean size measures the average grain size distribution in siliciclastics. It can be calculated by following the method suggested by Folk and Ward (1957) i.e**., Mz= (ϕ 16+ ϕ50+ ϕ84)/3**. The graphic mean size of the Barail sandstone ranges from 2.3ϕ to 3ϕ which indicate the mean size of Barail sediments fall mostly within medium grain to fine grain sands whereas the mean size of Surma sandstone varies from 2.7ϕ to 3.4ϕ signifying Surma sediments varies between medium grain sands to very fine grain sands.These low variations in grain size of both Barail and Surma sandstones indicate a minor variation in kinetic energy at the time of deposition of sediments [20].

Inclusive Graphic Standard Deviation (σ1)

Itis defined as the amount of sorting of sediments or variation of a distribution of grain size in phi scale and is calculated based on themethodproposed by [9] and [12] i.e., **σ1= (Φ 84 – Φ 16)/4 + (Φ 95 –Φ5)/6.6** and their verbal classifications are given below.

σ1 under 0.35 Φ	Very well sorted
0.35 to 0.50 Φ	Well sorted
0.50 to 0.71 Φ	Moderately well sorted
0.71 to 1.00 Φ	Moderately sorted
1.00 to 2.00 Φ	Poorly sorted
2.00 to 4.00 Φ	Very poorly sorted
Over 4.00 Φ	Extremely poorly sorted

The sorting values of Barailsiliciclasticss achieved from the study varies between 0.4 Φ and 0.68 Φ indicating well to moderately well sorted. Although, the sorting value of Surma ranges between 0.50 Φ and 0.87 Φ suggesting moderately well sorted to moderately sorted.

Inclusive Graphic Skewness (Sk_1)

Skewness (Sk_1) is an asymmetry measure for the distribution of grain size. If skewness is positive, grain size populations show a tail of excess fine particles which are skewed toward positive phi values and are said to be fine skewed. If the skewness is negative, coarse particles are excess in the tail where the data are skewed towards negative phi values are said to be coarse skewed. Graphic skewness is calculated by using the equation:

Sk_1 = (Φ84 + Φ16 – 2Φ50)/2(Φ84 - Φ16) + (Φ95 +Φ5 – 2Φ50)/ 2(Φ95 – Φ5)

Verbal-skewness

+ 1.00 to + 0.30	Very fine - skewed
+ 0.30 to + 0.10	Fine - skewed
+ 0.10 to - 0.10	Near - symmetrical
± 0.00	Symmetrical
- 0.10 – 0.30	Coarse - skewed
- 0.30 - 1.00	Very coarse - skewed.

The skewness values of present studied Barail sandstone ranges from – 0.12 to 0.2 where most of a samples fall in the classes of symmetrical to coarse - skewed and some samples fall under the very fine – skewed. While Surma sandstones vary from – 0.2 to 0.13 and fall under coarse - and symmetrical skewed. The positive values suggest skewness towards the fine grain sizes and negative values towards coarser grain sizes [21] and [22]. Symmetrical and coarse – skewed nature are mostly observed in both the Barail and Surma sandstones indicate minor kinetic energy of the depositional basin and occurrence of coarse, symmetrical & few samples of fine skewed nature in the study area suggest the mixing of different modal fractions [4].

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Graphic Kurtosis (K_G)

It is defined as a measure of ratio between the sorting in the tails of the curve and the sorting in the central portion. There are three types of Kurtosis (K_G). They are platykurtic, mesokurtic and leptokurtic. Platykurtic is define as the grain-size frequency curves which have less kurtosis from thenormal distribution whereas leptokurtic is directly opposite of platykurtic, having more kurtosis. A frequency curve having the same or close kurtosis as the normal distribution is known as mesokurtic.

A formula for calculating kurtosis and their verbal classifications are given below:

$$K_G = (\Phi 95 - \Phi 5) / 2.44 (\Phi 75 - \Phi 25)$$

Verbal Classification

KG under 0.67	Very Platykurtic
0.67 to 0.90	Platykurtic
0.90 to 1.11	Mesokurtic
1.11 to 1.50	Leptokurtic
1.50 to 3.00	Very Leptokurtic
KG over 3.00	Extremely Leptokurtic

Kurtosis value of the studied Barail sandstones vary from 0.8 to 1.09 in which most of the samples show mesokurtic while few samples fall under platykurtic indicating normal energy condition for the sorting of siliciclastics on the other hand for the Surma sandstones values ranges from 0.92 (mesokurtic) to 1.7 (very leptokurtic) indicating sediments were sorted in normal to low as well as high energy environments, however showing dominance for normal energy environment. Many of the Barail and Surma sandstones show unimodal distribution since the graph shows dominance of mesokurtic nature over the leptokurtic and platykurtic.

TABLE II: Parameters of grain size distribution of sediments for Renji Formation (Barail).

Sample No	Mean (M_Z)	Standard deviation(σ1)	Skewness (SK_1)	Kurtosis (K_G)	Median (Md)	Mode (Mo)
RS54	3	0.57	-0.05	0.8	3	3
RS59	2.8	0.54	0.07	1	2.6	2.6
RS61	2.8	0.58	0.2	1.3	2.5	2.5
RS62	2.9	0.49	0	1.09	2.7	2.7
RS64	2.9	0.53	-0.02	1	2.9	2.9
RS66	3	0.7	-0.01	0.92	2.7	2.7
RS70	3.1	0.4	-0.04	1.06	3.1	3.1
RS74	2.5	0.68	-0.12	1	2.4	2.4
RS78	3.1	0.47	-0.03	1.3	3.1	3.1
RS89	3.3	0.4	-0.04	1.06	3.1	3.1

TABLE III: Parameters of grain size distribution of sediments for Bhuban Formation (Surma).

Sample No	Mean (M_Z)	Standard deviation(σ1)	Skewness (SK_1)	Kurtosis (K_G)	Median (Md)	Mode (Mo)
RS3	3	0.57	0.13	1.11	2.8	2.8
RS13	3.4	0.55	-0.25	1	3.5	3.5
RS19	2.9	0.71	0	1.3	2.9	2.9
RS35	2.8	0.7	0.02	1.04	2.8	2.8
RS37	3.1	0.87	0.05	1	2.7	2.7
RS39	3.23	0.48	-0.2	1.7	3.3	3.3
RS43	2.9	0.6	-0.18	1	3	3
RS49	2.9	0.71	0.03	1	2.6	2.6
RS51	3	0.67	-0.07	1.1	2.9	2.9
RS80	3.03	0.68	-0.21	1.3	3.1	3.1

V. ENVIRONMENTAL DISCRIMINATION

Sahu's (1983) empirically retained discriminating Eigen's vectors V_1 and V_2 have been used here to discriminate the depositional environments in respect of Barail and Surma rocks under study. The discriminating Eigen's vectors V_1 and V_2 are expressed by

$$V_1 = 0.48048M_Z + 0.62301\ \sigma 1^2 + 0.40602\ Sk_1 + 0.44413\ K_G$$

$$V_2 = 0.24523M_Z + (-\ 0.45905)\ \sigma 1^2 + 0.15715Sk_1 + 0.83931KG$$

Where, M_Z =mean size, σI^2= size variance, Sk_1= graphic skewness and K_G =graphic kurtosis.

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The average values for V_1 and V_2 for (Renji Formation (Barail) was found to be V_1 = 2.06, V_2 = 1.46 and for Bhuban Formation (Surma) as V_1 = 2.21, V_2 = 1.49. These values were plotted in the V_1 and V_2 diagram in which V_1vs V_2 = 74.4° (after Sahu , 1983). The position of the points plotted with respect to bothRenji Formation (Barail) and Bhuban Formation (Surma) fall well within the range of shallow marine deposits(Fig- 4). V_1 and V_2 values for both Barail and Surma sandstones are presented in Table- IV.

TABLE IV: Table showing V_1 and V_2 values for the Barail and Surma sandstones.

	Sample No	V_1	V_2
	RS54	1.978859	1.250135
	RS59	1.999565	1.403096
	RS61	2.213498	1.654753
	RS62	2.027078	1.515797
	RS64	2.004405	1.418387
Barail Sandstons	RS66	2.151254	1.281349
	RS70	2.043707	1.570148
	RS74	1.884687	1.221262
		2.192299	1.745197
	RS89	2.139803	1.619194
		Av.2.063516	Av. 1467932
	RS3	2.189623	1.538608
	RS13	2.164718	1.494942
	RS19	2.28482	1.570863
	RS35	2.120635	1.337735
Surma sandstones	RS37	2.425475	1.259926
	RS39	2.369309	2.081725
	RS43	1.988722	1.356932
	RS49	2.163762	1.323784
	RS51	2.181231	1.441863
	RS80	2.236039	1.588884
		Av. 2.212433	Av. 1.499526

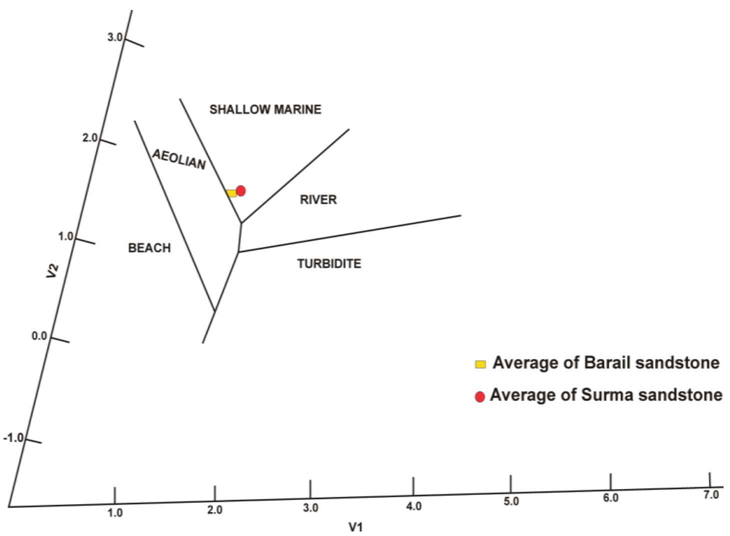

Fig-4: V1 vs V2 plot [17] showing overall depositional environment for the Barail and Surma Group of rocks.

VI. CONCLUSION

Grain size analysis of the sandstones in the Renji Formation (Barail Group) and its overlying the Bhuban Formation (Surma Group) in the Barak basin, Manipur, India has led to the following conclusions:

1. The sediments in the Renji Formation display medium to fine grain size, well to moderately well sorted, symmetrical to coarse – skewed, mesokurtic nature indicating minor variation in kinetic energy for the deposition of siliciclastic sediments which were sorted in normal energy environment. On the other hand, the Bhuban Formation (Surma) sandstones show medium to very fine grain size, moderate to moderately well sorted, coarse to symmetrical skewed, mesokurtic to very leptokurtic nature suggesting minor kinetic energy of the depositional basin where the sediments were sorted in normal to low and high energy environment, dominated by normal energy environment.
2. A shallow marine environment influenced by fluvial activities and shallow marine-mixed-tidal flat environment may be envisaged for the deposition of Renji Formation (Barail Group) and Bhuban Formation (Surma Group) respectively.
3. The saltation processes could have dominated during the transportation of their sediments.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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REFERENCES

[1] O. K. Wentworth, "A scale of grade and class terms for clastic sediments," Jour. Geology, vol. 30, pp. 377-392, 1922.
[2] W. C. Krumbein, and F. J. Pettijohn, "Manual of sedimentary petrography," Appleton-Century-Gofts, New York, 1938.
[3] R. L. Folk, and W. C. Ward, "Brazos River Bar – A study on the significance of grain size parameters," Jour. Sed. Pet., vol. 27, pp. 3–26, 1957.
[4] G. M. Friedman, "Distinction between Dune, Beach and River sands from their textural characteristics," Jour. Sed. Pet, vol. 31, pp 514-529, 1961.
[5] R. L. Folk, "A review of grain size parameters," Sedimentology, vol. 6, pp. 73 – 93, 1966.
[6] G. M. Friedman, "Dynamic process and statistical parameters compared for size frequency distribution of beach and river sand," Jour. Sed. Petrology, vol. 37, pp. 327–354, 1967.
[7] G. S. Visher, "Grain size distributions and depositional processes," Jour. Sed. Petrology, vol. 39, pp. 1074-1106, 1969.

doi: 10.32622/ijrat.102202209

[8] R. P. Glaister, and H. W. Nelson, “Grain size distributions; An aid in facies identification,” Bull. Canadian Petroleum Geology, vol. 22, pp. 203-240, 1974.
[9] R. L. Folk, “Petrology of Sedimentary Rocks,” Austin, TX, Hemphill Press, Second Edition, pp. 170 – 182, 1974.
[10] K. O. Sagoe, and G. S. Visher, “Population breaks in grain size distribution of sand- A theoretical model,” Jour. Sed. Petrol, vol. 47, pp 285-310,1977.
[11] J. A. Harrel, and K. Eriksson, “Empirical conversion equations for thin section an sieve derived size distribution parameters,” Jour. Sed. Petrology, vol. 49, pp. 230-273, 1979.
[12] R. L. Folk, “Petrology of Sedimentary Rocks,” Austin, TX, Hemphill Press, Second Edition, pp. 20 – 25, 1980.
[13] R.W. Tucker, and H. L. Vacher, “Effectiveness of discriminating beach, dune and river sands by movements and cummulative percentages,” Jour. Sed. Petrology, vol. 50, pp. 165-172, 1980.
[14] J. J. Bridge, “Hydraulic interpretation of grain size distribution using a physical model for bedload transport,” Jour. Sed. Petrology, vol. 51, pp.1109-1124, 1981.
[15] P. McLaren, “An interpretation of trends in grain size measures,” Jour. of Sed. Petrology, vol. 51, pp. 611-624, 1981.
[16] J. J. Lambiase, “Turbulance and the generation of grain-size distribution,” (Abst), Int. Congr. Sed, Hamilton, pp. 80-81, vol. 11, 1982.
[17] B. K. Sahu, “Multigroup discrimination of depositional environments using size statistics,” Indian Earth Science, vol. 10, pp. 20-29, 1983.
[18] Jr. S. Boggs, “Petrology of Sedimentary Rocks,” Text book, Cambridge University press, 2009, ch. , pp. 236-241.
[19] M. Chandra, P. Kundal, and R. A. S.Kushwaha, “Ichnology of Bhuban and Boka Bil Formations, Oligocene-Miocene Deposits of Manipur Western Hill, Northeast India,” Geol. Soc. Ind., vol. 76, pp. 573-586, 2010.
[20] T. Devala, “Texutural Characteristics and Depositional Environment of Olistostromal Sandstone of Ukhrul, Manipur,” Int. Jour. of Recent Dev. in Eng. and Tech., vol. 2, pp. 92 -100, 2014.
[21] A. R. Saeed, and S. Abdi, “Grain size analysis and depositional environment for beach sediments along Abu Dhabi Coast, United Arab Emirates,” Int. Jour. of Sci. and Tech. Research, vol. 5, pp. 106-114, 2016.
[22] K. D. Gautam, “Sediment grain size,” Encyclopedia of Estuaries,” 2016.
[23] I. L. Gloria, “Grain size analysis,” Encyclopedia of Earth Science Series, pp. 341-348, 2017.
[24] D. R. Marco, M. Michele, C. Nicola, and R. Alberto, “Stratigraphy, Petrography and Grain-size Distribution of sedimentary lithologies at Cahuachi (South Peru): Enso- Related Deposits or a Common Regional Succession?” Geosciences, vol. 9, pp. 1-18, 2019.
[25] S. Koushik, and S. Subhajit, “Grain size analysis and characterization of sedimentary process in tidal flat of Chandipur region, East Coast of Odisha, India,” Marine Geodesy, vol. 44, pp. 1-14, 2021.

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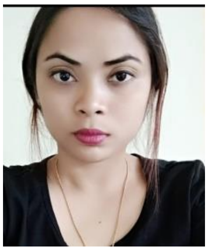

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