Journal of Geographical Research and Area Studies (JGRAS)
January-June, 2025 [Vol.1, Issue 1]

Determination of Sedimentary Environment through Grain Size Analysis of the Tyrsad and Weiloi Area, Meghalaya, India

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Cite as: Mero, K., Syiemlieh, H., and Walia, D., (2025), Determination of Sedimentary Environment through Grain Size analysis of the Tyrsad and Weiloi Area, Meghalaya, India, Journal of Geographical Research and Area Studies, 1(1), pg. 39- 52.

Abstract
Grain size characterization plays a vital role in understanding the environment of deposition. The study has been carried out along Tyrsad and Weiloi area of conglomerate outcrop, Meghalaya, India. The grain size statistical analysis has been carried out by using the Geometric (modified) Folk and Ward (1957) graphical measure, where the textural analyses of the grain size parameters reflect the history of its sedimentation. The result revealed that the maximum grain size of the conglomerate ranges between coarse-grained sand to granule grain-size, suggestive of the sediments being deposited under high-energy conditions. The analysed sediments show a standard deviation of 0.3 to 0.32. The sediment analysed indicates a very well sorted grain size and skewed towards the very coarse grain sizes in an extremely leptokurtic condition revealed that the sediment samples have achieved its sorting in high-energy environment. Interpretation of the frequency curve suggests that bulk of the sediments were transported in the form of traction and saltation. The sharp break in frequency curve indicates fluctuating energy during deposition. The study aims to address the paleo environmental depositional of the conglomerate as these deposits hold a significant geo-heritage importance.

Keywords: conglomerate, grain size, Tyrsad, Weiloi

Introduction
The Meghalaya plateau, located on the north eastern part of the Indian subcontinent, has a unique geological history, hosting a variety of rocks from the oldest Archean to the recent Cretaceous/Tertiary sediments. The study has been carried out on the paleo deposits of the conglomerate exposed along the Tyrsad and Weiloi area, located on the way to Mawsynram, the rainiest place on earth, which receives 467 inches of rain per year. The conglomerate of the study area has the potential to be conserved as a Rich Geo-heritage site for its significance. The Grain size studies are one of the most important and widely used sedimentological tools to classify sedimentary environments where the textural characteristics of grain size parameters like median, mean size, sorting, kurtosis and skewness have been methodically used to describe the sedimentary

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features and their depositional settings. It gives detailed information about the interior properties of the sediment discharge and its depositional environment (Ashley 1978; Francke et al.sss, 2013; Friedman, 1961; Gaillardet et al.1999; Xu 1999; Pandey et al., 2002; Zhang et al.2006; Chakrapani and Saini 2009; Friedman, 1978; Goudies, 1981; Folk and Ward 1957; Sahu 1964; Vincent 1998).

Many significant contributions have been made in the region from the earliest geological work carried out by T.Oldham (1858) he mapped two types of metamorphic rocks, the oldest and more metamorphosed gneissic rocks i.e., the Basement Gneissic Group (BGG) and the less metamorphosed rock of blue flaky schist with micaceous quartzose layers; H.B. Medlicott (1869) made significant contributions to the geology of the region. He proposed the existence of two distinct metamorphic rock series: the 'Older Gneiss Series' and a younger series called the 'Shillong Series', which he also referred to as 'Khasi Greenstone'. He noted that this Shillong Series was intruded by basic dolerite rocks in the form of sills and dykes, and was partially metamorphosed, resulting in green-coloured rocks.; P.N. Bose (1901–1902) conducted a study on the granite plutons of the Shillong Plateau. He suggested that these granite intrusions are younger than the Shillong Group of rocks, indicating a later phase of igneous activity in the region; Palmer (1923) conducted a geological study of the southern Khasi Pluton around Tyrsad and concluded that the Shillong Plateau represents an ancient gneissic mass, which has been mostly intruded by granitic bodies.

Many workers like Dasgupta (1934); Pasco (1950); Mathur and Evans (1964); Bordoloi and Ouddus (1964); Barooah and Goswami (1972); Geological Survey of India (1974); Ahmed (1976,1983); Barooah (1976); Bhattacharya and Bhattacharyya (1981,1987); Mishra and Sen (1998,2001 and 2004); Sarma et.al (2001); Das et al (2005) and Barthakur (2007) also has contributed much in understanding the geology of the regions. However, there still exist various problems in resolving the stratigraphic relationship of these sediments as the sediments of the Meghalaya plateau are highly deformed (Devi and Sarma, 2010). Therefore, the main aim of this paper is to identify the conglomerate environment of deposition using the grain size textural characteristics of mean, sorting, skewness, and kurtosis, which form one of the basic tools of classifying the sedimentary environments.

Study Area

The present study is carried out on the conglomerate exposed along the road section of Tyrsad and Weiloi area of East Khasi Hills, Meghalaya, India. The area contains outcrops of conglomerate (sedimentary deposits) of tertiary/cretaceous age. The Predominant Geological Formations present in the study area are Archaean Gneissic Complex-Granitic, Gneissic, and Schistose rocks, and Shillong Group- Quartzites and Phyllites. Geologically, the study area hosts a variety of rocks from the oldest Archean to the recent Cretaceous/Tertiary sediments. The conglomerate of the study area is exposed along the Shillong Group of rocks of the Proterozoic Age of approximately 2500 million years, intruded in between by the Khasi Green stones near Mawphlang area at the initial exposure of the conglomerate of the Umkaber-Lyniong outcrop. Further, as we go along the Southern slope of the plateau, we find the conglomerate intruded in between by the Granites Plutons (500 million years) of Neo-Proterozoic-Lower Palaeozoic age, found largely scattered all along the exposure of the study area. This exposure can be seen starting near Kyrphei conglomerate outcrops. The following

Figure 1 shows the location map and geology of the study area (modified after Geological Survey of India, Kolkata, 2012).

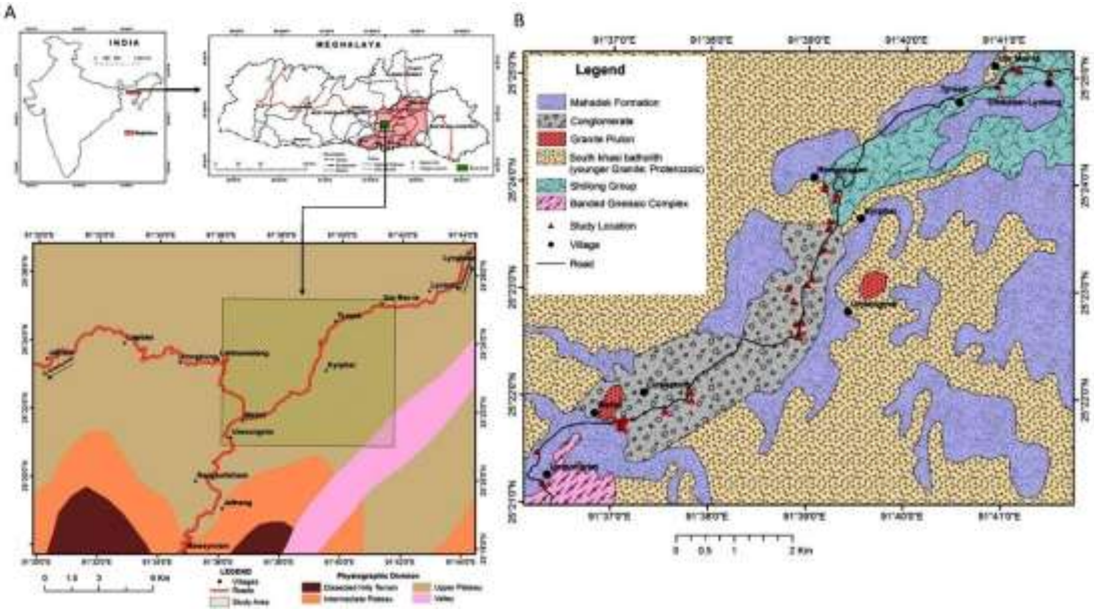

Fig. 1, Location map and Geology of the Study area

Materials and Methods

A total of one hundred conglomerate samples were collected for detailed sedimentological analysis from eight sampling sites. For laboratory analysis, the successive conning and quartering method was carried out to obtain an unbiased sample size. The samples are then sieved and weighed separately. A total of one hundred conglomerate samples were collected to determine the conglomerate depositional environment, as shown in Table 1.

Table 1, Particularities of each Sampling sites from Tyrsad and Weiloi Conglomerate exposure extracted during 2014-2018

Location	Latitude	Longitude	Elevation	Sampling Sites	No. of Samples
Nongmadan	25.39913	91.65318	1656	Site 1	5
Um Mar-ia	25.41572	91.68259	1649	Site 2	3
Um Mar-ia	25.41639	91.68319	1647	Site 3	6
Um Mar-ia	25.41772	91.68999	1668	Site 4	4
Umkaber-Lyniong	25.41793	91.68624	1663	Site 5	2
			Total	5	20
Kyrphei	25.38357	91.64764	1636	Site 1	4
Kyrphei	25.38424	91.64999	1639	Site 2	4
Kyrphei	25.38499	91.65075	1656	Site 3	3
Kyrphei	25.38922	91.65229	1650	Site 4	2
Kyrphei	25.38922	91.65229	1661	Site 5	2
Kyrphei	25.39247	91.65324	1663	Site 6	4

Kyrphei	25.39807	91.65487	1651	Site 7	4
Kyrphei	25.39719	91.65512	1659	Site 8	4
			Total	8	27
Weiloi	25.36336	91.61809	1587	Site 1	2
Weiloi	25.36154	91.61915	1596	Site 2	2
Weiloi	25.36143	91.61958	1588	Site 3	1
Weiloi	25.3618	91.62026	1579	Site 4	2
Weiloi	25.36245	91.61967	1589	Site 5	1
Weiloi	25.36318	91.61984	1588	Site 6	1
			Total	6	9
Lumspong	25.36371	91.62128	1591	Site 1	1
Lumspong	25.36371	91.62103	1600	Site 2	2
Lumspong	25.36431	91.62555	1595	Site 3	2
Lumspong	25.36601	91.63068	1594	Site 4	2
Lumspong	25.36733	91.63066	1588	Site 5	1
			Total	5	8
Umlangmar	25.3764	91.64832	1618	Site 1	2
Umlangmar	25.37661	91.64845	1616	Site 2	4
Umlangmar	25.37682	91.64865	1615	Site 3	3
Umlangmar	25.37822	91.64931	1623	Site 4	2
Umlangmar	25.37806	91.64829	1610	Site 5	6
Umlangmar	25.38084	91.64764	1629	Site 6	4
			Total	6	21
Umnongrim	25.35205	91.60626	1628	Site 1	4
Umnongrim	25.3521	91.60617	1632	Site 2	5
Umnongrim	25.35246	91.60559	1625	Site 3	2
Umnongrim	25.35799	91.60476	1612	Site 4	3
			Total	4	15

The Textural analysis of the grain size parameters like mean, sorting, skewness, and kurtosis was determined using the graphical moment formulae of Folk and Ward (1957) based on the metric scale and determined by the following formulae:

Where P_X is the grain diameter, in metric units, at the cumulative percentile value of x. The following equations 1-4 (Folk and Ward 1957) are used to derive the various grain size parameters. The following percentile; 5%,16%,25%,50%,75%,84% and 95% were used to calculate the statistical parameters of standard deviation, skewness, kurtosis, mean and median they are geometrically based on a log-normal distribution with metric size values following the terminology and formulae by Krumbein and Pettijohn (1938) and Folk & Ward (1957).

Mean: eq. 1

$$M_G = \exp \frac{\ln P_{16} + \ln P_{50} + \ln P_{50} + \ln P_{84}}{3}$$

Standard deviation (Sorting): eq. 2

$$\sigma G = \frac{\ln P_{16} - \ln P_{84}}{4} + \frac{\ln P_5 - \ln P_{95}}{6.6}$$

Skewness: eq. 3

$$SK_G = \frac{\ln P_{16} + \ln P_{84} - 2(\ln P_{50})}{2(\ln P_{84} - \ln P_{16})} + \frac{\ln P_{95} - 2(\ln P_{50})}{2(\ln P_{25} - \ln P_5)}$$

Kurtosis: eq. 4

$$K_G = \frac{\ln P_5 - \ln P_{95}}{2.44(\ln P_{25} - \ln P_{75})}$$

The mean grain size is described using a modified Udden-Wentworth grade scale 1922. Sorting, skewness, and kurtosis are described here using the scheme proposed by Folk and Ward (1957). However, in order to avoid confusion as to whether skewness terms relate to metric or phi scales, positive skewness is renamed 'fine skewed' (indicating an excess of fines), and negative skewness is renamed 'coarse skewed' (indicating a tail of coarser particles).

Table 2, Folk and Ward (1957) particle size parameters grading standard

Sorting (σ_G)		**Skewness (SK_G)**		**Kurtosis (K_G)**	
Range	**Definition**	**Range**	**Definition**	**Range**	**Definition**
<1.27	Very well sorted	-0.3 to -1.0	Very fine skewed	<0.67	Very platykurtic
1.27-1.41	Well sorted	-0.1 to -0.3	Fine skewed	0.67-0.90	Platykurtic
1.41-1.62	Moderately well sorted	-0.1 to +0.1	Symmetrical	0.90-1.11	Mesokurtic
1.62-2.00	Moderately sorted	+0.1 to +0.3	Coarse skewed	1.11-1.50	Leptokurtic
2.00-4.00	Poorly sorted	+0.3 to +1.0	Very coarse skewed	1.50-3.00	Very leptokurtic
4.00-16.00	Very poorly sorted			>3.00	Extremely leptokurtic
>16.00	Extremely poorly sorted				

Table 2 shows the Folk and Ward (1957) particle size parameters grading standard, they are used as an important sedimentological tool to determine the material depositional environments (Sahu, 1964; Zhu et al., 2014). The following Figure 2 shows the different sampling sites of the Conglomerate outcrop: (a) Umnongrim (b) Weiloi (c) Lumspong (d) Umlangmar (e) Kyrphei (f) Nongmadan (g) Um ma-ria (h) Umkaber-Lyniong

Fig.2, The different sampling sites of the Conglomerate outcrop: (a) Umnongrim (b) Weiloi (c) Lumspong (d) Umlangmar (e) Kyrphei (f) Nongmadan (g) Um maria (h) Umkaber-Lyniong

Results and Discussion

100 conglomerate samples were examined across different sites to identify the conglomerate environment of deposition. The grain size parameter of Mean (M_G) is the average size of the total distribution of sediments. It is an index to measure the nature as well as the depositional environment of the sediments (Visher 1969; Sly et al., 1982; Sahu 1964; Rao et al., 2005; Ramaamohanarao et al., 2003). The result showed that the analysed samples have a mean value ranging from 831.57mm to 3556.64 mm, indicating the samples are dominated by coarse-grained sand to granule grain-size, suggestive of the sediments being deposited under high-energy conditions. The graphical representation of mean, sorting, and skewness is shown in Figure 3, and the results are in Table 3.

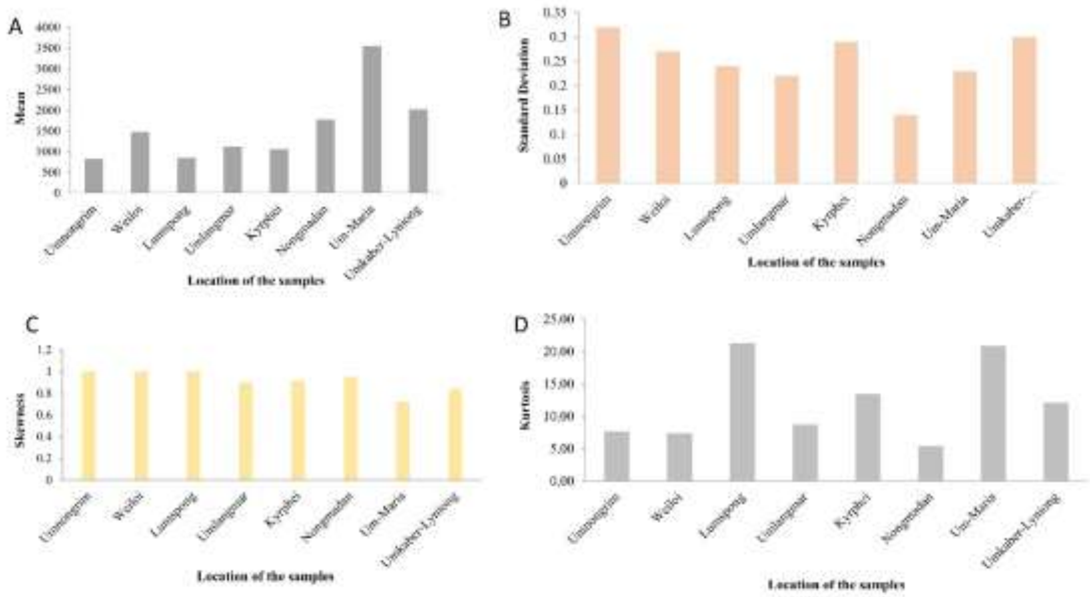

Fig. 3, Graphical representation of Mean, Sorting, and Skewness

Table 3, Result of the grain size statistical parameters (Average)

Table 3: Result of the grain size statistical parameters (Average)

Location	Samples	Mean	Sorting		Skewness		Kurtosis	
Umnongrim	S1-S15	831.57	0.32		1		7.64	
Weiloi	S16-S21	1472.67	0.27		1		7.4	
Lumspong	S22-S32	852.11	0.24	Very well sorted	1	Very coarse skewed	21.27	Extremely leptokurtic
Umlangmar	S33-S53	1117.82	0.22		0.9		8.69	
Kyrphei	S54-S80	1062.13	0.29		0.91		13.49	
Nongmadan	S81-S84	1768.94	0.14		0.95		5.41	
Um Mar-ia	S85-S95	3556.64	0.23		0.72		20.93	
Umkaber-Lyniong	S96-S100	2019.72	0.3		0.84		12.08	

Sorting is a measure of the standard deviation. The result analysed shows a standard deviation of 0.3 to 0.32, which indicates a very well-sorted grain size of a very high energy current, suggestive of a marine environment typically common on the shallow marine shelf (Blott & Pye, 2001). Skewness reflects the symmetry or asymmetry of the frequency distribution of the sediments, where its positive and negative sign relates to its environmental energy of deposition (Roy Lindholm, 1987). If there is more material in the coarse tail, it is considered as coarse skewed and the skewness is referred to as positive for metric scale and negative for phi scale. But for the present study, since we are using the metric scale, the skewness is considered positive to avoid confusion with the phi scale values (Blott and Pye, 2001). If there is more material in the fine tail (fine skewed), it is positive for the phi scale and negative for the metric scale.

The skewness values of the samples range from 0.72 to 1, thus indicating the presence of a very coarse fraction in the population of particles. The positive values indicate skewness towards the coarser grain sizes (metric scale), and the negative values indicate skewness towards the finer grain sizes. The analysed samples are skewed towards the very coarse grain sizes, suggestive of very high energy conditions. Thus, skewness is useful in environmental diagnosis because it is directly related to the fine and coarse tails of the size distribution, and hence suggestive of the energy of deposition.

Kurtosis is a measure of whether the data are heavy-tailed or light-tailed relative to a normal distribution. High kurtosis tends to have heavy tails, and low kurtosis tends to have light tails. If the central portion is better sorted than the tails, the frequency curve is said to be excessively peaked or leptokurtic. If the tails are better sorted than the central portion, the curve is said to be flat-peaked or platykurtic. Several kurtosis values reflect the flow characteristics of the depositing medium material (Seralathan and Padmalal 1994; Baruah et al.1997; Ray et al.2006) The kurtosis values of the samples range from 5.41 to 21.27 indicating an extremely leptokurtic condition suggesting that the sediment samples have achieved its sorting in high-energy environment (Friedman, 1962).

Grain Size Distribution Pattern

Grain size analysis is an essential tool for classifying sedimentary environments (Blott and Pye,2001). It is the most fundamental property of sediment particles, providing important clues to the sediment provenance, transport history, and depositional conditions (Folk and Ward,1957; Friedman, 1979; Bui et al., 1990). Systematic presentation and analysis of grain size data provide the basis for the reconstruction of sedimentary processes and the identification of depositional environments. The following Fig.4 shows the cumulative frequency curve for each station, and Fig. 5 shows the summarised cumulative frequency curve of the Trysad and Weiloi conglomerate.

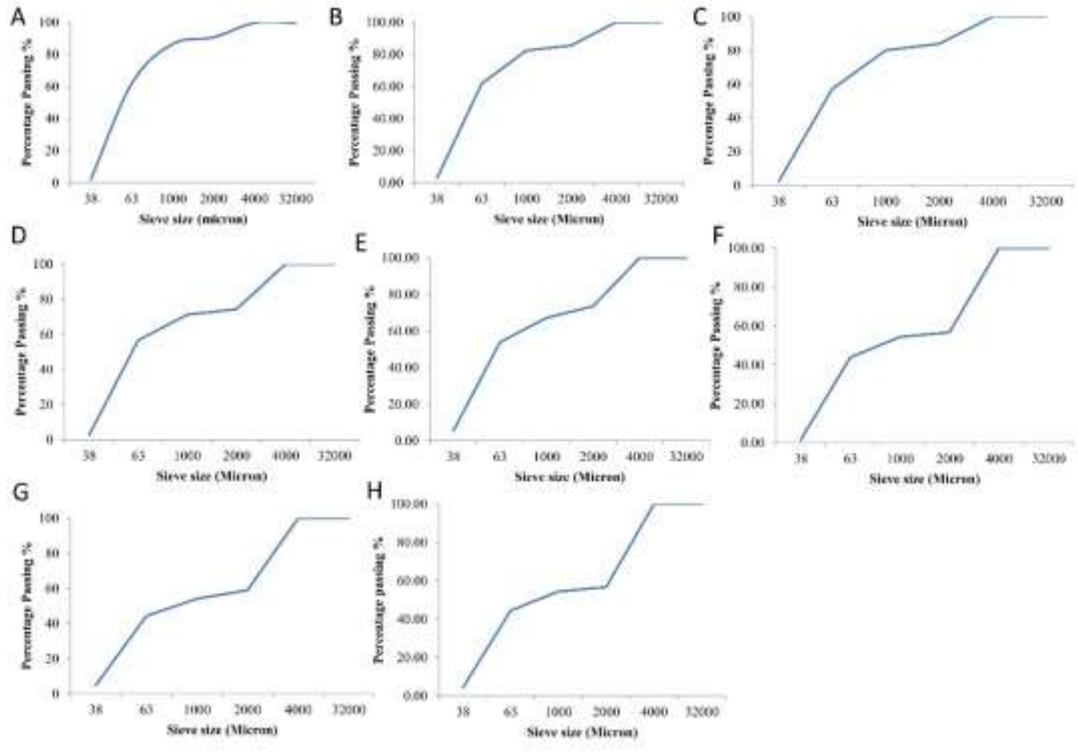

Fig.4, The cumulative frequency curve for each station

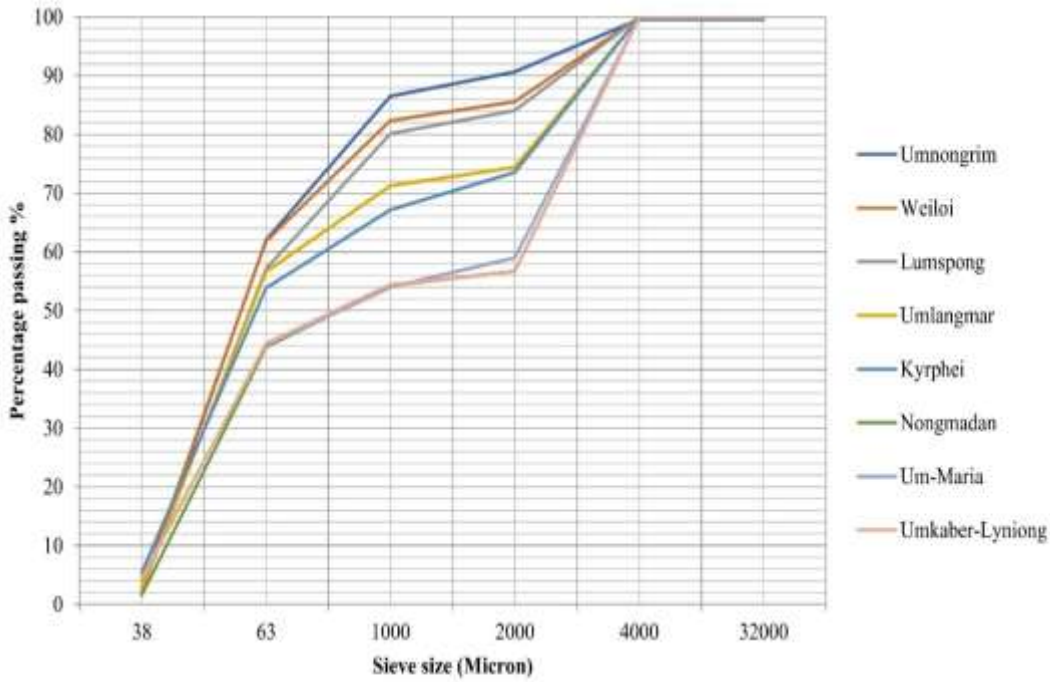

Fig. 5, Summarised cumulative frequency curve of the Trysad and Weiloi conglomerate.

The frequency curve in Fig. 5 indicates that the sediments were transported in the form of traction and saltation load, with a sharp break indicating a fluctuating energy during deposition.

Bivariate scatter graphs of grain size parameters

Bivariate plots/scatter graphs of grain size parameters have been widely used to distinguish between different depositional settings, which assumes that these statistical parameters are reliable to reflect differences in the fluid-flow mechanisms of sediment transportation and deposition. It explains certain grain size in relation to energy conditions, the medium of transportation, mode of deposition, etc (Sutherland and Lee, 1994). The correlation between mean grain size and sorting is presented in Fig. 6 (a). The analysed result showed clustering in coarse-grained sand to granule grain size. The result analysed showed that the samples are very well sorted and very coarse, skewed Fig. 6 (b), indicating a high energy environment of deposition.

Plotting of skewness against kurtosis is a powerful tool for interpreting the source of sediment, Fig. 6 (c). Based on various studies carried out by Baruah et al.1997 and Ray et al.2006 it has been suggested that variation in kurtosis values reflects the flow characteristic of the depositing medium. The result showed that all the analysed samples from eight sampling sites represent a positive skewness and are skewed towards the very coarse grain sizes, suggestive of very high energy conditions.

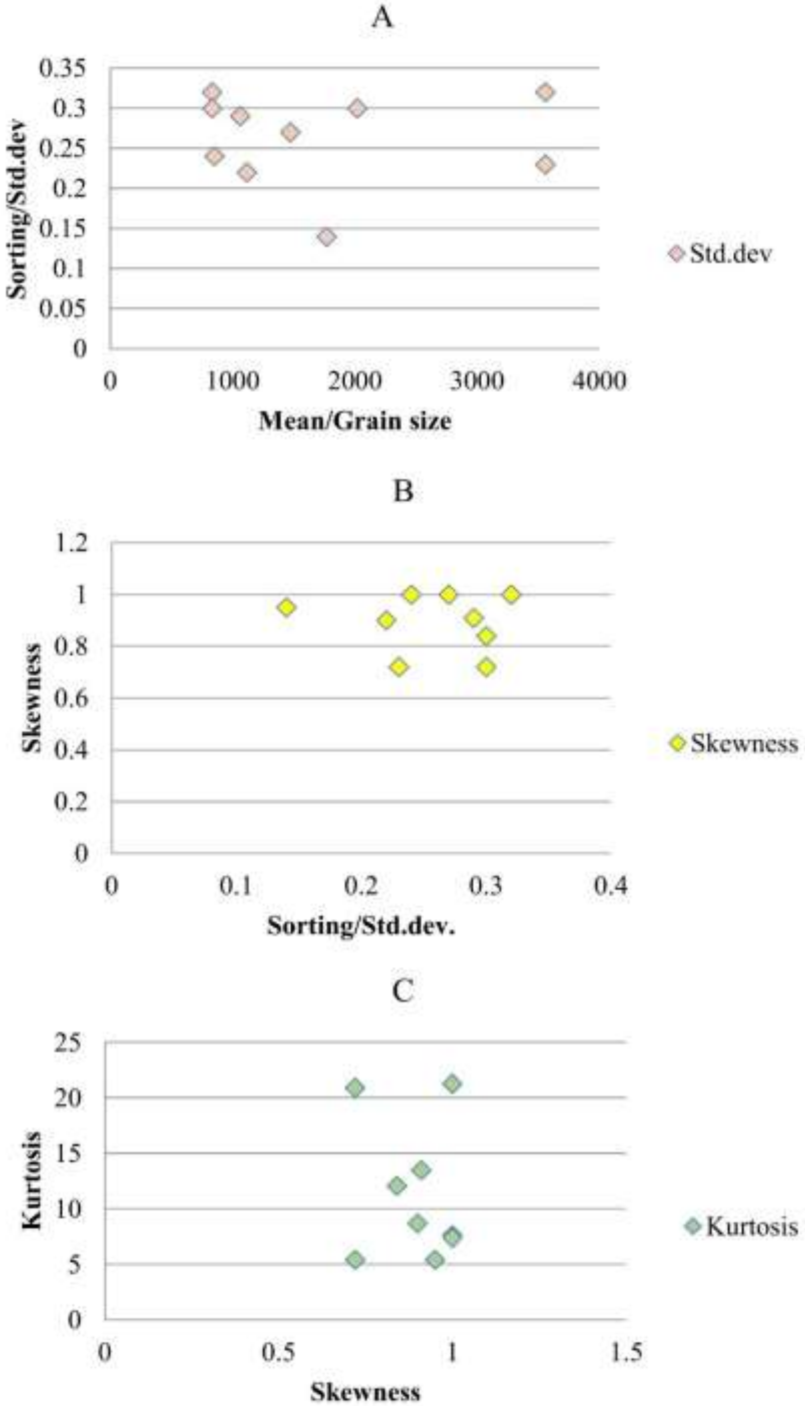

Fig.6, Correlation between mean grain size and sorting

Conclusion

The study has been carried out to address the conglomerate environment of deposition using the grain size sedimentological parameters, which form one of the basic tools for classifying sedimentary environments. The statistical summarisation of grain size parameters revealed that most of the sediments are dominated by coarse-grained sand to granule grain size, very well sorted and extremely leptokurtic, and transported in the form of traction and saltation in a fluctuating energy condition.

The exposure of these conglomerate outcrop deposits in certain pockets speaks of the enormous amount of material transported at some point in time in the distant past, displaying a high-energy environment. However, considering the dynamic tectonism in the study area, it is also difficult to determine the limits of such formations, though the present-day exposure can be defined. The Study area holds significant importance with regard to Geo-Heritage conservation as it reflects the depositional history of the conglomerates, preserving a spectacular geological age within the conglomerate deposition environment.

Acknowledgments:
This work was supported by F1-17.1/2016-17/NFST-2015-17-ST-NAG-3129/ (SA-III website) April 2016

Conflicts of Interest:
The authors declare no conflict of interest

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