GRANULOMETRIC ANALYSIS OF DEPOSITIONAL ENVIRONMENT FROM YAW FORMATION EXPOSED IN PIN DAUNG TAUNG – THA LAUK AREA, CHINDWIN BASIN

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Abstract

The research area lies within the Chindwin Basin, which is filled by the Cretaceous to Miocene clastic sedimentary rocks which are deposited between the marine to fluvial conditions. The Yaw Formation mainly consists of thin to medium-bedded, grey to bluish-grey carbonaceous silty shale and nodular clay with some intercalated buff-yellowish sandstones. Coal seams are also inter-layers with silty clay and sandstones. The Yaw Formation fall litharenites and the textural parameter shows unimodal, moderately to poorly sorted, nearly symmetrical to very positive skewness, mesokurtic to leptokurtic values that indicate fine to medium grains which are low to medium energy of current velocity condition. Bivariate plot of the standard deviation & median diameter distinguished between the river/wave and quiet water condition. Moreover, The PQ/OP segments of the CM pattern describe graded suspension with some rolled sediments as well as the segments QR point to saltation population and the grains size analysis as three populations. The log-probability curve of Yaw Formation sediments also supports the segments of the CM pattern. This indicates that the sediments of the Yaw Formation were transported and deposited in the different modes of saltation/suspension. According to petrography and grain size distribution, the sandstones of the Yaw Formation may be deposited at the low to medium energy state of the deltaic condition in shallow marine environments.

Keywords: Segment,Log probability,Yaw Formation,Chindwin Basin

Introduction

The research area is situated about 58 miles northwest of Monywa Township, Sagaing Region within the Chindwin Basin which was filled with Cretaceous–Eocene clastic sedimentary rocks (Wang *et al.*, 2014). This area lays one-inch topographic map 84J/12 (UTM-2294/07,08, 11&12) (Fig. 1 & 2). This basin was deposited in the continental environment in the northern part and shallow marine environment in the southern part at the time of Eocene (Chhibber.H.L.,1934). The mechanical analysis is to obtain numerical data about the sediment particle size. Moreover, to describe the significance of the transportation and depositional environment of the Yaw Formation in each sample.

Figure 1 Location map of the research area

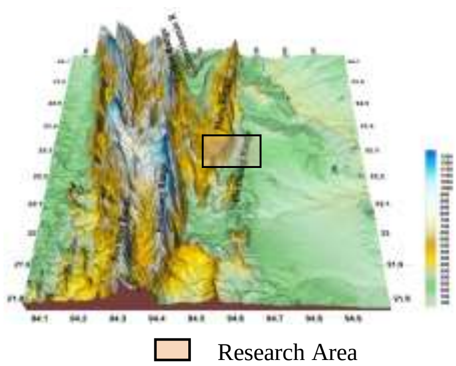

Figure 2 3-D map of the research area

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Method of Study

Firstly, loose sand samples were collected from Yaw Formation in the study area. The 100 grams of sand were sieved for 10 minutes. Sand samples in each formation were obtained by straight sieving method, using B.S screams that are spaced at one phi. The sieves are used for size determination in sand ranges between 0.625 mm and 2 mm (Folk, 1957). The results of the grain-size distribution of the sediments of the study area are shown in the form of a Histogram, Frequency, and Cumulative curve. The statistical parameter values of grain-size distribution calculated from phi values are drawn on the probability paper.

The results of the granulometric analysis were plotted as cumulative curves on arithmetic probability paper to obtain the value of the 5^{th}, 16^{th}, 25^{th}, 50^{th}, 75^{th}, 84^{th}, and 95^{th} percentile. The statistical parameter values of grain-size distribution analysis calculated from phi values are drawn on the probability paper. A study of grain size distribution thus results from the physical effect of the depositional environment conditions existing at the time of granulometric analysis.

The following formula proposed by Folk and Ward, 1957 represents the graphic mean size;

$$\text{Medium } M_d = \phi 50$$

$$\text{Mean } M_Z = \frac{\phi 16 + \phi 50 + \phi 84}{3}$$

$$\text{Sorting } \delta_I = \frac{\phi 84 - \phi 46}{4} + \frac{\phi 95 - \phi 5}{6.6}$$

$$\text{Skewness } Sk_I = \frac{\phi 16 + \phi 84 - 2\phi 50}{2(\phi 84 - \phi 16)} + \frac{\phi 5 + \phi 95 - 2\phi 50}{2(\phi 95 - \phi 5)}$$

$$\text{Kurtosis } K_G = \frac{\phi 95 - \phi 5}{2.44(\phi 75 - \phi 25)}$$

The value of C = one percentile and the value of M = 50ø (median). The baselines C-M was plotted along the co-ordinate and abscises respectively in a log-log graph paper.

Sedimentary Units

General Statement

The sedimentary units exposed in the area from descending order are the Pondaung Formation, Yaw Formation, Letkat Formation and Natma Formation from ranging Eocene to Pleistocene ages. The geological map of the study area is shown in (Fig. 3).

Yaw Formation

The term ‘Yaw stage’ was first applied by Cotter (1912) for an argillaceous sequence exposed at the Yaw Chaung at Pokakku District and the term ‘Yaw Formation’ by Aung Khin and Kyaw Win (1969).

The Yaw Formation is dominated by the sequence of thin to medium bedded, grey to bluish-grey, greenish grey, chocolate brown, purple, thinly laminated carbonaceous silty shale and nodular shale. These variegated silty shale and clay are intercalated with buff yellowish-colored, fine-grained sandstones (Fig.4). In some places, the intraformational conglomerates occurred in this Formation. Coal seams are also observed ranging in thickness from about 3 to 4 ft (Fig.5). The occurrence of grey to bluish-grey, greenish grey, chocolate brown, purple clays, carbonaceous silty shale and nodular shale with layers of coal seams (Reineck and Singh,1980) that the depositional site was influenced by shallow brackish and swampy conditions.

The lithofacies of the Yaw Formation with evidence for marine intervals, freshwater gastropod, and lignites are various yielding continental vertebrates (Licht et al., 2013) in the Chindwin Basin.

The *Nummulites yawensis*, *Discocyclina sella*, *Operculina* sp. as microforaminifera; *Velates perversus* as grastropod; and mollusca are collected from Yaw Formation and are assigned as Late Eocene age (Bender, 1983; Aye Ko Aung, 1999).

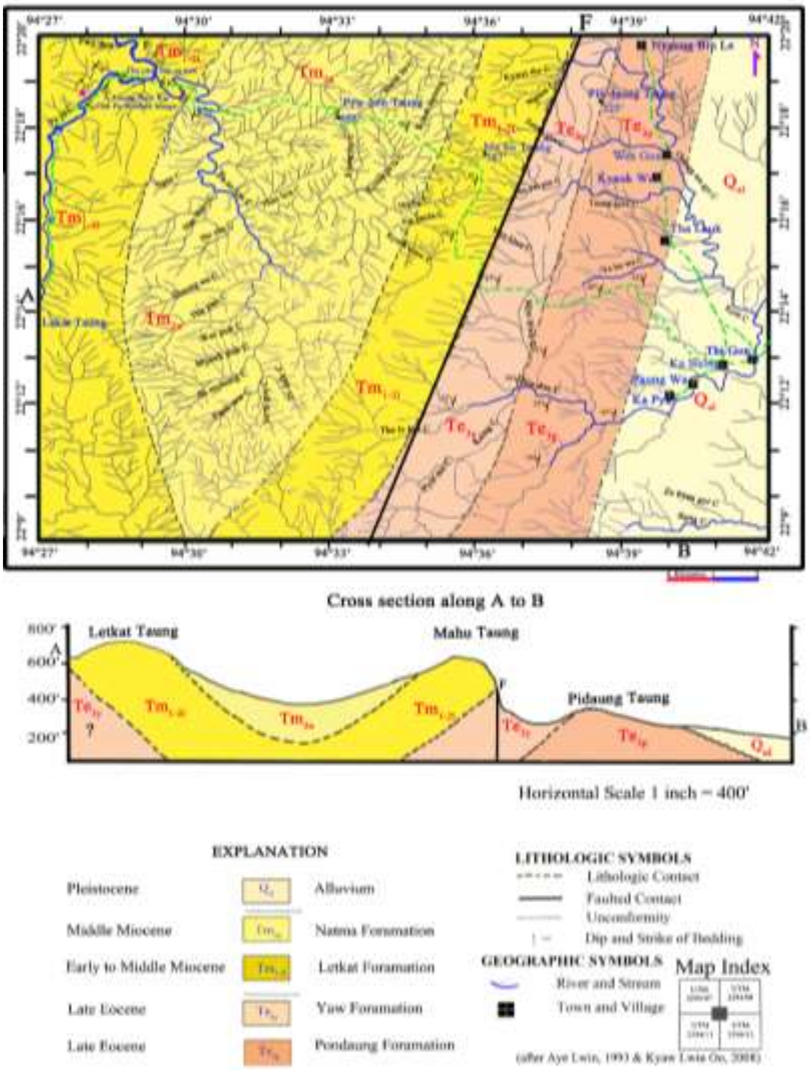

Figure 3 Geological Map of the Research Area

Figure 4 Sandstones are intercalated between the variegated clay of the Yaw Formation (22°12'07"N,94°37'10 "E)

Figure 5 Coal seams found wedge shape within the silty clay in the Yaw Formation (22°15' 40"N, 94°36'30"E)

Petrography

The sandstone of the Yaw Formation is mainly composed of about 95 % detrital grains and 5 % of chemical cement. They are poorly to moderately sorted, angular to subangular which textural maturity of this sandstone is immature.

Quartz comprises 49 to 55% of total rock volume in which monocrystalline quartz grains are more commonly than polycrystalline quartz grains (Fig.6). Generally, monocrystalline quartz shows prominent characteristics such as subrounded to angular, unique extinction, mineral inclusions and fractures.

Feldspar constitutes 19 to 24 % of the total detrital fraction. Alkali feldspar is more abundant than plagioclase feldspar. Alkali feldspar shows cross-hatched twin, lamellae twin and Carlsbad twin (Fig.7). Some plagioclase show complex twinning and is replaced by calcite cement.

Rock fragments occurred 26 to 35 % of the detrital volume (Fig. 8). Igneous rock fragments are more abundant than metamorphic and sedimentary rock fragments. Mica is composed of 3 to 5 % of the detrital fraction. Micas are frequently distorted and split apart by calcite cement.

Quartz is less than 75%, the total feldspars exceed rock fragments, and the matrix is less than 15%. So it may be termed as "Lithic arenite" (Fig. 9) condition (Pettijohn et al.,1975) in which sandstones were deposited in the deltaic environment (Tucker, M.E., 2001).

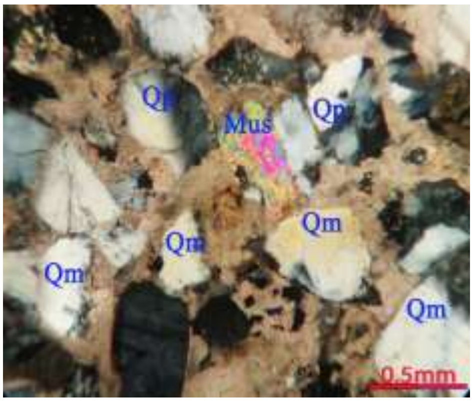

Figure 6 Showing polycrystalline quartz (Qp), monocrystalline quartz (Qm) and Muscovite (Mus) in the sandstone of the Yaw Formation under XN (10X).

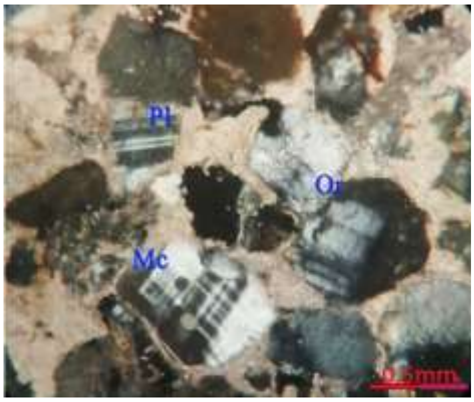

Figure 7 Showing orthoclase feldspar (Or) and plagioclase feldspar (Pl) in the sandstone of the Yaw Formation under XN (10X).

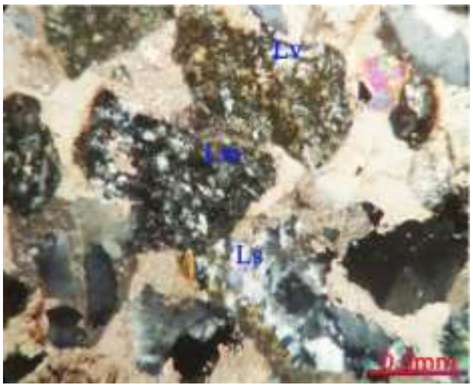

Figure 8 Showing Lv- volcanic lithic fragments, Lm- metamorphic lithic fragments, Ls- Sedimentary lithic fragments in the sandstone of the Yaw Formation under XN (10X).

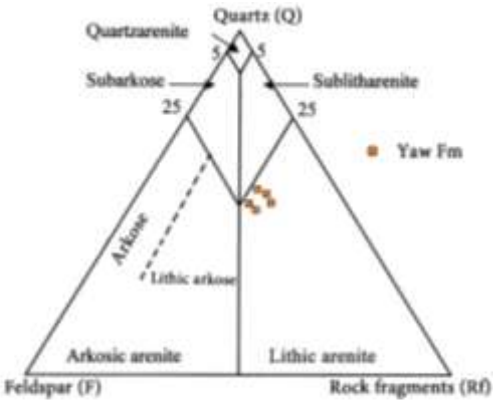

Figure 9 The samples of Yaw Formation plotted in the QFL diagram for the classification of sandstone after Dott (1964) and Pettijohn (1975).

Grain Size Distribution

The six representative samples were collected from the Yaw Formation in the research area. The C-M diagram and the analysis of log-probability size distribution curves are together used by the source of supply, depositional processes and environment (Passega 1964 & Visher 1969).

Histograms were drawn on a graph paper using the result data obtained from mechanical analysis of sands (Fig.10), which are simple bar diagrams showing the distribution of weight percent of grains in each size class in the Yaw Formation.

The shape of histograms indicates that the size distribution of the Yaw Formation's samples collected is unimodal. The unimodal sands are the result of uniformity in the force of transporting and depositing. Draw a line graph, cumulative frequency curve of the sediments that show the presence of grains coarser to finer grain size to cumulative percentage on the ordinate for each sample of the Yaw Formation (Fig.10).

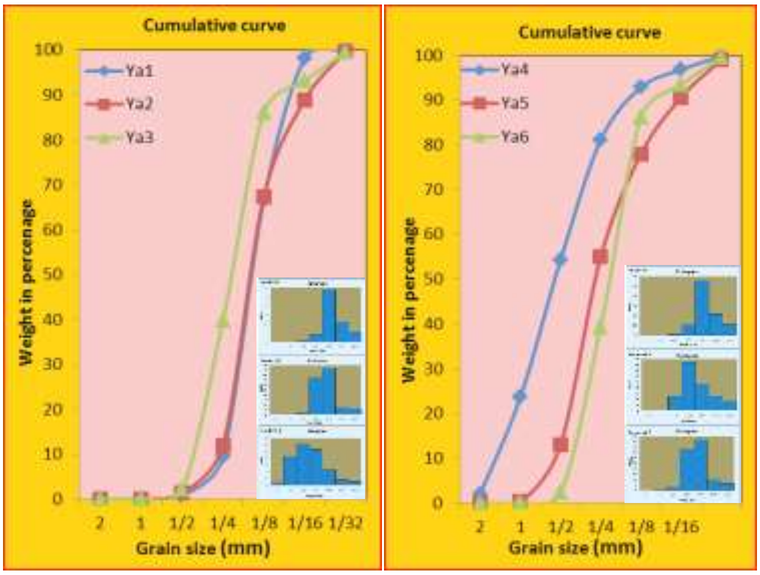

Figure 10 Representative histograms and cumulative curves of the size frequency distribution of the Yaw Formation

Statistical Calculation

The mode of Yaw sandstones is the highest midpoint on the histogram. Median indicates the corresponding 50 ø of the cumulative curve. It is significant that the median and mean diameter of the Yaw Formation range from 0.9 ø to 2.8ø and 0.9 ø to 2.9ø (Tab.1).

Table 1 Grain size distribution parameter values calculated from phi value on probability paper of the Yaw Formation

Grain size distribution parameters	**Ya_1**	**Ya_2**	**Ya_3**	**Ya_4**	**Ya_5**	**Ya_6**
Median diameter (Md)	2.8	2.6	2.5	0.9	1.9	2.4
Mean diameter (Mz)	2.8	2.9	2.3	0.9	2.1	2.3
Inclusive graphic (Sorting) standard deviation (δ_1)	0.8	0.9	0.9	1.2	1.0	0.9
Inclusive graphic Skewness (S_{KL})	0.09	0.5	0.07	0.2	0.5	0.06
Graphic Kurtosis (Kg)	1	1	1.1	1.1	1.4	1.2

Standard deviation describes the degree of scattering of the grain particles. The standard derivation varies from 0.8ø to 1.2ø (Fig. 11) which is moderate to poorly sorted in Yaw Formation. This sorting is about 20% moderate sorted and 80% poorly sorted that indicated the low to medium energy condition which will be recognized as minor variability in current velocity (Folk and Ward., 1957). The Yaw Formation is no longer transported agents as well as deposition agents due to the distribution of different grain sizes.

Skewness measures the asymmetry of the grain size frequency. The skewness ranges from 0.06ø to 0.5ø (Fig. 12) of the Yaw Formation indicating nearly symmetrical (33%) to very positive skewness (66%). In the positively skewed distribution, the mean is always higher or greater than the median or mode, supporting that both the median and mean are shifted toward finer grains size (Fig. 12). So that many medium to fine sand, silt and clay are not removed by current, but trapped between large grains distribution (Friedman. 1967). Most of the samples are strongly fine skewed and the rest are nearly symmetrical. These sediments show a tendency for more material in the fine tail.

Kurtosis shows the peakedness of a grain size-frequency distribution curve. The kurtosis value of the samples ranges from 1ø to 1.4ø (Fig. 13) representative of mesokurtic to leptokurtic kurtosis in the Yaw Formation. About 67% mesokurtic, and 33 % leptokurtic value shows that in major cases, tails and the central portion are equally sorted which has a better sorted central portion (Folk and Ward, 1957).

Statistical parameters obtained by the method were plotted in different bivariate diagrams to confirm prevailing environment conditions (Stewart, 1958). In the case of statistical parameters obtained by the graphic method as a river, wave, deltaic and quiet water condition subenvironments. The plot between standard deviation and median diameter is also absorbed by proportions of two size modes in the mixture. According to Stewart (1958), most of all Yaw sediments were plotted in the research area between the quiet water and wave water processes (Fig.14). The bivariate shows that most of the samples clustered in the deltaic environment.

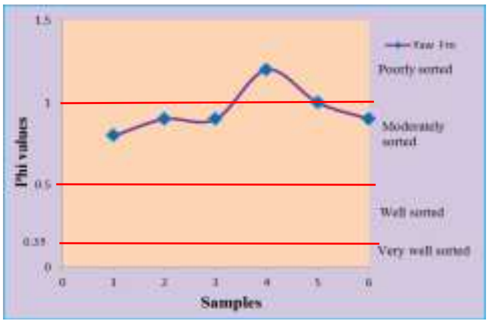

Figure 11 Sorting values of the Yaw Formation (Folk and Ward, 1957)

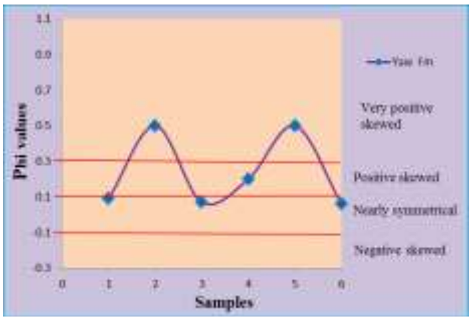

Figure 12 Skewness values of the Yaw Formation (Folk and Ward's,1957)

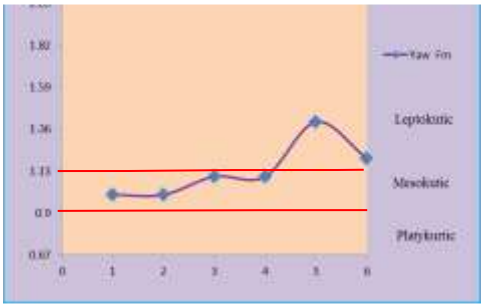

Figure 13 Kurtosis values of the Yaw Formation (Folk and Ward, 1957)

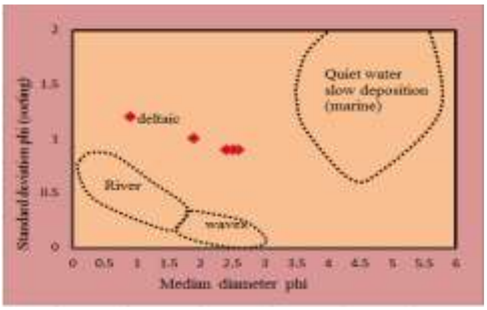

Figure 14 Bivariate plot showing standard deviation & median diameter of Yaw Formation (Stewart,1958)

C-M Pattern

Passega (1964) suggested the use of C-M diagrams for environmental analysis. The relationship between the C and M pattern of Yaw Formation is the effect of sorting by bottom confusions (Tab.2). It helps to establish a relationship between the depositional environment and prevailing hydrodynamic conditions. The plotted result of Yaw sediment samples are transported by suspension and rolling (PQ), rolling and suspension (OP) and graded suspension, mainly saltation (QR) sector supply (Fig.15). The PQ/OP segments express graded suspension with some rolled sediments as well as the segments QR point to the saltation population. Yaw sediments are predominantly rolling, saltation and suspension population because some deposits to be formed in the deltaic condition (Passega,1964).

Therefore, the C-M pattern may be interpreted that the sediments of the Yaw sandstones being deposited by the tractive current through graded suspension processes in the deltaic condition.

Table 2 Result of the percentiles, C-M pattern of the Yaw Formation

Sample No.	ø 1 (one phi percent)	ø50 (Median)	**C-M** values	
			C in micron	**M** in micron
Ya1	1	2.8	500	144
Ya2	0.8	2.9	572	134
Ya3	0.5	2.3	710	203
Ya4	0.4	0.9	752	536
Ya5	2	2.1	250	234
Ya6	0.6	2.3	662	203

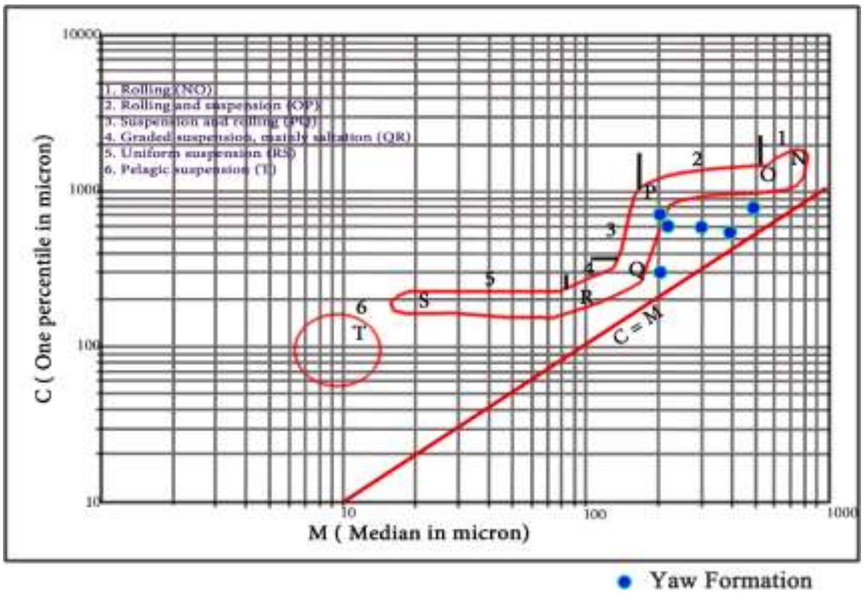

Figure 15 C-M pattern of the Yaw Formation

Log-Probability Curve

The grain sizes of the frequency curves to separate the populations are aided by the use of log probability plots (Visher, 1969). Visher plot for sediments from the Yaw Formation shows the dominance of double saltation suspension with single suspension and traction population (Fig.16). The saltation and suspension populations may range up to 29% and 95% respectively. The saltation populations are fairly better sorted than the suspension population. However, one of the samples indicates around 0.8ø values and the other samples show around 3.4ø values of the traction population. The break population of the log-probability curves for the Yaw Formation could be due to the mixing of detritus carried by tractive currents with different energy. Three and four segments of the population, truncation and saltation population are related to the traction that was confirmed by coarse truncation and fine truncation in the study area. From above the log probability data, the samples of the Yaw were deposited in the deltaic environment (Visher, 1969).

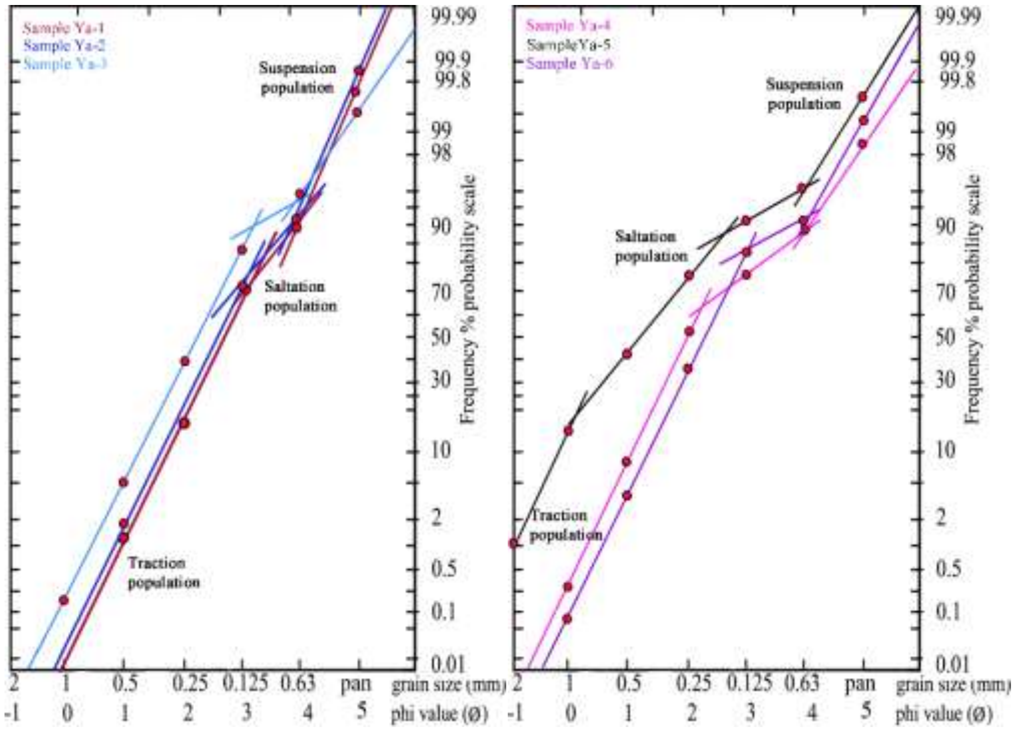

Figure 16 Log-probability curve of the Yaw Formation

Discussion and Conclusion

The research area is placed within the Chindwin basin which was deposited by continental to shallow marine sediments. According to the sequence stratigraphy (Myo Thant, 2006 & Kyaw Linn Oo, 2008), the sedimentary facies (Licht et al., 2013) in the Kalewa-Mawleik Area, at the Chindwin basin was deposited in the delta front to delta plain environment condition.

Thus, various approaches were made to interpret grain size analysis for depositional environments in the research area. The lithic arenite sandstones of the Yaw Formation were deposited from deltaic environmental conditions. The grain size distribution of the Yaw Formation is moderate to poorly sorted, nearly symmetrical to positive skewed and mesokurtic to leptokurtic kurtosis that is not removed by current, but trapped between large grains distribution indicated a relatively low to medium energy condition. Furthermore, PQ, OP and OR segments of the C-M pattern of the Yaw sediments indicate they were deposited mostly from suspension, rolling/ saltation and graded suspension. Then, the saltation and suspension population from the log probability curve ranges about nearly 29% and 95% that suggesting a different mode of transport and deposition which is deposited in deltaic conditions.

The basis of facies description, petrology and grain size analysis, it can be determined and interpreted that all sediments of the Yaw Formation have been deposited by the low to medium energy state in a deltaic condition which lies between the marginal marine and the shallow marine environment.

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