Grain Size Analysis of the Khabo Sandstone Exposed in Aungchantha-Hlaingpan Area, Pyawbwe Township, Mandalay Region

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Abstract

The present work mainly focuses on the grain size analysis of the Khabo Sandstone exposed in the Aungchantha-Hlaingpan area, Pyawbwe Township, Mandalay Region. The characteristics of the depositional agents are reflected in the texture of the sediments. Seven samples of friable sandstone from the Khabo Sandstone were collected and analysed in order to obtain graphical presentation, statistical parameters and log-probability plots. The histograms show unimodal distribution and the total weight percent of the finer admixtures are more than that of the coarse admixtures. It indicates these sediments are considered to be deposited far from the source. Based on the results of the sorting values, the sediments were derived from the distal source area and deposited in river estuaries and delta environments. The sandstones may have been deposited into a turbulent environment because of these sediments are nearly symmetrical- to fine-skewed. Many samples are mesokurtic but some are leptokurtic. This indicates that Khabo Sandstone was deposited in high energy flow environment. The log-probability plots of the Sandstone generally have distinct shapes characterized mainly by fine grained and largely transported by saltation processes. Grain size data indicated that the sediments of the Khabo Sandstone were probably deposited under shallow marine to tidal channel environments.

Keywords: Khabo Sandstone, grain size, saltation processes, shallow marine, tidal channel environment

Introduction

The research area is situated in the Pyawbwe Township, Mandalay Region. This area lies between North Latitude 20° 30' to 20° 45' and East Longitude 95° 45' to 95° 55', referring to one inch topographic map 84 P/14 (referring to UTM topographic map 2095/14), and covering an area of 476 km^2. The Yangon-Mandalay highway road passes through the western part of the study area. Therefore, it can be directly accessible from Mandalay and Meikhtila throughout the year. The location map of the research area is shown in Fig.1.

Regional Geologic Setting

Geotectonically, the research area is located in the Central Cenozoic Belt, which is separated into eastern trough and western trough by Central Plutovolcanic Line. This area lies in the eastern trough of the Central Plutovolcanic Line, and northern part of Pegu Yoma. In the east, this area is bounded by regional longitudinal north-south trending strike-slip fault, which is known as Sagaing Fault. In accordance with one million-scaled geological map of Myanmar (1977), the study area is composed of Miocene sediments.

The present study mainly emphasizes on the grain size analysis of the Khabo Sandstone. Grain size distribution of the sedimentary rocks is one of the fundamental textural characteristics to indicate the evaluation of depositional environment and transportation history of sediments (Passega, 1977). Mc Laren & Bowel (1985) suggested a mathematical model which can be applied to deduce the sediment transport direction and to understand the depositional environmental conditions of the sedimentary basin.

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Grain size analysis was carried out in order to describe the significance of the statistics in sedimentology, to determine the medium of deposition and transportation, and to contribute the reasonable points for conclusive suggestions on the provenance and depositional environments of rock units in the research area.

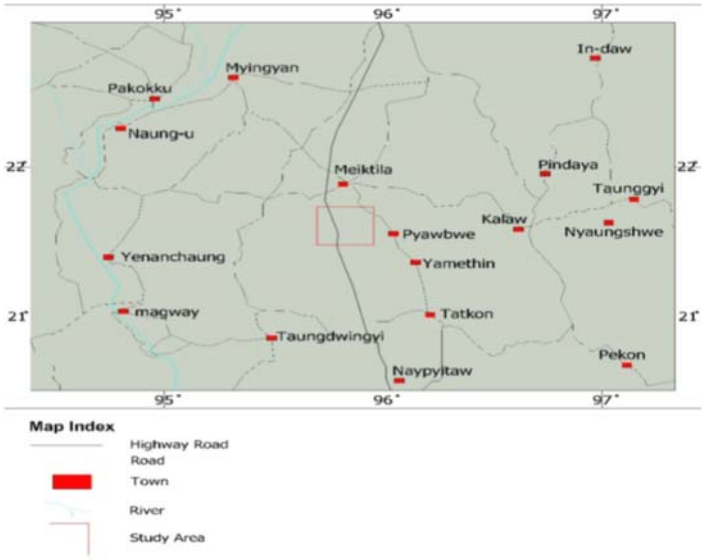

Figure (1). Location map of the Aungchantha-Hlaingpan Area, Pyawbwe Township, Mandalay Region.

Stratigraphy

In the research area, the lithologies are comprised by sandstone, siltstone, shale, mudstone, clay and intraformational conglomerates. Based on lithologic characters, sedimentary structures, paleontological evidences and the presence of an unconformity, the rock units of the present area may be divided into four main lithostratigraphic units. They are, in ascending order, Taungtalon Sandstone (Early to Middle Miocene), Moza Formation (Middle Miocene), Khabo Sandstone (Middle Miocene) and Irrawaddy Formation (Late Miocene (Pontian) to Pliocene).

Methods of Study

Loose and friable sandstone samples were collected from sections where stratigraphic measurements were made. Seven samples of friable loose sandstone were collected; 100 grams each were weighed and sieved with an ETI-PROETI-SA machine for 10 minutes using B.S sieves spaced at one-phi interval. The shape of histograms and cumulative curves depend on the weight percent in each size class. The cumulative frequency curves were plotted on a probability paper in order to obtain the values of 5^{th}, 15^{th}, 16^{th}, 25^{th}, 50^{th}, 84^{th}, 95^{th} percentiles. The mechanical data thus obtained were used in the preparation of the histograms and grain size distribution curves. Statistical parameters such as mean, median, sorting, skeweness and kurtosis were calculated by using the methods of Folk and Ward (1957).

Graphical presentation

Histograms

Histograms are simple bar diagrams showing the distribution of weight percent of grains in each size class. They can easily be constructed on a graph paper using the data obtained from mechanical analysis of sands from study area. The data to be used for histograms is shown in Table -1. According to the modal classes, the histograms of the Khabo sands are unimodal and formed by medium to fine sand (0.5-0.125 mm). The total amount by weight in coarse admixture varies from (1-42.5%) and that of fine admixtures varies from (10.6-28.9%). However, total weight in percent of the fine admixtures are more than that of coarse admixture for this formation (Table 1). It indicates that these sediments are must be far from the source (Tucker, 2001).

Cumulative Frequency Curves

Cumulative frequency curve is constructed to show the percent of grains coarser or finer than any given grain size for individual sample. They can be easily done on a semi-logarithmic paper using the data obtained from mechanical analysis of sands. The cumulative weight percent is plotted on the vertical axis with a scale running from 0 to 100 percent at corresponding class boundaries. Connecting the points thus plotted, smooth curves can be drawn when an arithmetic ordinates scale. These cumulative curve is shown in figure (2), and show mostly S shaped. The critical phi values are obtained from this curve and as shown in Table (2).

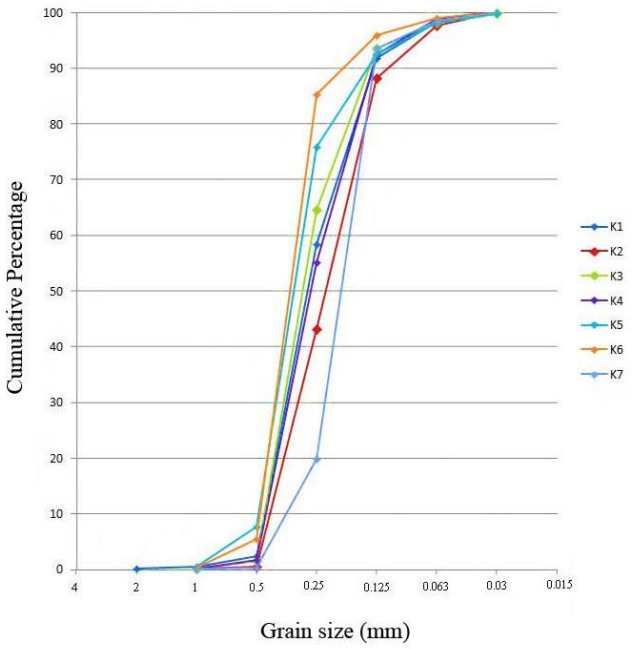

Figure (2). Cumulative curve: arithmetic ordinate scale of the Khabo Sandstone.

Table (1) Representative Mechanical Analysis of the Khabo Sandstone after sieving for cumulative curves and histogram.

Grain size (mm)	K1		K2		K3		K4		K5		K6		K7	
	Wt%	Cu Wt%	Wt%	Cu Wt%	Wt%	Cu Wt%	Wt%	Cu Wt%	Wt%	Cu Wt%	Wt%	Cu Wt%	Wt%	Cu Wt%
4-2	0.1	0.1												
2-1	0.3	0.4	0.1	0.1	0.1	0.1	0.1	0.1	0.4	0.4	0.2	0.2	0.1	0.1
1-0.5	2	2.4	0.4	0.5	1.3	1.4	1.5	1.6	7.3	7.7	5.3	5.5	0.2	0.3
0.5-0.25	56	58.4	42.7	43.2	63.1	64.5	53.6	55.2	68.2	75.9	79.8	85.3	19.5	19.8
0.25-0.125	33.4	91.8	45.1	88.3	29.1	93.6	37.3	92.5	16.7	92.6	10.7	96.0	73.8	93.6
0.125-0.063	6.5	98.3	9.3	97.6	4.5	98.1	6.3	98.8	5.5	98.1	3.1	99.1	4.9	98.5
Pan	1.8	100.1	2.4	100	1.7	99.8	1.4	100.2	1.8	99.9	1.0	100.1	1.6	100.1
Total	100.1		100		99.8		100.2		99.9		100.1		100.1	
Loss/Gain	+0.1				-0.2		+0.2		-0.1		+0.1		+0.1	

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Statistical Parameters of Grain Size

The statistical parameter of the grain size distribution such as 5th, 15th, 16th, 25th, 50th, 84th, 95th percentiles read from the segments by finding the corresponding grain size value in phi (ϕ) which were plotted on probability ordinate scale in Table (2). The grain size distribution parameter values can be obtained by the formula as defined by Folk and Ward (1957). These parameter values are shown in Table (3).

Table (2) Results of the critical Phi (ϕ) values from the Khabo Sandstone.

Sample No	ϕ5	ϕ16	ϕ25	ϕ50	ϕ75	ϕ84	ϕ95
K1	1.15	1.48	1.63	1.93	2.45	2.7	3.32
K2	1.39	1.68	1.8	2.12	2.62	2.85	3.52
K3	1.2	1.46	1.6	1.85	2.24	2.5	3.05
K4	1.2	1.5	1.64	1.92	2.4	2.62	3.17
K5	0.79	1.2	1.35	1.67	1.98	2.4	3.3
K6	0.98	1.22	1.35	1.6	1.88	2.0	2.83
K7	1.58	1.98	2.07	2.38	2.68	2.81	3.18

Table (3) Grain size distribution parameter values of the Khabo Sandstone.

Sample No	Grain Size Distribution Parameters				
	Median Diameter (M_d)	Mean Diameter (M_z)	Inclusive graphic Skewness (SK_1)	Graphic Kurtosis (K_G)	Standard sorting deviation (σ_1)
K1	1.93	2.036	0.179	1.084	0.634
K2	2.12	2.127	0.281	1.064	0.616
K3	1.85	1.937	0.274	1.184	0.540
K4	1.92	2.013	0.259	1.063	0.578
K5	1.67	1.757	0.247	1.659	0.686
K6	1.6	1.607	0.163	1.446	0.478
K7	2.38	2.39	0.018	1.075	0.450

Median and Mean size

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Median size is the central tendency of the size distribution which is determined by the point of crossing the cumulative curve and the 50th percentline. Mean size is the average size which is determined by the formula ((ϕ16 + ϕ50 + ϕ84)/3) of Folk and Ward (1957). The value of mean size is a better measure of average size than median. The values of the median and mean diameter are not much different each other shown in Table (3). Values of median size range from 1.6 to 2.38, and mean size ranges from 1.607 to 2.39. Generally, it is noted that mean diameter is little greater than the median diameter in all samples.

Standard Deviation (Sorting)

Standard deviation is a measure of spread around the mean. Folk and Ward's 1957 measure of sorting is the inclusive graphic standard deviation (σ_1). Sorting values of the sediments of the Khabo Sandstone range from 0.450 to 0.686 and their positions are plotted in the Folk and Ward's 1957 verbal scale of sorting shown in figure (3). From this figure, it is noted that all sediments of the Khabo Sandstone are moderately well sorted to well-sorted. It is dependent only on the transportation. Well sorted, fine- to medium- grained sandstone was derived by far from the source area and deposited in river estuaries and deltas environments (Reineck and Singh, 1980).

Skewness

Skewness measures the asymmetry of the distribution around the mean. Folk and Ward's 1957 measure of skewness is the inclusive graphic skewness (S_K). If there is more material in the coarse tail (coarse skewed) with negative skewness, whereas more material in the fine tail (fine skewed) with positive skewness. It is also a reflection of the depositional environment. Skewness values of the sediments are range from 0.018 to 0.281 respectively. The sediments are nearly symmetrical- to fine-skewed shown in figure (4). These sediments may have been deposited into a turbulent environment (Tucker, 2001).

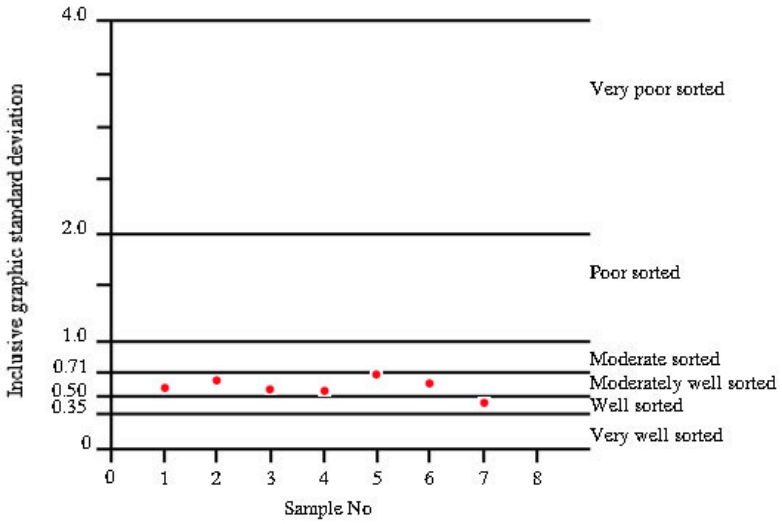

Figure (3) Sorting values of the sediments for the Khabo Sandstone.

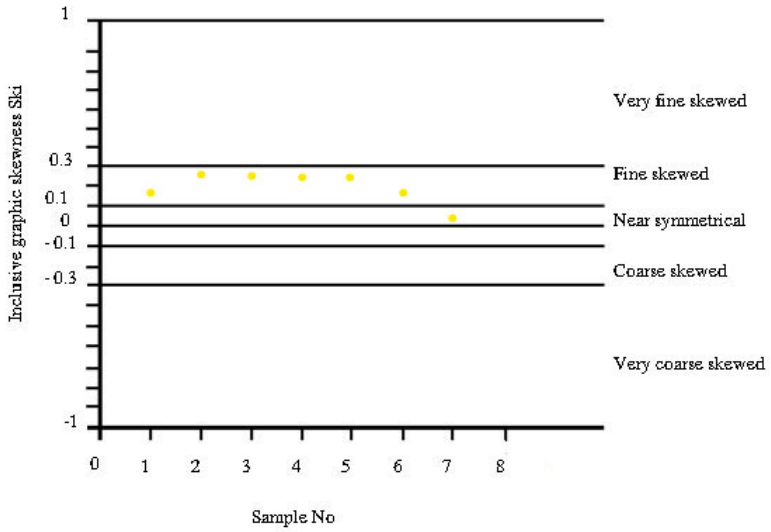

Figure (4) Skewness values of the sediments of the Khabo Sandstone plotted in the Folk and Ward's (1957) verbal scale of sorting.

Kurtosis

Kurtosis measures the ratio between the sorting in the tails of the distribution and the sorting in the central portion of the distribution. Folk and Ward's 1957 measure of kurtosis is the graphic kurtosis (K_G). Kurtosis values of the Khabo Sandstone range from 1.063 to 1.659 respectively. Following Fork and Ward's verbal limit, most samples of the Khabo Sandstone are mesokurtic and some are leptokurtic (figure 5). Mesokurtic show moderate energy flow and leptokurtic show high energy flow. This fact indicates that Khabo Sandstones were deposited by moderately to high energy flow environment.

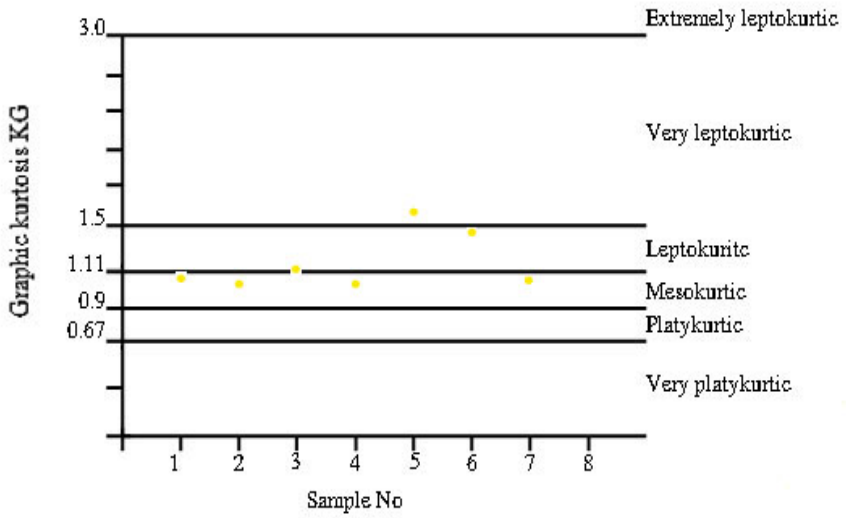

Figure (5) Kurtosis values of the sediments of Khabo Sandstone plotted in the Folk and Ward's (1957) verbal scale of sorting.

Log Probability Plots of the Khabo Sandstone

The relation of sediment transport dynamics to the population and truncation points in the grain size distribution can be well represented by the log-probability plots (Visher, 1969). Visher (1969) suggested that cumulative frequency curves could often be subdivided into two, three or four linear segments and each of which are represent a separate sub populations whose character was determined by dynamics of transport: traction, saltation and suspension separated by coarse truncation (C.T) and fine truncation points (F.T). In the log probability plot, the coarsest grained sediments were represented by the population transported as surface creep or rolling. The intermediate segments which also known as saltation transport, whereas the suspension population is well illustrated by the fine end segment or the last segment. The number, amount of size range, mixing and sorting of the sub-populations of a sample vary systematically in response to provenance, sedimentary process and sedimentary dynamics (Visher, 1969).

From the study, it has been observed that the sediments were transported mostly by saltation, suspension and rolling processes. The C.T and F.T vary from 0.9ϕ to 1.25ϕ and 1.9ϕ to 3.1 ϕ respectively (Table 4). Representative log-probability grain size distribution curves are shown in figure (6). The rolling of the present sediments varies from 0.3% to7.5% (Av. 2.99%) which the size range 0ϕ to 1ϕ. It indicates that a little amount of sediments were transported by rolling which further implies the continuous action of current. The saltation population here varies from 42.5% to 93.2% (Av. 73.29%) having a size range of 1ϕ to 3ϕ (Table 4). The dominance of this population indicates that the majority of the sediments were fine grained and transported mainly by saltation processes. The sediments of the Khabo Sandstone belonging to this population were well sorted and size range varies from fine to very fine grained indicate that shallow marine environment to tidal channel environment (Visher, 1969).

Table (4) Phi values of C.T and F.T and different population percentages of the Khabo Sandstone.

Sample No	C.T (phi)	F.T (phi)	Saltation (%)	Suspension (%)	Surface Creep or Rolling (%)
K1	1	1.9	56.5	41	2.5
K2	1	2.1	42.5	57	0.5
K3	1.1	2.8	86.4	10.1	3.5
K4	0.9	2.3	82.4	17	0.6
K5	1.1	2.1	70.5	22	7.5
K6	1.1	2	81.5	12.5	6
K7	1.25	3.1	93.2	6.5	0.3

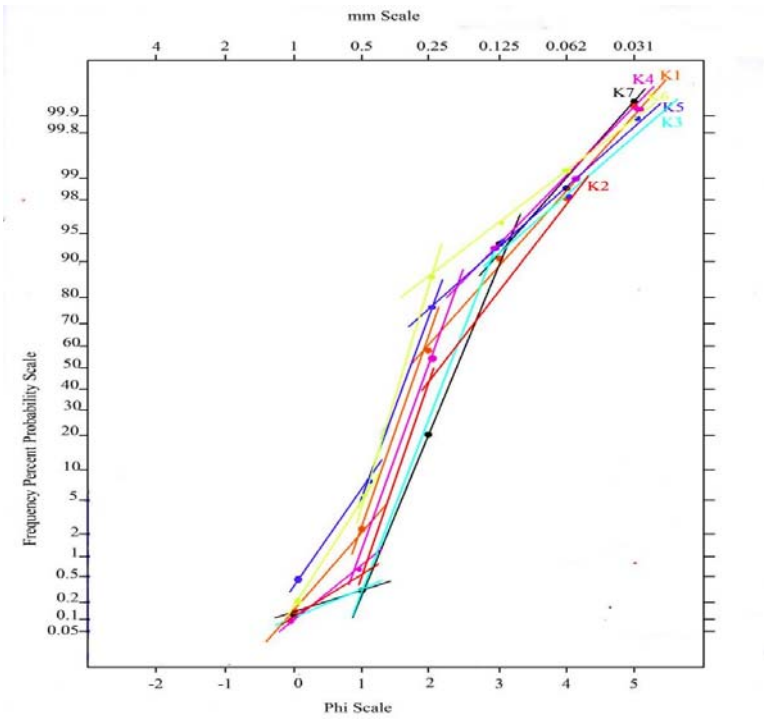

Figure (6) Log-probability grain size distribution curves of the sandstone of the Khabo Sandstone.

Summary and Conclusions

The determination of the depositional environments of the ancient sand is a difficult problem, and in most processes: physical, biological and chemical criteria are needed before a strong interpretation is possible. Although the depositional environment obtained from other information such as sedimentary structures, fauna and mineralogy, textural information may provide probably the confirming data needed for environmental information. Therefore, the emphasis of this research has been studied to know the depositional environment of the area by the approach to textural analysis. The histograms of the Khabo Sandstone are unimodal, and the total weight percent of the fine admixtures are more than that of coarse admixture. It indicates that these sediments are must be far from the source. The values of median and mean diameters are not much different each other. Well sorted, fine to medium grained sandstone was derived by far from the source area and deposited in river estuaries and delta environments. These sediments may have been deposited into a turbulent environment because of the sediments are nearly symmetrical to fine skewed. Many samples are mesokurtic and some are leptokurtic. This fact indicates that Khabo Sandstone deposited by moderately to high energy flow environment. The analysis of log-probability grain size distribution curve appears to be an effective method for studying sedimentary dynamics. As the results of the log-probability grain-size distribution curve, the majority of the sediments were fine grained and transported mainly by saltation processes. The sediments belonging to this population were well sorted and size range varies from fine to very fine grained indicates that the Khabo Sandstone of the research area may be deposited in the shallow marine environment to tidal channel environment.

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References

Folk, R. L. and Word, W. C., 1957. Brazos River bar, a study in the significance of grain-size parameters. J. Sediment. Petrol., 27: 3-27.

Myint Thein, 1966. Stratigraphy and Structure of the Taungtalon Area. MSc thesis, Mandalay University.

Myint Thein, 2010: Relation of Grain-Size Patterns (CM Pattern & Log-Probability Plots) to Environment of the Mezaligyaung Fanglomerate, Sagaing Township. Journal of the Myanmar Geosciences Society. Vol.3, no.1, pp. 71-81.

Passega,R., 1957. Textures as characteristics of Clastic Deposition. Am. Assco. Petroleum Geologists Bull., v.41 p 1952-1984.

Passega. R., 1964. Grain size representation by CM patterns as a Geological Tool. Journal of Sedimentary Petrology, Vol. 34, No.4, pp. 830-847.

Pettijohn, F.J., Potter, P.E., Siever, R., 1987. Sand and Sandstone, 2nd ed. Springer-Verlag, New York, 553pp. https://doi.org/10.1007/978-1-4612-1066-5.

Tucker, M. E., 2001. Sedimentary Petrology: An Introduction to the Origin of Sedimentary Rocks, 3 rd edition, Black Well Scientific Publication. 262 p.

Robert L. Folk. 1964. A Review of Grain-Size Parameters. Department of Geology, University of Texas, Austin, Texas (U.S.A).

Visher, G. S., 1969. Grain-Size Distributions and Sedimentary Processes. Jour. Sedimentary Petrology, v.39, No. , p. 1074-1106.