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Granulometric Analysis Indices As Signatures of The Depositional Environment of The Bima (I) Formation At Wuyo Area, Part of Gongola Sub-Basin, Upper Benue Trough, Northeastern Nigeria

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Abstract— The Benue Trough is a major NE-SW trending rift basin of 50-150km width. It extends for over 1000km, starting from the northern margin of the Chad Basin in the north. The trough is a sedimentary basin of up to 6000m of Cretaceous to Tertiary sediments associated with volcanic rocks. It is geographically sub-divided into lower, middle and upper portions. The textural parameters computed from granulometric analysis of the Bima (I) i.e. graphical mean size, standard deviation, skewness and kurtosis yielded values ranging from 0.10 Φ -1.20 Φ, 0.624 Φ to 1.29 Φ, 0.073Φ - 0.666 Φ and 1.08 Φ - 1.55 Φ respectively. The granulometric analysis indicated that the Bima (I) is dominantly moderately sorted and are mostly positively skewed. The bivariate plots of mean versus first percentile, standard deviation versus first percentile and mean versus standard deviation of the representative samples of the Bima (I) at the Wuyo area showed mainly fluvial environments. The probability curve plots all showed two sand population which is indicative of fluvial environment of deposition. The study is significant in providing evidence for the fluvial (braided stream) origin of the Bima (I) Formation.

Keywords—Benue Trough, Bima (I) Formation, Granulometric analysis, Bivariate plots, Fluvial origin.

I. INTRODUCTION

Bima Sandstone is the name given to the continental intercalaire in the Chad Basin and Upper Benue Trough of Nigeria. It is the oldest sedimentary deposit in these regions. The composition of Bima Sandstone mainly arkose to quartz arenite and its depositional structures have generated wide speculations as to the source and environment of deposition. The Early Cretaceous continental Bima Sandstone (which is the formation of concern) unconformably overlies the Pan African basement rocks. In most places it represents by far the greatest proportion of the lithostratigraphic succession in the Upper Benue Trough. The Formation is divided into three siliciclastic members: lower (B1); middle (B2) and upper (B3) members.

Grain size is the most fundamental property of sediment particles, affecting their entrainment, transport and deposition. Grain size analysis therefore provides important clues to the sediment provenance, transport history and depositional conditions [19]. This research is aimed at determining the origin of the sediments, using results from the sieve analysis, together with other evidences from lithofacies analysis to infer the transportation history and delineate the paleoenvironment of deposition of the Bima (I) Formation exposed at Wuyo area of Gombe State.

STUDY AREA

The study area is located in Wuyo town in Borno State and the studied section lies between latitude $10^0$15' N and longitude 11^0 12' E (Figure 1). It is characterised by undulating terrain with few flat plains. The climate is semi-arid with three distinct seasons; a long hot dry season from April to May. Day time temperatures are in the range of 36^0 to 40^0C and night time temperatures fall to 10^0 to 17^0C. This is followed by a short rainy season from May to September with a daily minimum temperature of 20^0C and a maximum of 31^0C with relative humidity of 40 to 60% and annual rainfall from 860 to 900 mm. Finally, the cold (harmattan) season runs from October to March when temperatures fall to about 20^0C and a dry dusty wind blows from the Sahara desert.

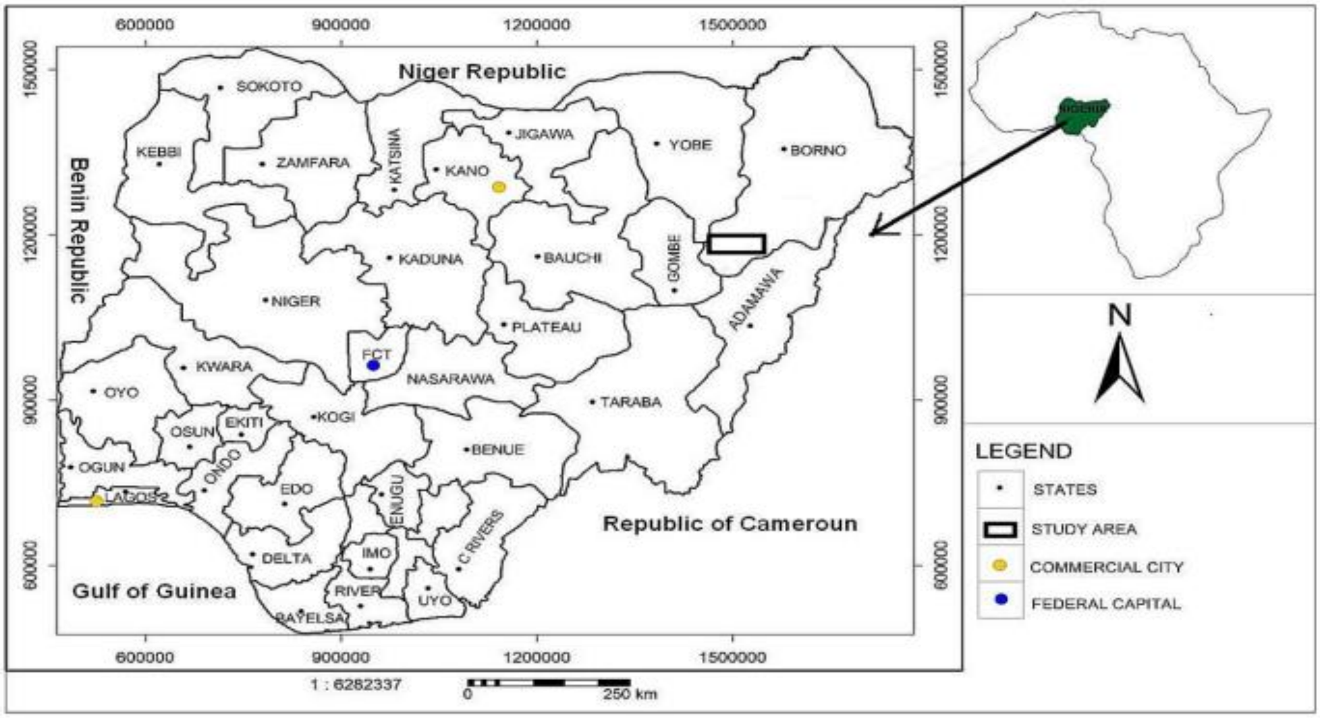

Figure 1: Map showing the location of study area

II. RELATED WORK

The regional geology and stratigraphy of the Benue Trough have been comprehensively discussed, reviewed and presented by [10,15,24,31,33,48,50]. In both arms of the Upper Benue Trough (Figure 2), the continental Albian Bima Sandstone lies unconformably on the Precambrian basement as the oldest known Cretaceous sediment in the region. The Yolde Formation which is Cenomanian to Turonian in age lies conformably on the Bima Sandstone. It is made up of a variable sequence of sandstones and shales that marks the transition from continental to marine sedimentation.

The sandstone occurrence is suggestive of a beach environment [31]. In the Gongola Arm, the laterally equivalent Gongila and Pindiga Formations lie conformably on the Yolde Formation. These Formations represent full marine incursion into the Upper Benue during the Turonian-Santonian times and are lithologically characterized by dark/black carbonaceous and pale colored limestones and shales with minor sandstones. In the Yola Arm, Dukul, Jessu, Sekule and Numanha are the Turonian-Santonian equivalents of the Gongila and Pindiga Formations. These successions are overlain by the Campanian to Maastrichtian Gombe Sandstone in the Gongola Basin and Lamja Sandstone (Lateral equivalent) in the Yola Basin [10]. The Tertiary Kerri-Kerri Formation caps the succession west of Gombe in the Gongola Basin. The Gombe Sandstone and the Kerri-Kerri Formation are lithologically composed of sandstones, siltstones and abundant coal intercalations.

AGE	UPPER BENUE TROUGH	
	GONGOLA BASIN	YOLA BASIN
PALEOCENE	KERRI-FORMATION	
MAASTRICHTIAN	GOMBE SANDSTONE	LAMJA SANDSTONE
CAMPANIAN		
SANTONIAN	PINDIGA FORMATION	NUMANHA
CONIACIAN		JESSU /SEKULE
TURONIAN	GONGILA	DUKUL FORMATION
CENOMANIAN	YOLDE FORMATION	YOLDE FORMATION
ALBIAN	BIMA SANDSTONE	BIMA SANDSTONE

Figure 2. A Generalized Stratigraphic Correlation in the Gongola and Yola Basin [33]

III. METHODOLOGY

In the field, careful examination of exposures in a section was done to have an idea about the different types of structures and textures present. This tends to give an idea on how to view a bigger picture of a whole section. The thickness across exposure was measured, the name of the locality and coordinates were recorded in a field note book. The lithological characteristics of the rocks were observed and recorded i.e. colour, sorting, grain shape, structures, fossil content, degree of induration and mineral composition of the rock. Samples were collected and labelled accordingly. Only friable and unconsolidated arenaceous samples were subjected to sieve analysis. The samples were first disintegrated into individual grains by the use of the ceramic mortar and pestle for about 200g of the loose samples collected. Each of the samples was soaked with hydrogen peroxide for about 2 to 3 hours in a beaker. This was done to further aid the disintegration of the samples, so as to get rid of the effect of cementation. The samples were then washed through a 63um mesh until it is clear of mud. The samples were then dried using electric oven and then allowed to cool down to low temperature. The samples were then weighted again in order to determine the weight of the mud that has been removed. Each of the samples was then placed in a sieve shaker and sieved for about 30 minutes using standard sieve openings of 4.75mm, 3.35mm, 2.26mm, 1.18mm, 0.850mm, 0.425mm, 0.300mm, 0.212mm, 0.106mm, 0.075mm, and 0.063mm. The statistical parameters of the grain size frequency distribution were then computed by the methods of [18,28]. A probability scale was used in plotting the normal cumulative curves of grain size distribution following the method of [14,48].

IV. RESULTS AND DISCUSSION

LITHOSTRATIGRAPHY OF THE STUDIED SECTION

The lithology of the Bima (I) Formation usually ranges from medium to coarse grained feldspathic and calcareous sandstones. A total of about 61.9m of sediments were measured consisting of mudstones and medium-coarse grained sandstones. The section consists of ten fining upwards sequence with individual cycles characterized by an erosional base overlying lithologies of either sandstone or mudstone beds. The succession of the cycles from base to top is described as follows:

The first fining upwards cycle consist of about 4.7m of sediments. The cycle comprises of 3.5m grey, poorly sorted, medium grained, and trough crossbedded sandstone overlain by a 1.2m dark grey mudstone bed.

The second cycle consists of about 6.5m of sediments. Its base is defined by a 5m grey poorly sorted, very coarse grained trough crossbedded sandstone with sub-angular grains and erosional base associated with mudclasts. This is followed by a 1.5m grey poorly sorted, very coarse grained trough crossbedded with sub-angular grains.

The third cycle consists of about 9.3m of sediments. The sequence comprises of 5m grey poorly sorted, very coarse grained trough crossbedded sandstone with sub-angular grains and erosional contact associated with pebble logs and mudclasts at it base. This is succeeded by a bed of 2.5m grey poorly sorted, very coarse grained trough crossbedded sandstone with sub- angular grains. This unit is overlain by a 1.8m dark grey mudstone.

The fourth cycle consists of about 3m of sediments and made up of one bed of grey poorly sorted, very coarse grained trough crossbedded sandstone with erosional contact.

The fifth cycle consists of about 5.7m of sediments. The succession comprises of a 2.5m grey poorly sorted, very coarse grained trough crossbedded sandstone with sub-angular grains and erosional contact at its base, and this is overlain by another bed of about 2m grey poorly sorted, very coarse grained, parallel laminated sandstone and capped by a 1.2m dark grey mudstone.

The sixth cycle is made up of three beds and it is about 6m thick. The first bed from the base is a 2m grey poorly sorted, very coarse grained trough crossbedded sandstone with sub-angular grains and erosional base associated with mudclasts. It is overlain by 2.5m grey poorly sorted, very coarse grained trough crossbedded sandstone with sub-angular grains and capped by a 1.5m dark grey mudstone.

The seventh cycle consists of about 6.5m of sediments. Its base is defined by a 5m grey poorly sorted, very coarse grained trough crossbedded sandstone with sub-angular grains and erosional base associated with mudclasts. This passes upwards to a 1.5m dark grey mudstone.

The eighth cycle consists of about 6.4m of sediments. The base is defined by a 5m grey poorly sorted, very coarse grained, trough crossbedded sandstone with sub-angular grains and erosional base associated with mudclasts. This is overlain by a 1.4m dark grey mudstone.

The ninth fining upwards cycle is composed of a 4m thick, grey poorly sorted, very coarse grained trough crossbedded sandstone with sub-angular grains and erosional base. The bed is further overlain by a 1.8m dark grey mudstone. This cycle is about 5.8m thick.

The tenth cycle consists of about 8m of sediments. The base is defined by a 6m grey poorly sorted, very coarse grained, trough crossbedded sandstone with sub-angular grains and erosional base associated with mudclasts. The bed is overlained by a 2m dark grey mudstone.

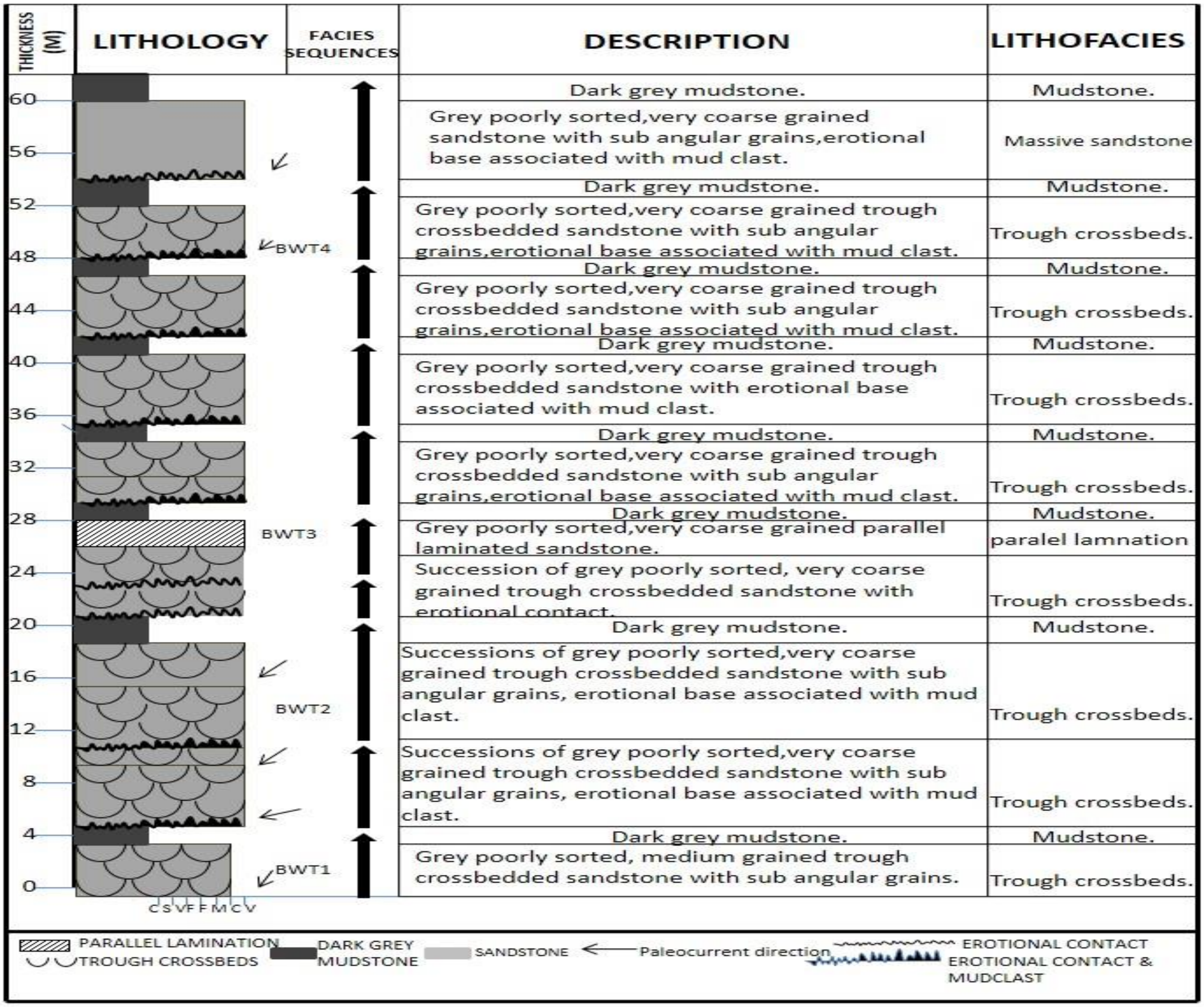

Figure 3: Studied section of Bima (1) Formation at the Wuyo Village

GRANULOMETRIC ANALYSIS

Table 1 and 2: shows the calculated values of sieve analysis and various grain size parameters. The mean, median, skewness, kurtosis and the standard deviation of the samples. The calculation of the various parameters follows [20].

SAMPLES	Φ1	Φ5	Φ 16	Φ 25		Φ 50	Φ 75	Φ 84	Φ 95
BWT1	-1.4	-0.91	-0.45	0.00		0.50	0.90	1.40	2.50
BWT2	0.1	0.10	0.30	0.40		0.60	1.50	1.90	3.50
BWT3	-1.9	-1.70	-1.10	-0.70		-0.10	0.90	1.50	2.50
BWT4	-1.0	-0.5	0.20	0.45		1.10	1.80	2.30	3.60

Samples	Graphic Mean	Graphic Sorting	Graphic Skewness	Graphic Kurtosis
BWT1	0.483 coarse grained	0.979 moderately sorted	0.073 near symmetrical	1.55 very leptokurtic
BWT2	0.933 coarse grained	0.915 moderately sorted	0.666 strongly positively skewed	1.269 leptokurtic
BWT3	0.100 coarse grained	1.29 moderately sorted	0.28 positively skewed	1.08 mesokurtic
BWT4	1.20 medium grained	0.624 moderately sorted	0.181 positively skewed	1.25 leptokurtic

GRAPHIC MEAN
The graphic mean is a parameter related to the overall grain size [20].The graphic mean value for the samples ranges from 0.10Φ -1.20 Φ, i.e. from coarse grained to medium grained sandstones. The graphic mean values of all the samples indicate the predominance of coarse grained sandstone

GRAPHIC STANDARD DEVIATION
The standard deviation measures the sorting or the uniformity of the grain-size distribution. The values obtained from the samples ranges from 0.624 Φ to 1.29 Φ, indicating moderate sorting.

SKEWNESS
Skewness is a measure of the symmetry of the distribution, i.e. the proportion of coarse or fine fractions. It is very useful in describing the depositional processes of the sediments. The skewness values derived from the samples ranges from 0.073Φ - 0.666 Φ i.e. from near symmetrical to strongly positively skewed respectively. The values obtained are indicative of a fluvial environment.

KURTOSIS
The kurtosis expresses the peakedness of the grain size distribution. The kurtosis values of the samples range from 1.08 Φ - 1.55 Φ, i.e. from mesokurtic to very Leptokurtic respectively.

PROBABILITY PLOTS
The probability plots are of environmental significance. They are indicative of either fluvial, beach, wave zone, e.t.c. According to [48] characterization. Two sand populations indicate a fluvial setting; three sand populations indicates a wave zone bars; while a four sand population is indicative of beach setting.

The probability curves were plotted from the data obtained from the sieve analysis. This is actually established from the plot of the cumulative weight percent against grain size in (phi, Φ) (figure 4 and 5).

From the Cumulative probability distribution curves (figure 4 and 5) of the analyzed samples, it is observed that all curves have only two sand population distribution (straight line segments).i.e. saltation and suspension. Thus, indicating a fluvial environment [14,48].

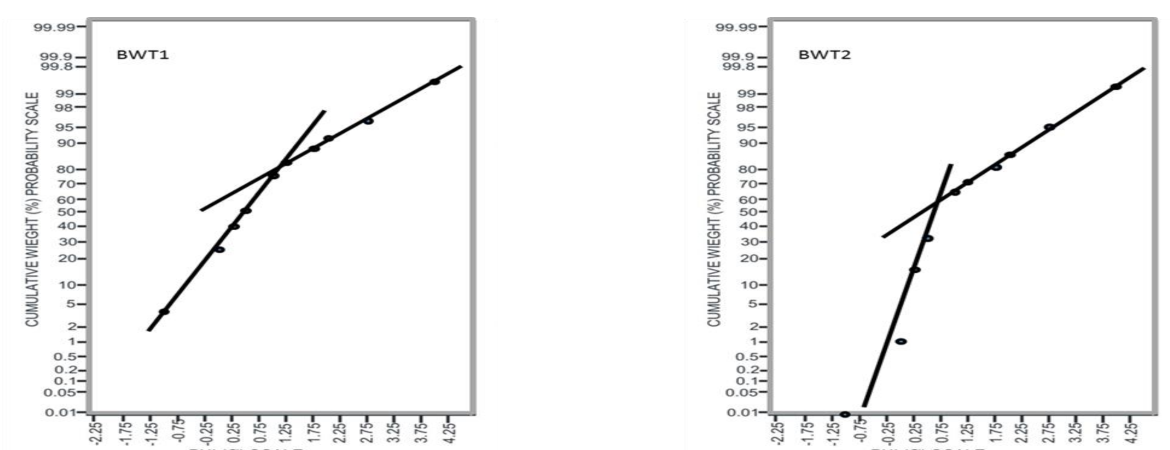

Figure 4: Plot of cumulative weight against Phi Φ Scale for sample BWT1and BWT2

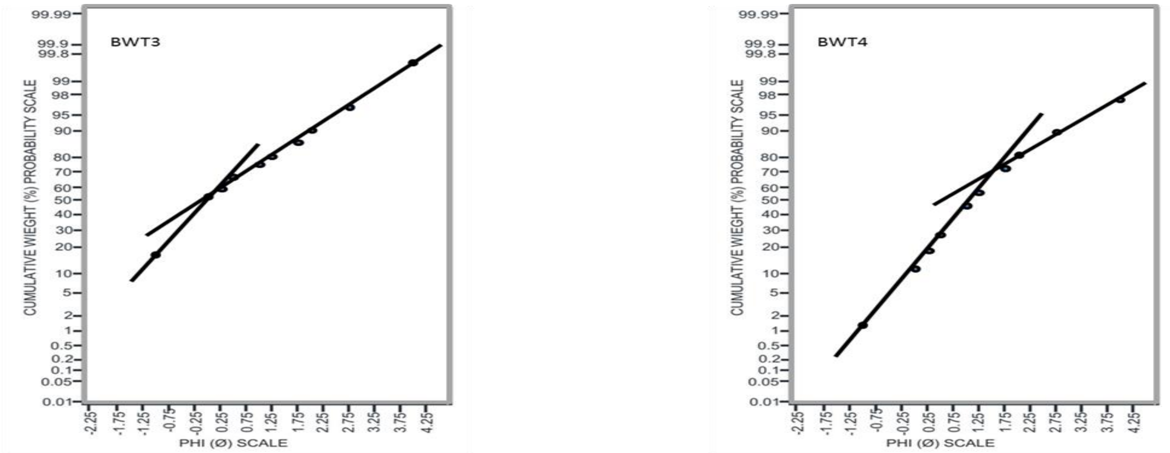

Figure 5: Plot of cumulative weight against Phi Φ Scale for sample BWT3 and BWT4

BIVARIATE GRAIN SIZE PARAMETERS

Graphic Mean, Standard Deviation, Skewness and graphic First Percentile are the parameters used in separating sands based on origin in accordance to standard plots devised by various workers. These bivariate plots include the plot of mean versus first percentile [21], standard deviation versus First percentiles [21], standard deviation versus mean [21,22,29].

MEAN VERSUS FIRST PERCENTILE

The standard plot of mean versus first percentile was based on the work of [21] which was used in distinguishing lnland dune sand from river sand (Figure 6). The plots for the samples tend to show that about 75% of the samples fell in the river sand environment and 25% on the inland dune sand.

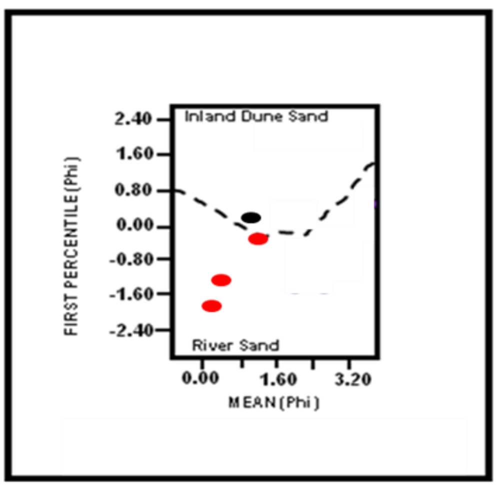

Figure 6: Bivariate plot of first percentile against mean

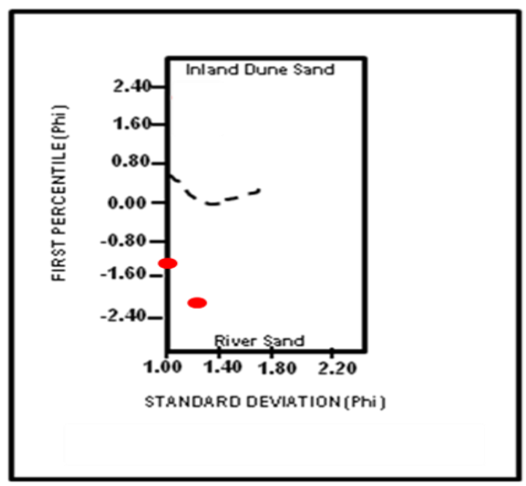

Figure 7: Bivariate plot of first percentile against Standard Deviation

STANDARD DEVIATION VERSUS FIRST PERCENTILE

The standard deviation versus first percentile is plotted in the bivariate plot (Figure 7) based on [21]. The plots indicate that about 100% of the samples plotted within the river sand field.

STANDARD DEVIATION VERSUS MEAN SIZE

The [29] plots of standard deviation versus mean size is also used in delineating dune sand from river sand. 100% of the studied samples are plotted within inland dune Sand (Figure 8).

STANDARD DEVIATION VERSUS MEAN SIZE

The plot of standard deviation versus mean size based on [21] tends to show that 100% of the sands fell into the river sand field (Figure 9).

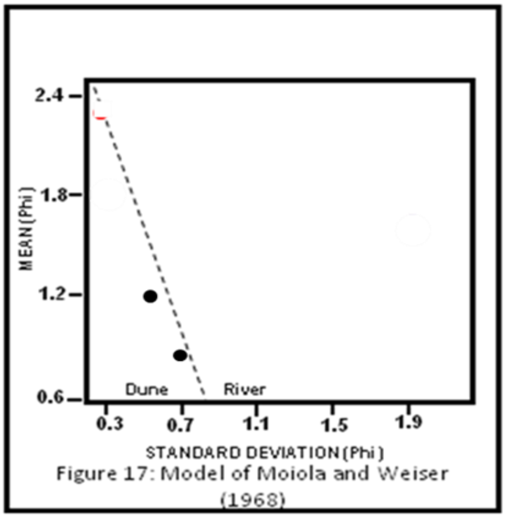

Figure 17: Model of Moiola and Weiser (1968)

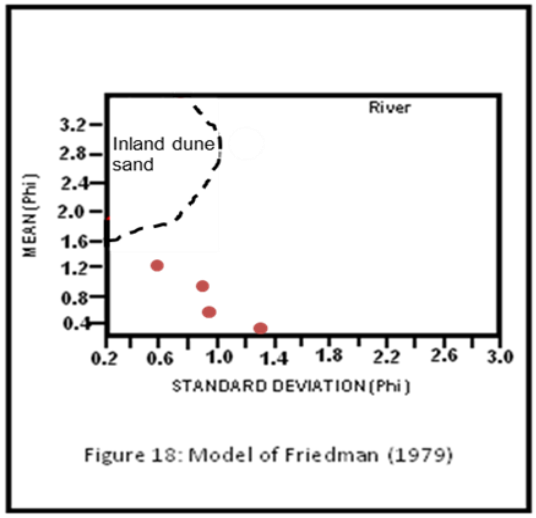

Figure 18: Model of Friedman (1979)

Figure 8 and 9: Bivariate plot of Mean against Standard Deviation

DISCUSSION

FACIES ANALYSIS (SEQUENCE)

The section of Bima (I) exposed at the Wuyo village is composed of succession of poorly sorted, medium to coarse grained sandstones with sub-angular grains usually associated with erosional base and mudclasts, these are fining to mudstone beds.

Considering the fact that there is no marine indicators, and coupled with the poorly sorting of the grains, it may be possible to suggest that the cycles are of fluvial environment. This is further supported by the unidirectional pattern of the current system.

Furthermore, due to the presence of higher percentage of sand than clay or mud in the section, the fluvial setting can be said to be formed by a braided river system. This is due to the lateral nature of the stream movement and the unstable nature of the flood plains.

Based on these facts, the environment can be suggested to be a fluvial environment and formed by braided river deposits. This is true for all the cycles as the similarities of the cycles shows that they are formed under the same hydrologic conditions.

GRANULOMETRIC ANALYSIS

The univariate grain size parameters cannot conclusively suggest a depositional environment, but it can give clues to some significant processes occurring within an environment of deposition.

Sorting depends on the sediments source, grain size and depositional regime [1].the standard deviation obtained from the granulometric analysis of the samples collected ranges from 0.624Φ – 1.29Φ, i.e. they are all moderately sorted (table 2) and this might suggest deposition under relatively moderate energy regime.

Furthermore, the fluctuation in skewness may reflect change in depositional energy level [2]. However, the samples analysed have skewness ranging from 0.073Φ -0.666Φ,i.e. from near symmetrical to strongly positively skewed(table 2). These values are characteristics of fluvial environment [21]

The results obtained from the bivariate plots of [21] for skewness versus standard deviation, [29] for skewness versus standard deviation and mean versus standard deviation suggest fluvial origin for the Bima (I) formation (figure 11-14).In addition, the results obtained from [21] plots for standard deviation versus first percentile (figure 7) supports the same claim.

These claims can further be supported by the two sand population (saltation and suspension) displayed by the samples in the probability curves (figure 4-5); which are all indicative of fluvial settings [48].

Base of the results obtained from the bivariate and univariate grain size parameters and probability plots, the Bima (I) sandstone exposed at the Wuyo village can be suggested to be deposited in a fluvial environment.

V. CONCLUSION AND FUTURE SCOPE

The section of the Bima (I) Formation at the Wuyo village composed of finning upward cycles of mudstones and medium to coarse grained sandstones sediments with total thickness of about 61.9m. It consists of ten fining upwards sequence with individual cycles characterized by an erosional base overlying lithologies of either sandstone or mudstone beds. The lithofacies similarities may also suggest hydrodynamic condition leading to their deposition is similar throughout. From the granulometric analysis and facies analysis, it is deduced that the sediments were deposited in a braided fluvial environment settings.

Extensive research should be carried out to locate and establish the mineral potentials in the Upper Benue Trough in order to rejuvenate the prospecting interest of the basin.

REFERENCES

[1] Abdel-Wahab, A., Kholief, M. and Salem, A. (1992). Sedimentological and Palaeoenvironmental studies on the clastic sequence of Gebel El-Zeit area, Gulf of Suez, Egypt. Jour. Afr. Earth sci., 14(1). 121-12.

[2] Adegoke, O.S., Agumanu, A.E., Benkhelil, M. J. and Ajayi, P.O. (1986). New stratigraphic, sedimentologic, and structural data on the Kerri-Kerri Formation, Bauchi and Borno States, Nigeria. Journal of African Earth Sciences 5(3). 249-277.

[3] Allix, P. (1983). Environment Mesozoque de la pattanard orientale de fusses de la benare (Nigeria) stratigraphic sedimentologic evolution geology namigue trav. Lab sci Terr. St. journal Marssive France B21. 1-200.

[4] Ayoola, E.O., Avbovbo, A.A and Osahon, G.A. (1986). Depositional and structural styles in Chad Basin of northeastern Nigeria. Bulletin American Association Petroleum Geologists 70. 1787-1798.

[5] Benkhelil, J. (1982). Benue Trough and Benue Chain. Geological Magazine. 119. 155-168.

[6] Benkhelil, J. (1989). The origin and evolution of the Cretaceous Benue Trough (Nigeria). Journal African earth Sciences. 8. 251-282.

[7] Bhatia, M.R., (1983). Plate tectonics and geochemical composion of sandstones, Journal of Geology. 91. 611-624.

[8] Boggs, S. Jr. (1995). Principle of Sedimentology and Stratigraphy, 2nd ed.: Prentice Hall, New Jersey. 109p.

[9] Burke. K.C., Dessauvagie, T.F.J. and Whiteman, A.J. (1970). Geological History of the Benue valley and Adjacent Areas. In: Dessuvagie, T.F. J. and Whiteman, A.S. (Editors) African Geology. Ibadan University Press, Ibadan, Nigeria. 305p.

[10] Carter, J. D., Barber, W., Tait E.A and Jones, G.P. (1963). The geology of parts of Adamawa, Bauchi and Borno provinces in north-eastern Nigeria. Bulletin Geological Survey Nigeria 30. 1-99.

[11] Coleman, J.M. and Prior, D.B. (1982). Deltaic environment of deposition in: Scholle, P.A. and Spearing, D. Sandstone and depositional environment. American Association of Petroleum Geologist special publication. Tulsa, Oklahoma. 7(2). 189-178.

[12] Cratchley, C.R. and Jones, G.P. (1965). An interpretation of the geology and gravity anomalies of the Benue Valley, Nigeria. Overseas geological Survey Geological paper. 1. 1-26.

[13] Crook, K.A.W. (1974). Lithogenesis and Geotectonics. The Significance of Compositional variations in flysch arenites (grawackes), In: Dott, R.H and Shver, R.H (Eds). Modern and Ancient Geosynclinal Sedimentation. Society of Economic Paleontologists and Mineralogist, Special Publication, 19. 304-310.

[14] Dike, E.F.C. (1972). Sedimentology of the Lower Greensand of the Isle of Wight, England. Unpub. D. Phil. Thesis, University of Oxford, England. 204p.

[15] Dike, E.F.C. (2002). Sedimentation and tectonic evolution of the Upper Benue Trough and Bornu Basin of N.E. Nigeria. NMGS/ELF Award winning paper at the 38th Nigeria Mining and Geoscience Society 2002 Annual and International Conference, Port-Harcourt.

[16] Fairhead. J.D. (1986). Geological Control on Sedimentation within African Rift Systems. Geological Society of London, special publication, 25:19-27pp.

[17] Falconer, J.D. (1911). The Geology and Geography of Northern Nigeria. Macmillian, London, 295p.

[18] Folk, R.L (1974). Petrology of sedimentary rocks. Austin Texas, Hemphill Book Store. In: scolle P.A. (Ed), A Colour illustrated guide to constituents, textures, cements and porosities sandstones and associated rocks. AAPG Memoir 28. 170-179.

[19] Folk, R.L. (1951). Stages of textural maturity in sedimentary rocks. Jou. Sed. Pet. 21. 127-130.

[20] Folk, R.L. and Ward, W.C. (1957). Brazos River bar, a study in the significance of grain-size parameters. Jou. Sed. Pet. 30. 514-529.

[21] Friedman, G.M. (1979). Differences in size distribution of populations of particles among Sands of various origins. Jou. Sed. Pet 26. 1-32.

[22] Friedman, G.M. and Sanders, J.E. (1978): principles of sedimentology. John Willey and Sons, U.S.A. 215p.

[23] Genik, G.S. (1993). Petroleum Geology of Creteceous –Tertiary Rift Basins in Niger, Chad and Central Africa Republic. Bulletin of the American Association of Petroleum Geologist 77. 1405-1434.

[24] Guiraud, R. and Maurin, J.C. (1992). Early Creteceous Rift of Western and Central Africa. Tectonophysics. 213. 152- 168.

[25] Guiraud. M. (1990). Tectono-sedimenatry framework of the Early Cretacecous continental Bima Formation (Upper Benue Trough N.E. Nigeria). Jour. Afr. Earth Sci. 10. 341-353.

[26] King, L.C. (1950). Outline and distribution of Gondwanaland. Geol. Mag. 87. 353-359.

[27] Kogbe, C.A. (1976). Outline of the geology of the Iullemmeden Basin in north-western Nigeria. In: Geology of Nigeria (Edited by Kogbe, C.A.). Elizabethan Pub. Co., Lagos, Nigeria. 331-338.

[28] Krumbien, W.C. and Pettijohn, F.J. (1938). Manual of Sedimentary Petrography: Appleton Century Craft Inc., New York. 549p.

[29] Moiola, R.J. and Weiser, D. (1968). Textural parameters: Jour. Sed. Pet. 38. 45-53.

[30] Obaje, N.G. and Abaa, S.I. (1996): Potentials for local derived gaseous hydrocarbon in the middle Benue Trough Nigeria. Jour Pet. Geo. 19. 74-89.

[31] Obaje, N.G., Olu, O.K. and Petters, S.W. (1999). Boistratigraphic and geochemical controls of hydrocarbon prospect in the Benue trough and Anambra Basin, Nigeria. NAPE. Bul. 14(1). 18-54.

[32] Offodile, M.E. (1976). The geology of the Middle Benue, Nigeria, Special Volume Palaeontological Institution University Uppsala 4. 1-66.

[33] Ojo, O. J. (1999). Depositional Environments, Palynological and organic Geochemical studies of Gongola and Yola Basins, Nigeria: Implications for Hydrocarbon Potential. Unpubl. Ph.D.The University of Ilorin, Ilorin. 355P.

[34] Olade, M.A. (1974). Evolution of Nigerian’s Benue Trough (aulacogen): a tectonic model. Geological Magazine 112. 575-583.

[35] Passega, R. (1957). Texture as characteristics of clastic deposition AAPG. Bull. 41. 1952–1984.

[36] Petters, S.W. (1978). Mid Cretaceous paleoenvironments and biostratigraphy of the Benue Trough, Nigeria, Bulletin Geological Society American. 89. 151-154.

[37] Petters, S.W. (1982). Central West African Cretaceous Tertiary benthic foraminifera and Stratigraphy. Palaeontographica Abt. Av. 179. 1-104.

[38] Pettijohn, F. J., Potter, P.E. and Siever, R. (1973). Sand and Sandstones (2nd Ed).Springer- Verlag, 407p.

[39] Pettijohn, F.J., Potter, P.E. and Siever, R. (1972). Sand and Sandstones. Springer- Verlag, New York, 618p.

[40] Popoff. M., Wiedmann, J. and De Klazz, I. (1986). The Upper Cretaceous Gongila and Pindiga Formations, Northeeastern Nigeria. Subdivisions, age stratigraphic correlations and paleogeographic implications. Ecologea Geol. Helv. 79. 343-363.

[41] Reyment, R.A. (1965). Aspect of the Geology of Nigeria, Ibadan. University Press, Nigeria. 98p.

[42] Roser, B.P. and Korsch, R.J. (1986). Determination of tectonic setting of sandstone-mudstone suites using SiO2 content K2O ratio. Jounal of Geology. 94. 635-650.
[43] Sahu, B.K. (1964). Depositional mechanisms from the size analysis of clastic sediment Jour. Sed. Pet. 34. 73-83.
[44] Samaila, N.K., Obaje, N.G. and Dada S.S. (2001). Geochemical Classification of Creteceous Bima Sandstone from the Gongola Arm, Upper Benue Trough, N.E Nigeria,. Science Forum. Journal of Pure and Applied Science, 4 (2). 190- 197.
[45] Shettima, B., Dike, E.F.C., Abubakar, M.B. and Muhammad, A.V. (2007). Facie and Facie Architecture of the Creteceous Yolde Formation in the Gongola Basin, Upper Benue Trough Nigeria. 43rd Annual and International NMGS Conference, Akure. Abstract. 48. 123-137.
[46] Simons, D.B., Richardson, E. V. and Nordin C. F. (1965). Sedimentary structures generated by flow in alluvial channel in: Middleton G.V. (Ed.), Primary sedimentary structures and their hydrodynamic interpretation. SEPM, special Pub., Tulsa, Oklahoma. 2. 34-52.
[47] Tucker, M.E. (1988). Sedimentary Petrology (ECBS. Ed) Blackwell sci. pub. Osney, Mead , Oxford Ox2. OEL. 252p.
[48] Visher., G.S. (1969). Grain-size distribution and depositional processes. Jour. Sed. Pet. 39. 1074-1106.
[49] Wright, J.B. (1981). Review of the Origin and evolution of the Benue Trough in Nigeria. Earth evolution science 2. 98- 103.
[50] Zaborski, P., Ugodulunwa, F., Idornigie, A., Nnabo, P. and Ibe, K. (1997). Stratigraphy, Structure of the Cretaceous Gongola Basin, Northeastern Nigeria. Bull centre Rech. Prod., Elf Aquitatine. 22. 153-185.
[51] Zaborski, P.M. (1998). A review of cretaceous system in Nigeria. Africa Geosciences Review, 5(3). 386-439.

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