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SEDIMENTOLOGY AND PALEOENVIRONMENT OF DEPOSITION OF THE DEBA-FULANI MEMBER OF PINDIGA FORMATION IN THE GONGOLA ARM OF THE UPPER BENUE TROUGH, NORTHEASTERN NIGERIA

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Abstract
The sedimentology and paleoenvironment of the Deba-Fulani Member of the Pindiga Formation were investigated on the basis of their grain size distribution. Granulometric analysis has indicated that the samples are generally well to moderately sorted with skewness values ranging from negatively to positively skewed which may indicate influence of both marine and fluvial conditions. Bivariate plot relationships of standard deviation vs. mean, standard deviation vs. skewness, first percentile vs. mean also indicated both fluvial and marine setting for the middle part of the Pindiga Formation member. However, most of the bivariate plot showed dominance of fluvial environment. The probability curve plot shows a prevalence of three-sand population curves which are usually associated with wave processes indicating marine conditions for most part of the Deba-Fulani Member.

Key words: Sedimentology, Paleoenvironment, Deba – Fulani Member

1. Introduction

The Deba-Fulani Member of the Turonian-Campanian Pindiga Formation are regressive sandstone defining the middle part of the formation (Zaborski *et al*.,1997). This formation is confined to the Gongola Basin of the Upper Benue Trough and it is deposited during the global marine transgression of the mid-Turonian period (Petters, 1982). Depositional environments are defined by distinct physical, chemical and biological activities. The fluctuations in energy level, climate and provenance usually defines the physical activities in a setting and this largely governs the nature of the grain size, rounding and packing of the sediments that may eventually form. The relicts of these physical activities are of environment significances and their imprints on the sandstones forming are determined statistically.

The Benue Trough is a major NE-SW trending rift basin of 50 – 150km width and over 1000km length. It is geographically sub-divided into lower, middle and upper portions (Figure 1). The Upper Benue Trough is Y shaped made up of three arms, namely: the E – W trending (Yola Arm), N – S trending (Gongola Arm or Gongola Basin) and the NE – SW trending main arm (Muri – Lau Basin) (Dike, 2002) (Figure 2). In the Gongola Arm, the (Aptian–Albian) Bima Sandstone, a continental formation represents the basal part of the sedimentary succession. It unconformably overlies the Precambrian Basement Complex and consists of three siliciclastic members: the lower Bima (B1), middle Bima (B2) and the upper Bima (B3). Its lithology and depositional environments have been discussed by (Guiraud, 1990) (Figure 3).

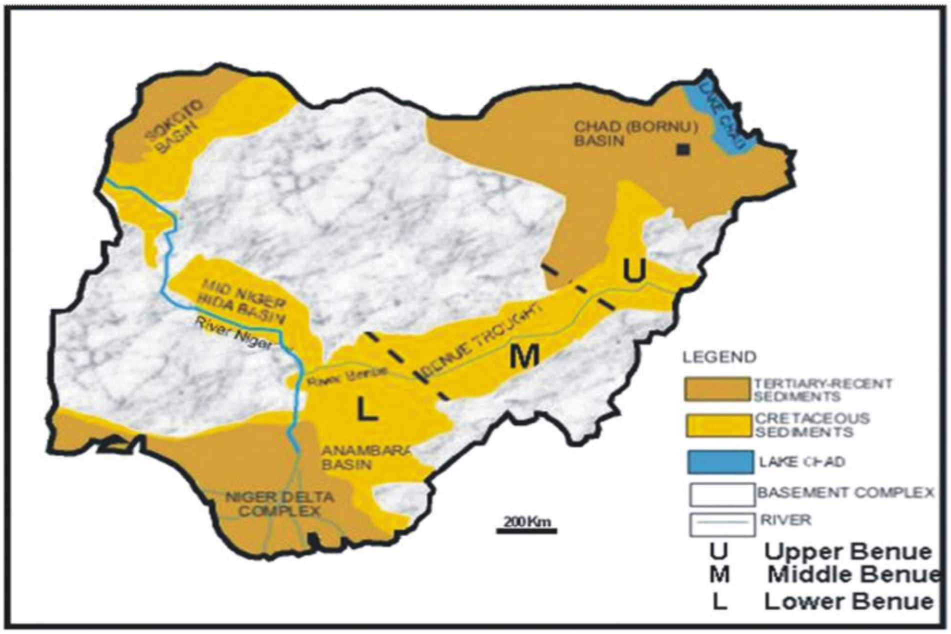


Figure 1: Geological map of Nigeria showing the Benue Trough

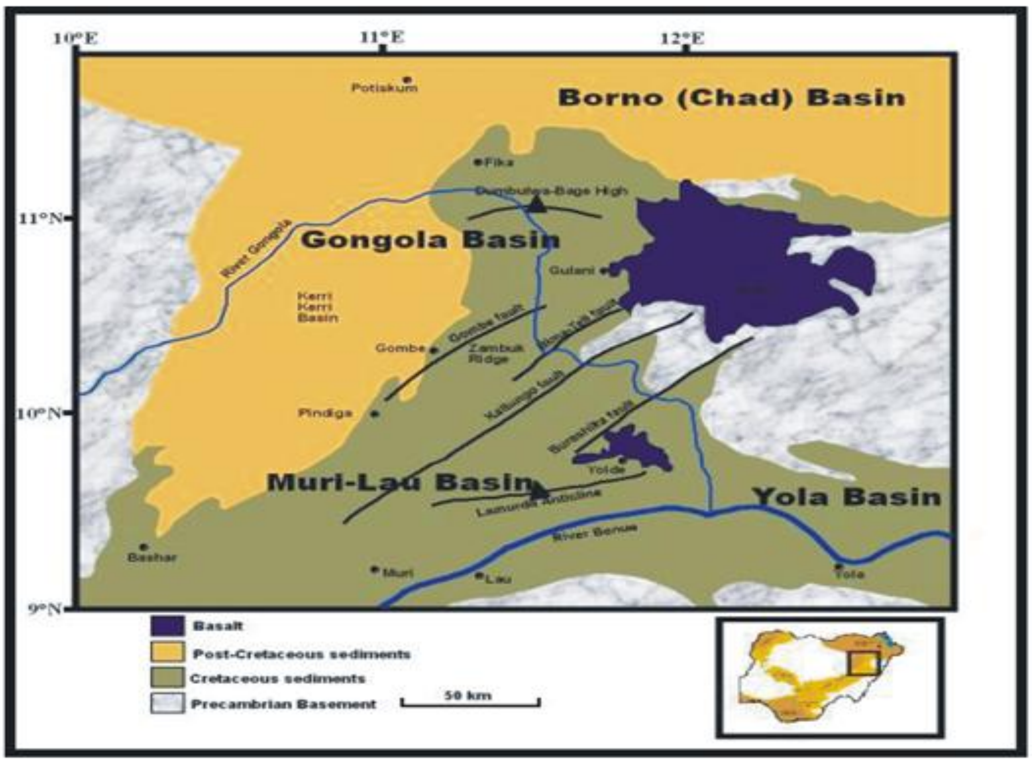


Figure 2: Geological map of the Upper Benue Trough

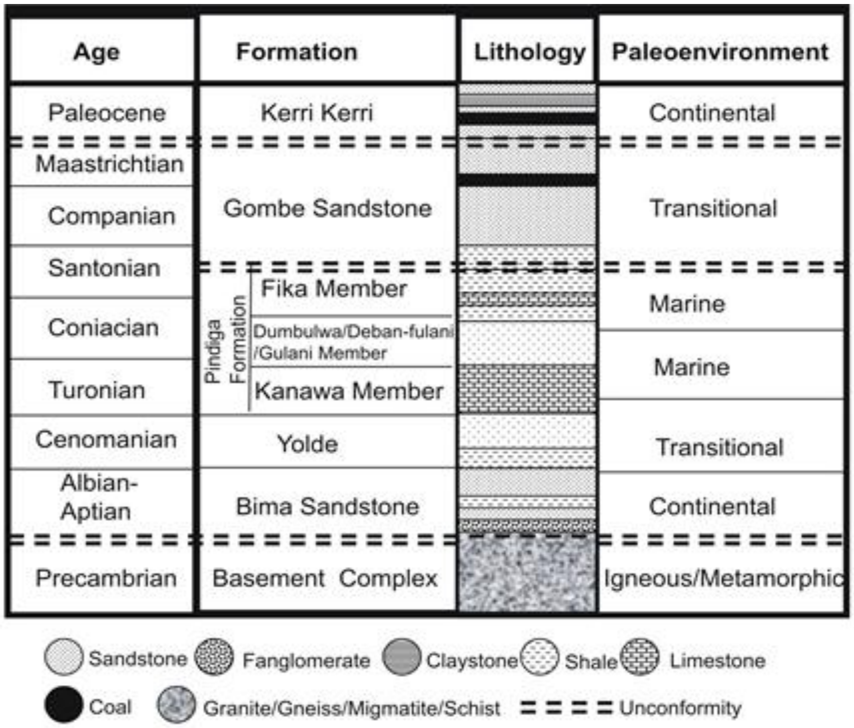


Figure 3: Stratigraphy of Gongola Basin

The Yolde Formation lies conformably on the Bima Sandstone. This formation of Cenomanian age (Lawal and Maullade, 1986) represents the beginning of marine incursion into the Gongola Arm. The Yolde formation was deposited in a barrier island, deltaic settings (Shettima, 2005; Abubakar *et al*., 2006). The Turonian-Campanian Pindiga Formation conformably overlies the Yolde Formation (Popoff *et al*., 1986; Zaborski *et al*.,1997). Zaborski *et al.* (1997) subdivided the Pindiga Formation into five lithostratigraphic members: the Kanawa Member which is the basal member comprises of limestone and shale intercalations, the Gulani Member, the Deban-Fulani Member, the Dumbulwa Member and the Fika Member which is the top most member consisting of shale and very few limestones. The Gulani, Deba-fulani and the Dumbulwa members are lateral equivalents occurring in the middle part of the Pindiga Formation. They are deposited during the middle Turonian regional regressive episode that occurred in the Benue Trough (Zaborski, *et al*., 1997). The estuarine/deltaic Gombe Sandstone of Maastrichtian age (Carter *et al.*, 1963) overlies the Pindiga Formation and it represents the youngest Cretaceous sediment in the Gongola Arm. The Paleocene Kerri Kerri Formation unconformably overlies the Gombe Sandstone and represents the only record of Tertiary sedimentation in the Gongola Arm (Adegoke *et al*., 1978; Dike 1993).

This study is aimed at determining the depositional environment of the Deba-Fulani Member of the Pindiga Formation by using univariate textural parameters which include grain size, sorting, skewness and kurtosis. Bivariate grain size analysis will also be carried out in this study and where possible, ichnofossils will also be used to support the sedimentological data.

2. Methodology

Lithologic section of the Deba-Fulani Member of the Pindiga Formation was studied in the Gongola Basin at Ashaka quarry, River Difa and Damfami stream (Figure 4). Sampling was carried out on outcrops by digging a trench of about 60cm so as to avoid weathered horizons. Thirteen samples were collected from outcrop sections of the Deba-Fulani Member of the Pindiga Formation for granulometric analysis (Figures 5, 6 and 7). Granulometric analysis was carried out by the conventional method and about 200g of each sample was sieved for about 30 minutes in a Ro-Tap shaker. The graphical parameters of graphic mean, standard deviation, skewness and kurtosis were determined using the formula of Folk and Ward (1957). The bivariate plots of Friedman (1961, 1967 and 1979), and Moiola and Weiser (1968) were applied to interprete the paleoenvironments of these sandstone. The log probability curve plots of grain size distribution of the analysed samples based on Visher (1969) and Dike (1972) were also plotted.

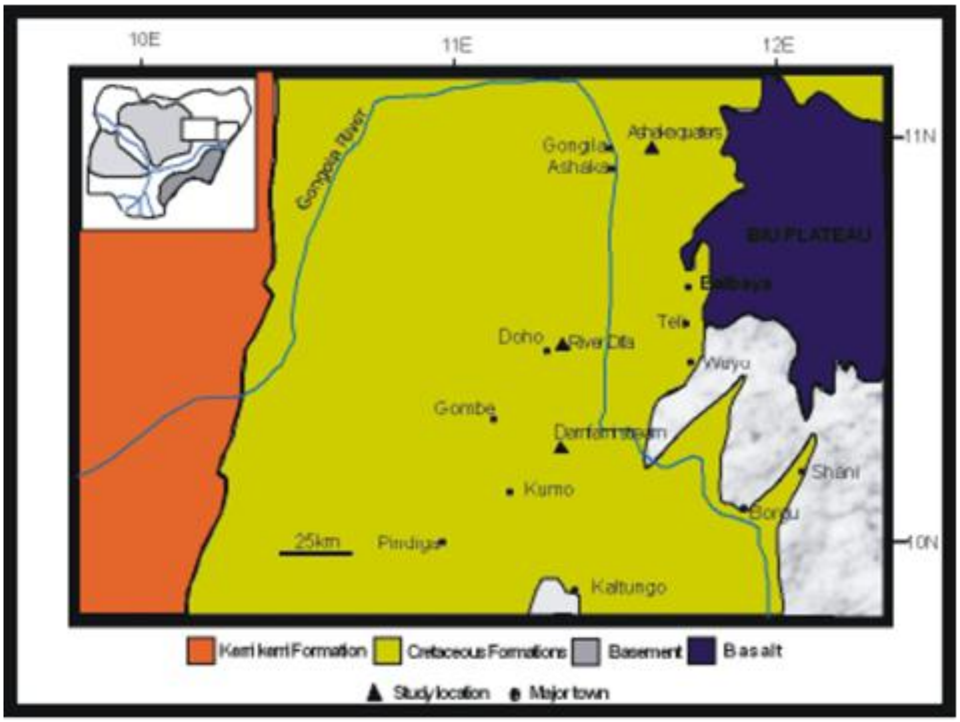


Figure 4: Map showing geology and sample locations of study area

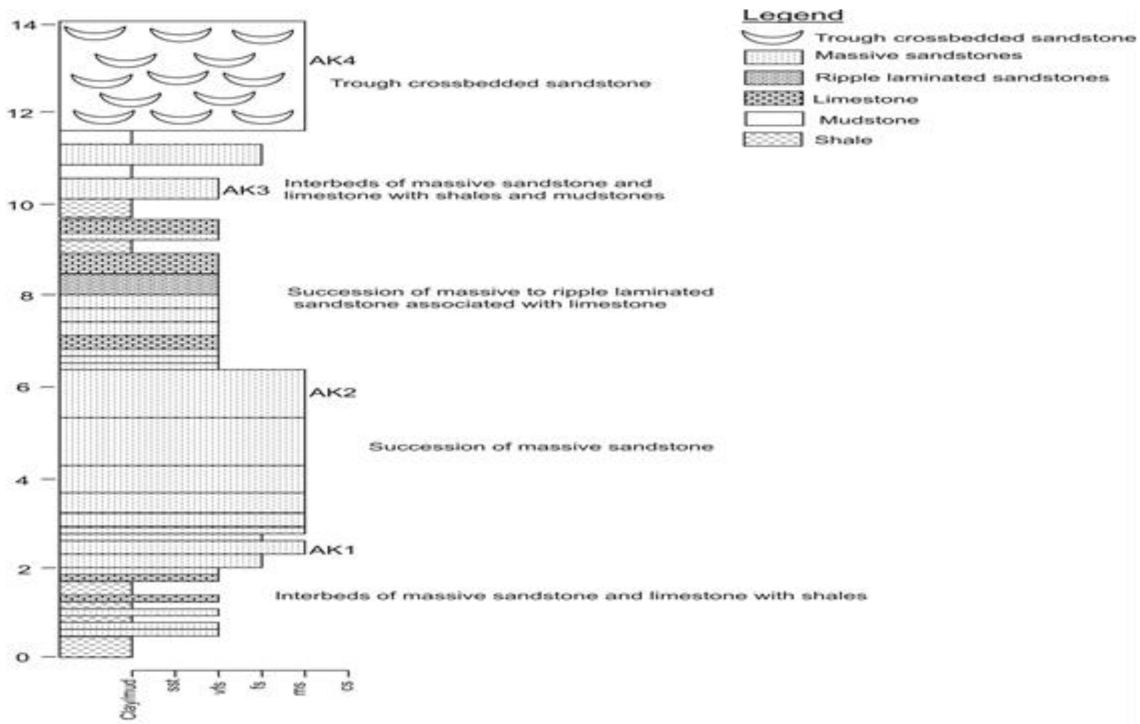


Figure 5: Ashaka quarry section (Deban –Fulani Member)

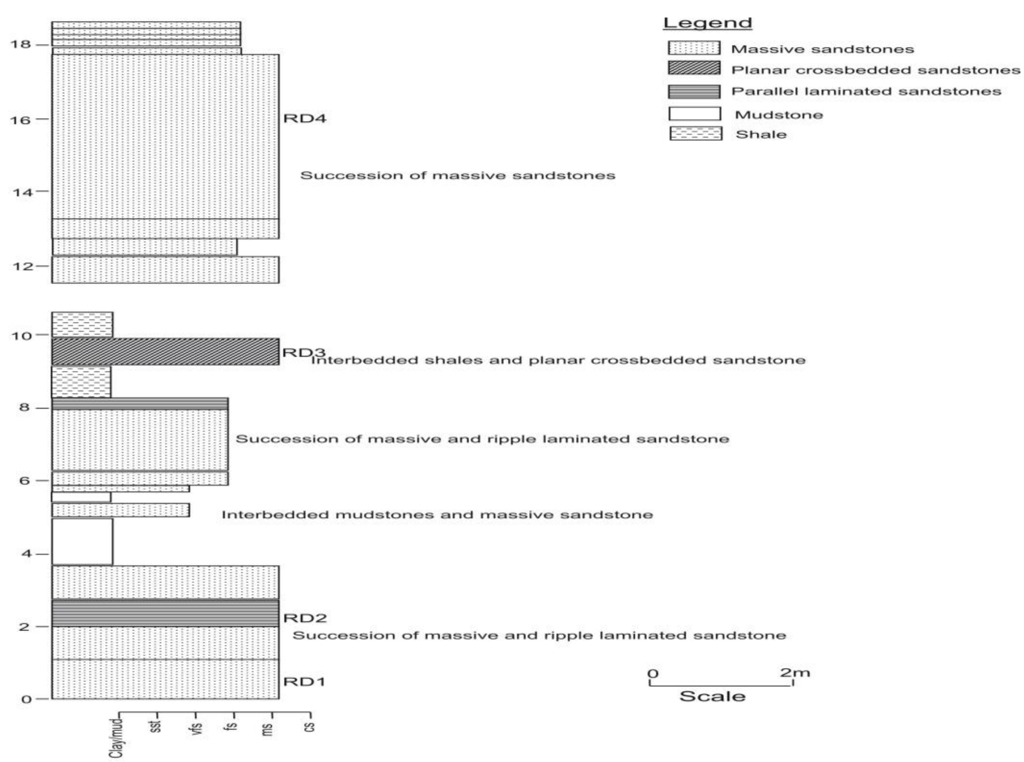


Figure 6: River Difa section (Deban –Fulani Member)

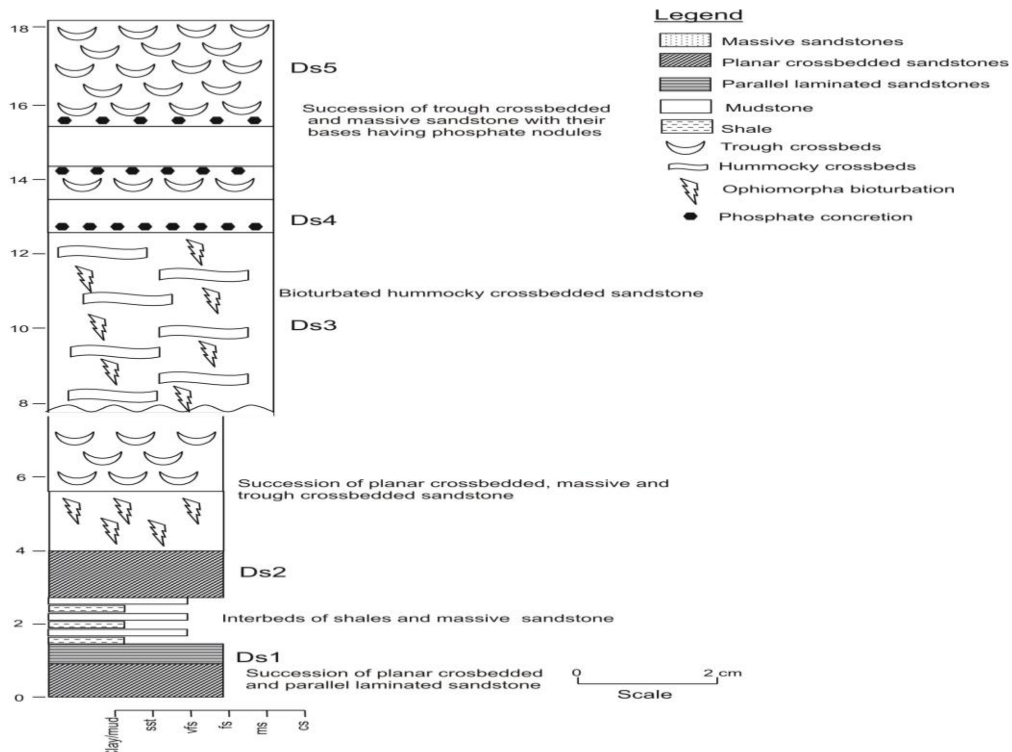


Figure 7: Damfami stream section (Deban –Fulani Member)

3. Results

3.1 Univariate Grain Size Parameters

The graphic mean size for the various samples (Table 1) ranged from (1.38ø – 3.17ø), for medium to very fine grained sandstone and average of 1.98ø for medium grained sandstone. The mean size of a grain still has no definite trend to support any environmental interpretation. Furthermore, Friedman (1967) pointed out that the average mean size is not sensitive as an environmental indicator. However, the fluctuation of the values may suggest variation in the energy of the depositing medium.

3.2 Inclusive Graphic Standard Deviation (Sorting)

The values of standard deviation (Table 1) tended to show well sorted (0.45ø) to poorly sorted (1.08ø) with an average of (0.74ø) which implies that the whole formation is moderately sorted. The dominance of well and moderately sorted sample may suggest that the transportation responsible for the deposition was very turbulent where there is a lot of winnowing and waxing activities.

3.3 Inclusive Graphic Skewness (Ski)

The samples analysed have skewness values ranging from (-0.17ø to 0.70ø) i.e. from negatively skewed to very positively skewed respectively (Table 1). These values may suggest that the samples must have been formed in an environment with a highly fluctuating energy conditions.

3.4 Inclusive Graphic Kurtosis (Kc)

The values of kurtosis (Table 1) for the various samples range from 0.83ø – 11.90ø indicated platykurtic to very leptokurtic, with an average of 2.81ø (leptokurtic). Little geologic information can be derived from values of kurtosis (Pettijohn *et al*, 1987), but, with the dominance of leptokurtic, it may be suggested that the samples were affected by similar depositional conditions.

SAMPLE NO.	GRAPHIC MEAN (Mz)	GRAPHIC STANDARD DEVIATION (SORTING)	GRAPHIC SKEWNESS (Ski)	GRAPHIC KURTOSIS (Kc)
AK1	1.38 Medium grained	0.45 Well sorted	-0.17 Negatively skewed	3.57 Very leptokurtic
AK2	1.90 Medium grained	0.76 Moderately sorted	0.19 Nearly symmetrical	3.76 Very leptokurtic
AK3	3.15 Very fine grained	0.70 Moderately sorted	0.03 Nearly symmetrical	0.83 Platykurtic
AK4	1.38 Medium grained	0.98 Moderately sorted	0.26 Positively skewed	1.78 Leptokurtic
DS1	3.17 Very fine grained	0.77 Moderately sorted	0.41 Positively skewed	1.62 Leptokurtic
DS2	1.74 Medium grained	0.93 Moderately sorted	0.38 Positively skewed	1.56 Leptokurtic

Table 1. Grain size distribution and qualitative parameters for samples analysed

3.5 Bivariate Grain Size Parameters

Mean grain size, standard deviation (sorting), skewness, median and graphic first percentile are the parameters needed to separate sands based on origin according to standard plots of various workers. These are bivariate plots of mean versus first percentile (Friedman, 1979), standard deviation versus first percentiles (Friedman, 1979), standard deviation versus skewness (Friedman, 1961, 1967, 1979) and Moiola and Weiser (1968).

3.6 Mean Versus First Percentile

The standard plot of mean versus first percentile was based on the work of Friedman (1979) which was used in distinguishing lnland dune sand from river sand (Figure 8a). The plots for the sample tends to show that 46.1% of the samples fell into the river sand environment, while 53.9% plotted into the inland dune sand environment.

3.7 Standard Deviation Versus Skewness

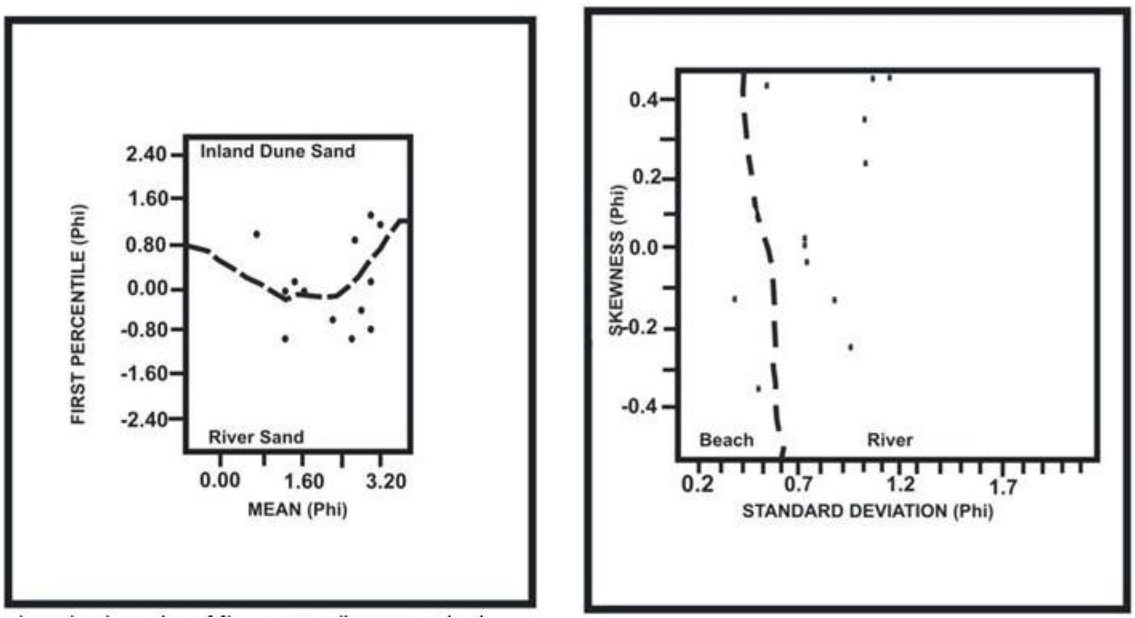
The bivariate plots of standard deviation versus skewness are based on the work of Friedman (1961, 1967, 1979) and Moiola and Weiser (1968). The plot of Friedman (1961) tends to show the distribution of samples between the field of beach and fluvial environment. 83.3% fell into the river field while 16.7% fell into beach field (Figure 8b). Friedman (1967, 1979) likewise showed the distribution of sand between river and beach environment. For Friedman (1967), 77.8% of the samples fell into the river field environment while 22.2% belong to the beach environment (Figure 9a).

The plots based on Friedman (1979) shows that 15.43% of the samples plotted within the river field environment while 84.6% plotted within the beach environment (Figure 9b). The plots of Moiola and

Weiser (1968) also helps to separate river sand from beach sands and it tends to show that 71.4% of the studied samples plotted within the river field environment while 28.6% fell into the inland dune sands environment (Figure 10a).

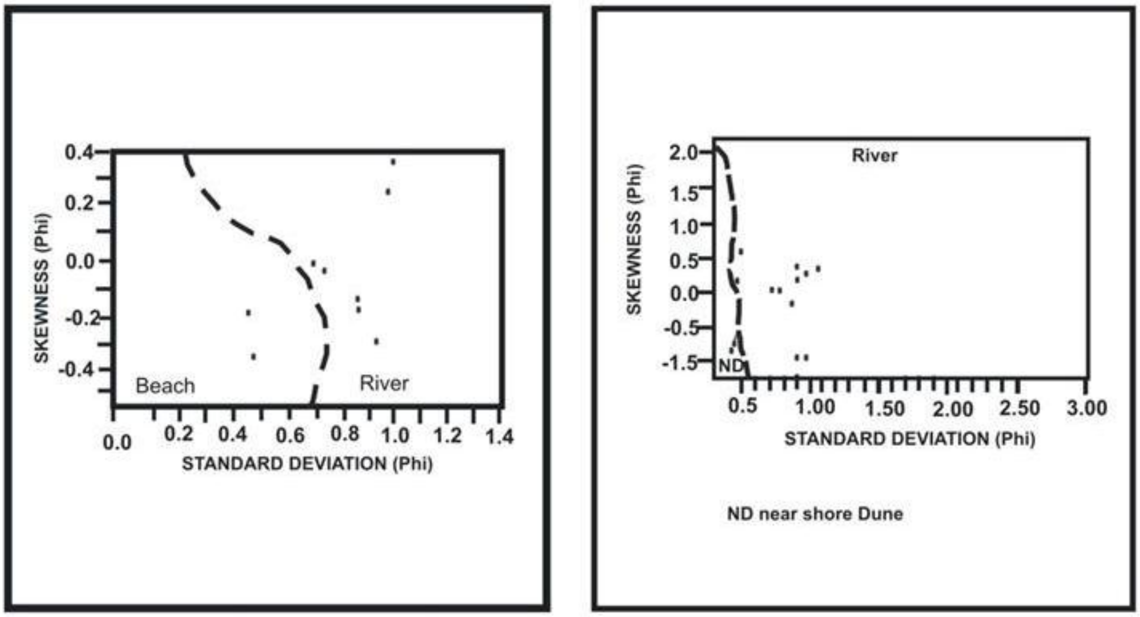
3.8 Standard Deviation Versus Mean Size

The Moiola and Weiser (1968) plots of standard deviation versus mean size is used in delineating dune sand from river sand. 77.8% of the studied samples plotted within the river field environment while 22.2% plotted into beach environment (Figure 10b). The plot of standard deviation versus mean size based on Friedman (1979) tends to show that 66.7% of the sands fell into the river sand field, while 33.3% fell into the inland dune sand (Figure 11).



(A) (B)

Figure 8: Bivariate plot of (A)- first percentile vs mean Friedman (1967) and (B)- skewness vs standard deviation Friedman (1961)

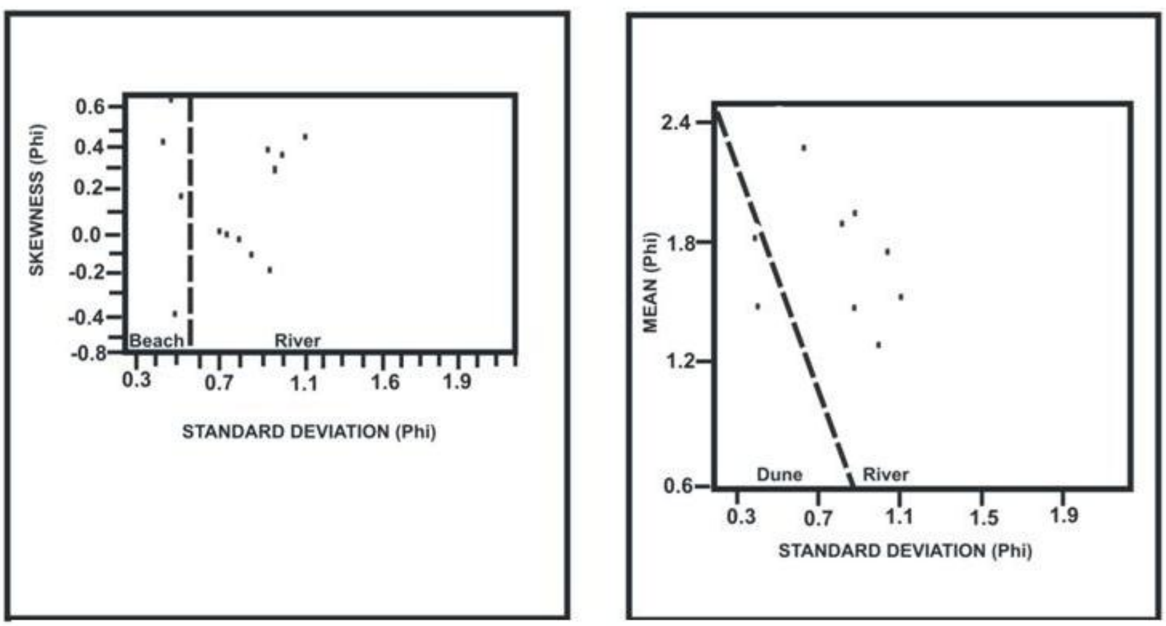


(A) (B)

Figure 9: Bivariate plot of skewness vs standards deviation, A- Friedman (1967) and B- Friedman (1979)

3.9 Probability Plots

The different sand populations in a probability curve plot are of environmental significance. Such sand population members are characteristic of either fluvial, beach or wave zone. According to Visher (1969) characterization: two sand population is characteristic of fluvial setting; three sand population is characteristic of wave zone bars; four sand population is characteristic of beach setting.



(A) (B)

Figure 10: Bivariate plot of (A) skewness vs standard deviation and (B) mean vs standard deviation

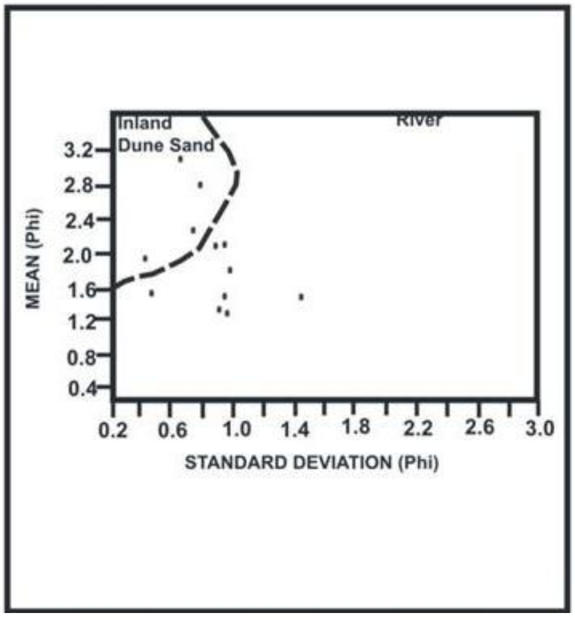


Figure 11: Bivariate plot of mean vs standard deviation (Friedman, 1979)

Cumulative probability distribution curves (Figure 12) of analysed samples tend to show two to three straight line segments. Sample displaying three segments probability curve are: AK1, AK2, AK3, DS1, DS4, DS5, RD2, RD3 and RD4. They are characterized by:

Suspension segment with a slope of 15^o – 57^o that forms 4% - 27% of the distribution.

Well sorted saltation population with a slope of 67% - 79% that forms 43% - 81% of the distribution.

Poorly sorted traction population with a slope of 23^o – 42^o that forms 0.2% - 10% of the distribution.

The samples characterized by two segments probability curve are: AK4, DS2, DS3 and RD1. They are characterized by:

Poorly sorted suspension population with a slope of 7^o – 43^o that forms 3% - 48% of the distribution.

Well sorted saltation with a slope of 53^o – 84^o that forms 42% - 89% of the distribution.

4. Discussion

The mean grain size of a deposit is largely controlled by the energy of the depositing current, initial size and source materials (Folk and Ward, 1957; 1964; Pettijohn *et al*., 1987). The mean size for the Deba-Fulani Member of the Pindiga Formation ranges from 1.38ø-3.17ø (i.e. medium grained to very fine grained sandstones) with an average of 1.98ø indicating medium grained sandstone (Table 1). Freidman pointed out that the average grain size is not sensitive as an environmental indicator, however, since most of the samples tends to consists dominantly of either very fine – fine grained sandstone, it may be suggested that the deposition is dominantly in one phase with little reworking or redeposition (Kukal, 1971). Hence, the deposition may probably be by a weak current.

Sorting depends on sediment source, grain size and depositional regime. It is indicative of hydrodynamic conditions (ranges of velocities and degree of turbulence) operating in the transporting medium and to some extent, it is suggestive of distances of travel (Reineck and Singh, 1973; Abdel-Wahab *et al*., 1992). The values of sorting ranges from (0.45ø-1.08ø) i.e. well sorted to poorly sorted, with a mean value of (0.74ø) indication moderate sorting (Table 1). The poor to well sorted sandstones of the Deba-Fulani Member (Table 1) may suggest that the sediments went through different phases of dynamic processes in the course of their transportation. This range from weak current as indicated by the poor sorting to moderate and high energy conditions as shown by the moderate and well sorted samples respectively.

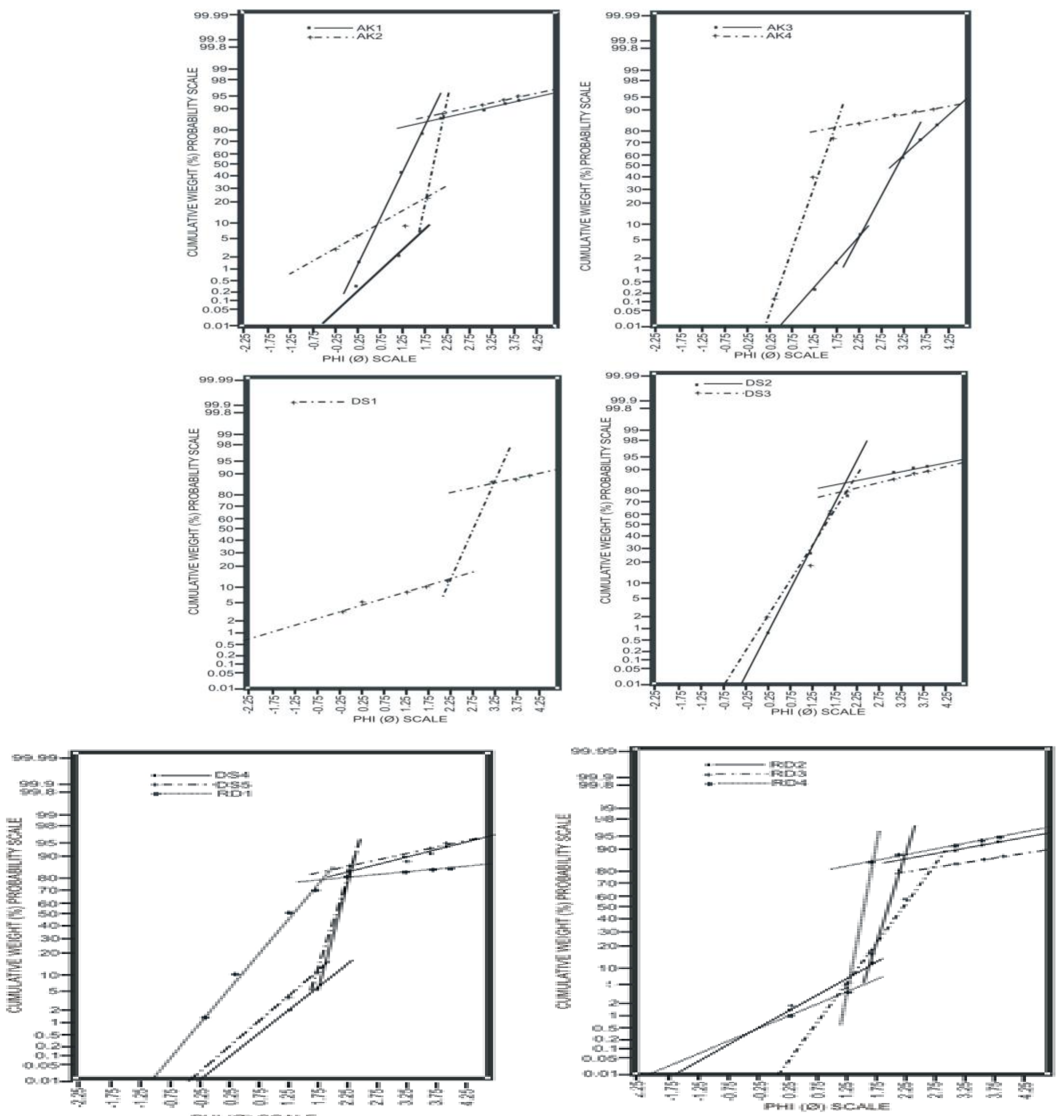


Figure 12: Sand distribution population curves based on log probability plots

Skewness is the measure of the symmetry of the distribution and it is a very useful descriptive term for the depositional processes of sediments. The samples analysed ranged from (-0.17ø-0.70ø) i.e. negatively skewed to positively skewed (Table 1). These investigated samples are dominantly positively skewed, indicating so much matrix in the framework of the sandstones. River sands are generally positively skewed since most of the silts and clays are not removed by current (Friedman, 1961, 1967), however, the negatively skewed samples may suggest waxing and winnowing conditions under which matrix are been removed from the sandstones (Agumanu, 1993), and this is usually associated with coastal setting (Friedman, 1979). Hence, these sandstones must have been formed in settings prone to both fluvial and coastal activities.

Kurtosis is the measure of the peak of distribution and the values ranges from (0.83ø – 11.90ø) i.e. platykurtic to very leptokurtic (Table 1). Very little geologic information could be derived from kurtosis (Pettijohn *et al*., 1987), however, the fluctuation of the values may suggest changes in the intensity of the depositing medium and it also largely agrees with Abdel-Wahab (1988) data for fluvial sands. The bivariate plot models adopted in this analysis indicates both fluvial and marine environment for the middle member of the Pindiga Formation (Deba-Fulani). The bivariate plots of Friedman (1961, 1967, 1979) and Moiola and Weiser (1968) based on skewness versus standard deviation (Figures 8a and b, 9a and b) respectively, suggested a dominance of fluvial conditions over marine and this may indicate dominance of fluvial environment. Likewise, the plot of Moiola and Weiser (1968) and Frieman (1979) based on standard deviation versus mean size also suggested a prevalence of fluvial setting (Figures 10a and b). However, the bivariate plots of Friedman (1979) for first percentile versus mean, (Figure7) indicated dominance of marine environment over fluvial. The interpretation from these models may probably indicate that the Deba-Fulani Member of the Pindiga Formation was formed in a coastal environment in which there is a marked fluctuation in geological conditions promoting the predominance of either fluvial or marine conditions over time.

Probability curve plots based on Visher (1969) and Dike (1972) indicates that all the samples tend to show two and three-sand populations curves (saltation and suspension) but with the three-sand populations curve dominating (Figures 11 and 12). The two-sand probability curve types generally indicate unidirectional depositional currents, which is usually associated with fluvial or tidal setting, while the three-sand probability curves are indicative of wave processes (Visher ,1969; Dike,1972), hence, there is significant marine influence on the Deba – Fulani Member of the Pindiga Formation.

5. Conclusion

This research carried out on the bases of grain size distribution has indicated that the Deba-Fulani Members of the Pindiga Formation was probably deposited in a coastal setting, thereby showing fluctuations in fluvial activities over marine and vice versa over time which may possibly be due to transgression and regression along the coast.

References

Abdel-Wahab, A. 1988. Lithofacie and diagenesis of the formation at the central eastern desert, Egypt. 9th Egyptian Exploration Conference, 20-23 November, 1988, Cairo, pp9.

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. Journal of African Earth Sciences, 14(1): 121-132.

Abubakar, MB., Dike, EFC., Bukar, S. and Tukur, A. 2006. Lithostratigraphy and paleoenvironment of deposition of the Yolde Formation of the Gongola Arm, Upper Benue Trough, Nigeria. Nigerian Mining and Geosciences Society. Abstract, 42: 48.

Adegoke, OS., Jan du Chew, RE., Agumanu, AE. and Ajayi, PO. 1978. Palynology and age of the Kerri-Kerri Formation, Nigeria, Revista Espanola Micropalaco-tologia, 10: 2-28.

Agumanu, AE. 1993. Sedimentology of Owelli Sandstone (Campano-Maastrichtian) Southern Benue Trough Nigeria. Journal of Mining Geology, 29(2): 21-35.

Carter, JD., Barber, W., Tait EA. and Jones, GP. 1963. The geology of parts of Adamawa, Bauchi and Borno provinces in north-eastern Nigeria. Bulletin Geological Survey Nigeria. 30, 1-99.

Dike, EFC. 1972. Sedimentology of the Lower Greensand of the Isle of Wight, England. Unpublished D. Phil. Thesis, University of Oxford, England, pp204.

Dike, EFC. 1993. The Statigraphy and structure of the Kerri-Kerri Basin Northeastern Nigeria. Journal of Mining and Geololgy, 29(2): 77-93.

Dike, EFC. 2002. Sedimentation and tectonic evolution of the Upper Benue Trough and Bornu Basin, Northeastern Nigeria. Nigerian Mining Geosciences Society 38th Annual and International Conference, Port Harcourt 2002 (NMGS/ELF award winning paper) Abstract, pp45.

Folk, RL. and Ward, WC. 1957. Brazos River bar, a study in the significance of grain-size parameters. Journal of Sedimentary Petrology, 30: 514-529.

Friedman, GM. 1961. Distinction between dune, beach and river sands from their textural characteristics. Journal of Sedimentary Petrology, 30: 514-529.

Friedman, GM. 1967. Dynamic processes and statistical parameters compared for size frequency distribution of beach and river sands. Journal of Sedimentary Petrology, 37: 327-354.

Friedman, GM. 1979. Differences in size distribution of populations of particles among sands of various origins. Sedimentology, 26: 3-32.

Guiraud. M. 1990. Tectono-sedimenatry framework of the Early Cretaceous continental Bima Formation (Upper Benue Trough N.E. Nigeria). Journal of African Earth Sciences, 10: 341-353.

Kukal, Z. 1971. Geology of recent sediments. Academy Press, London and New York, pp490.

Lawal, O. and Moullade, M. 1986. Palynological biostratigraphy of Cretaceous sediments in the Upper Benue Basin, N.E. Nigeria. Revenue Micropaleotologie, 29: 61-83.

Moiola, RJ. and Weiser, D. 1968. Textural parameters: An evaluation. Journal of Sedimentary Petrology, 38: 45-53.

Petters, SW. 1982. Central West African Cretaceous Tertiary benthic foraminifera and Stratigraphy. Palaeontographica, 179: 1-104.

Pettijohn, FJ., Potter, PE. and Siever, R. 1973. Sand and Sandstones (2nd Ed) Springer-Verlag, pp407.

Popoff. M., Wiedmann, J. and De Klazz, I. 1986. The Upper Cretaceous Gongila and Pindiga Formations, Northeastern Nigeria. Subdivisions, age stratigraphic correlations and paleogeographic implications. Ecologea Geologie Helv., 79: 343-363.

Shettima, B., 2005. Sedimentology and Reconstruction of the Depositional Environments of the Yolde Formation in the Gongola Arm of the Upper Benue Trough (N.E. Nigeria). MSc. Thesis (unpublished), Abubakar Tafawa Balewa University, Bauchi, pp84.

Visher, GS. 1969. Grain-size distribution and depositional processes. Journal of Sedimentary Petrology, 39: 1074-1106.

Zaborski, P., Ugodulunwa, F., Idornigie, A., Nnabo, P. and Ibe, K. 1997. Stratigraphy and Structure of the Cretaceous Gongola Basin, Northeastern Nigeria. Bulletin, Centre for Research Production Elf Aquitaine, 22: 153-185.