GLOBAL JOURNAL OF GEOLOGICAL SCIENCES VOL, 9, NO.2, 2011 205-214

www.globaljournalseries.com, Email: info@globaljournalseries.com

SEDIMENTOLOGY AND PALEOENVIRONMENTAL STUDIES ON THE CHAD FORMATION OF BORNU BASIN, NORTH-EASTERN NIGERIA

B. SHETTIMA, A. M. KYARI, A. SULEIMAN AND F. BUKAR

(Received 12 June 2008; Revision Accepted 13 October 2009)

ABSTRACT

This study deals with sedimentology and Paleoenvironmental studies of the Chad Formation in the Bornu Basin. The sandstones which build up this formation are fine, medium to coarse grained sands which are dominantly poorly sorted. The skewness ranges from positive to very positive while the kurtosis varies from very platykurtic to very leptokurtic. The bivariate plots of standard deviation vs. mean, standard deviation vs. skewness, standard deviation vs. first percentile, mean vs. first percentile and log probability plots have conclusively define the depositional environment of the arenaceous samples of the Chad Formation as fluvial in origin.
The paleocurrent analysis indicates a trend in the northwestern direction which implies that the sediments forming the Chad Formation were derived from the southwest.

KEYWORDS: Paleoenvironment, Sedimentology, Provenance

INTRODUCTION

The Chad Basin is a broad structural depression in Central-West Africa and it is the largest intracratonic basin in Africa, covering an area of about 2,335,000 sq km (Carter et al., 1963). Its eastern and northern boundaries lay partly in central Sudan and partly in Niger Republic respectively. Approximately one tenth of the surface area of the Chad Basin is in northern Nigeria and it is bordered to the west by the northern Nigeria Basement Complex and in the South by the Benue Trough and the Biu Plateau (Fig. 1)

The topography of the Bornu Basin tends to show a relatively flat monotonous landscape over almost all its landmass. However a prominent low sand ridge feature is quite discernable in the landscape and is addressed as the Bama-Maiduguri ridge complex (Du,Preez,1949; Jones,1959). It is located in the Southeastern part of the of the Bornu Basin and trends in a Southeast-Northwest direction over a distance of about 160km from Dar-el-Jimeil in the Republic of Cameroon, through Bama then Maiduguri where it is best developed in thickness and ultimately begins to die out at Magumeri northwest of Maiduguri (Du,Preez, 1949; Jones, 1959) (Fig.2).

The Chad Formation of (Pliocene-Pleistocene) age consists of loose sandstones and siltstones, mudstones and claystones, and due to the low relief nature of the basin, the outcrops exposed by streams are rarely preserved. However, those occurring along the Bama-Maiduguri ridge complex are well preserved because the morphology of the ridge controls the drainage system, hence, its dissection has yielded cliffs in numerous places where good exposure could be studied. This study concentrates predominantly on the area around the Bama-Maiduguri ridge complex and it is aimed at determining the depositional environment of the Chad Formation.

TECTONIC AND STRATIGRAPHIC SETTING

The origin of the Chad Basin is associated with the separation of the African and South American continents in the early Cretaceous (Burke, 1976; Genik, 1993). An active phase of sea floor spreading in the Atlantic during the mid Cretaceous resulted in the subsidence of the West African intracratonic basins, leading to the widespread Cenomanian-Turonian marine transgression into the Chad Basin (Carter *et al*., 1963).

Sedimentation in the Chad Basin began in the Albian with the deposition of a continental, sparsely-fossiliferous medium to the coarse grained feldspathic sandstone known as the Bima Sandstone. This formation rests directly on the Precambrian Basement Complex and it is composed mainly of sandstone and with some shale intercalations (Carter *et al.,*1963; Avbovbo *et al.,*1986).

The Bima Sandstone is conformably overlain by the Gongila Formation which is composed of calcareous shale and sandstones, deposited in a shallow marine environment (Popoff *et al.,* 1986) (Fig. 3). The deposition of this formation marks the beginning of marine incursion into the Bornu Basin (Carter *et al.,* 1963). The marine transgression which started in the Albian reveals its peak in the Turonian during which the bluish-black, ammonites-rich open marine Fika Shale was deposited, and this deposition

B. Shettima, Department of Geology, University of Maiduguri, Borno State.
A. M. Kyari, Department of Geology, University of Maiduguri, Borno State.
A. Suleiman, Department of Geology, Gombe State University.
F. Bukar, Department of Geology, University of Maiduguri, Borno State.

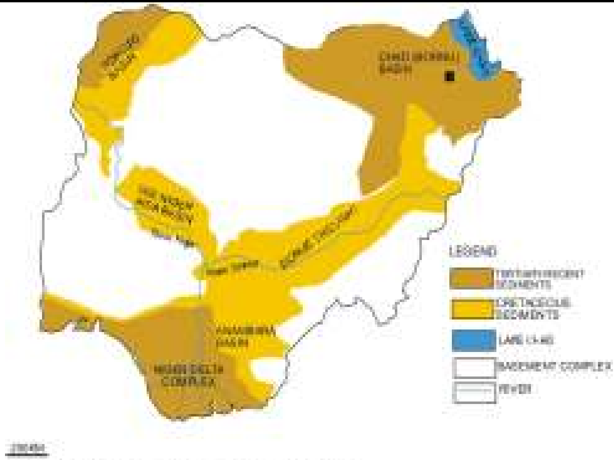


Fig. 1 Map of Nigeria showing the major sedimentary basins

Fig.2 Map showing the Bama-Maiduguri Ridge Complex and study area

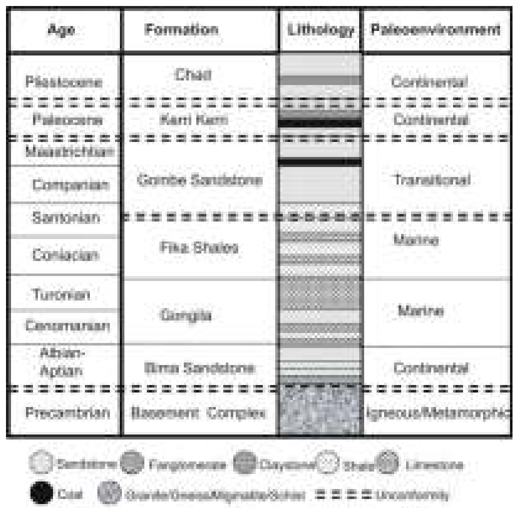


FIG. 3 Stratigraphic subdivisions of the Bornu Basin

continued into the Santonian (Carter *et al.,* 1963). The Gombe Sandstone which contains intercalation of siltstone, shale, ironstone and sandstone was deposited in the Maastrichtian and it unconformably overlies the Fika Shale.

A phase of extensional deformation occurred in the Bornu Basin in the Late Maastrichtian times and this continued up to the end of Cretaceous. As a result of that, the basin was reconstructed into an elongate NE-SW garben system and the remnant basin that succeeded the deformation formed the site for the deposition of the Kerri-Kerri Formation, which unconformably overlies the Cretaceous sediments (Carter *et al.,* 1963).

In the Pleistocene and presumably during the Pliocene, the continental deposits of the Chad Formation were unconformably laid down on top of the Kerri-Kerri Formation (Carter *et al.,* 1963). Toward the end of the Tertiary and until recent times, widespread volcanic activities occurred in the south and central part of the basin (Burke, 1976)

MATERIALS AND METHODS OF STUDY

Five stratigraphic sections of the Chad Formation outcropping along Bama-Maiduguri ridge complex were logged and measured to record data on lithologic variations, texture and biogenetic and physical sedimentary structure at locations A, B, C, D and E (Figs. 4, 5, 6, 7 and 8) respectively.

Fifteen arenaceous samples were collected from the outcrop sections of the Chad Formation and these samples were subjected to the granulometric

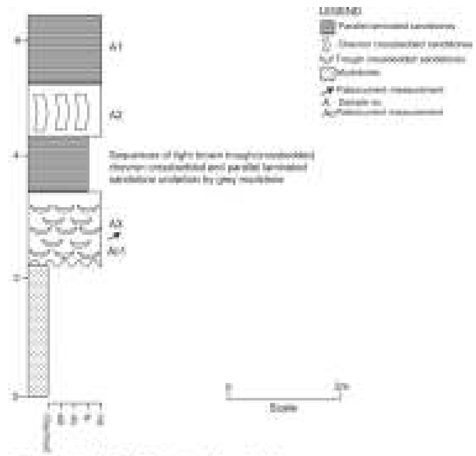


Fig. 4 Section of Chad Formation at locality A

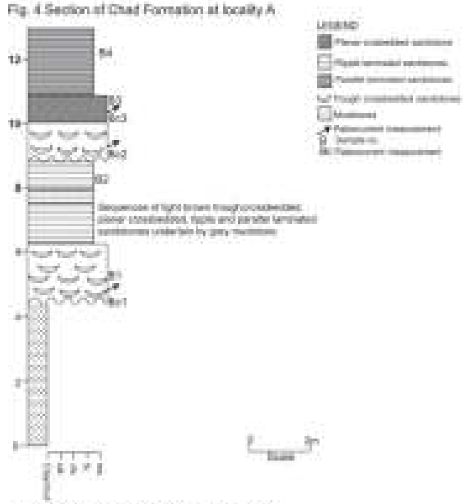


Fig. 5 Section of Chad Formation at locality B

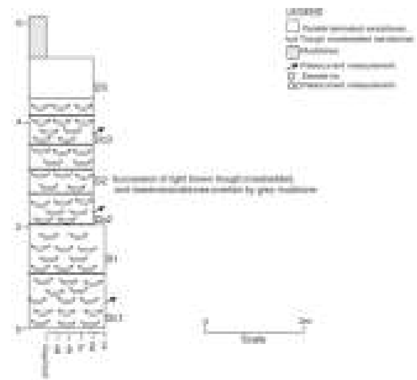


Fig. 7 Section of Chad Formation at locality D

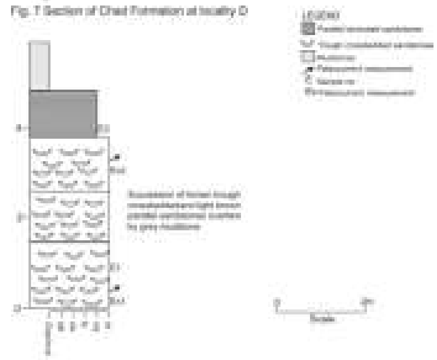


Fig. 8 Section of Chad Formation at locality E

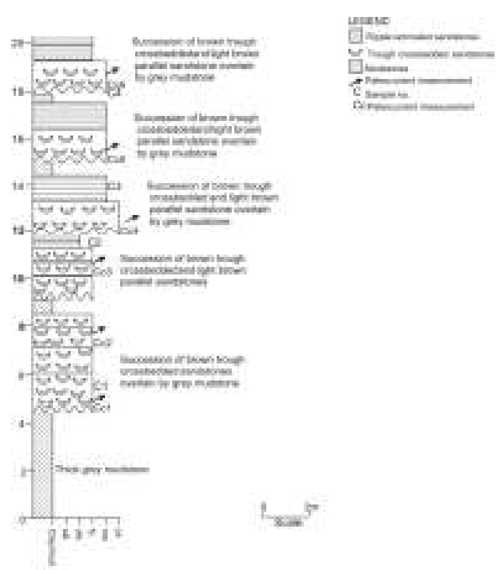


Fig. 6 Section of Chad Formation at locality C

analysis. 200gms of each ample was sieved for about 30 minutes in Ro-Tab sieve shaker. The statistical parameters; mean, standard deviation, skewness and kurtosis were determined using the formula of Folk and Ward (1957). Bivariate plots of Friedman (1961, 1967, 1979) and Moiola and Weiser (1968) were used to interprete the paleoenvironments of these sandstones. Log probability population curve plots of grain size distribution based on the methods of Visher (1969) and Dike (1972) were also used to aid in the interpretation.

A total of (150) readings were measured for both declination (azimuth) and inclination of the foresets planes and these data were used in constructing the paleocurrent rose diagrams for the Chad Formation.

RESULTS

Univariate grain size parameters:

The graphic mean size for the various samples (Table 1) ranges from 0.82ø –3.22ø i.e. (coarse to very fine-grained sands) and the fluctuation of the values may reflects change in the strength of the deposition medium.

The values of standard deviation (Table 1) tends to show that the samples ranged from moderately sorted (0.99ø) to poorly sorted (1.84ø) with an average of (1.14ø) which implies that the whole formation is poorly sorted.

The samples analysed have skewness values ranging from 0.015 ø to 0.80ø i.e. from nearly symmetrical to very positively skewed respectively. However, positively skewed values predominate (Table 1), and this may be due to the fact that much of the silt and clay were not removed by current, though the clay may be secondary.

The values of kurtosis (Table 1) for the various samples range from 0.62ø to 1.56ø (very platykurtic to very leptokurtic), with an average of 0.97ø (leptokurtic).

Table 1. Grain Size Distribution and Qualitative Paramerters for the samples analysed

Sample No	Graphic Mean Mz	Graphic standard deviation (sorting)	Graphic skewness (Ski)	Graphic Kurtosis (kc)
A1	1.6 medium grained	1.3 poorly sorted	0.36 very positively skewed	0.95 very leptokurtic
A2	1.42 medium grained	1.59 poorly sorted	0.31 positively skewed	0.98 very leptokurtic
A3	1.83 medium grained	1.28 poorly sorted	0.38 very positively skewed	0.80 platykurtic
B1	1.08 medium grained	1.20 poorly sorted	0.015 nearly symmetrical	1.12 leptokurtic
B2	2.79 fine grained	1.15 poorly sorted	0.27 positively skewed	1.02 mesokurtic
B3	1.88 medium grained	1.31 poorly sorted	0.29 positively skewed	0.62 very platykurtic
C1	2.79 fine grained	1.15 poorly sorted	0.27 positively stewed	1.06 mesokurtic
C2	3.22 very fine grained	0.99 moderately sorted	0.56 very positively stewed	0.86 platykurtic
C3	1.87 medium grained	1.16 poorly sorted	0.39 very positively stewed	1.56 very leptokurtic
C4	1.98 medium grained	1.23 poorly sorted	0.36 very positively stewed	1.06 mesokurtic
D1	0.82 coarse grained	1.13 poorly sorted	0.64 very positively stewed	1.55 very leptokurtic
D2	1.73 medium grained	1.41 poorly sorted	0.18 positively stewed	1.04 mesokurtic
D3	1.77 medium grained	1.84 poorly sorted	0.31 positively skewed	0.82 platykurtic
E1	0.99 coarse rained	1.06 poorly sorted	0.35 very positively skewed	1.02 mesokurtic
E2	1.86 medium grained	1.25 Poorly sorted	0.80 positively skewed	1.51 very leptokurtic

Bivariate grain size parameters:

Mean versus First Percentile

The standard plot of mean versus first percentile was based on the work of Friedman (1979) used in distinguishing inland dune sand from river sand (Fig. 9) indicates that 73.3% of the samples fell into the river sand environment, while
26.7% plotted into the inland dune sand environment.

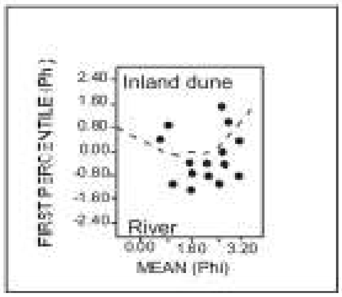
Standard Deviation versus Skewness

The bivariate plots of standard deviation versus skewness are based on the work of Friedman (1961, 1967, and 1979) and Moiola and Weiser (1968). Using the bivariate plot of Friedman (1961) which distinguishes river sand from beach sand, all the studied samples plotted within the river field (Fig.11). Friedman (1967) and Friedman (1979) also shows distribution of sand parameters between river and beach environment and in both cases, 100% of the present samples fell into the river field environment (Fig. 12 and 15). The plots based on Moiola and Weiser (1968) likewise shows distribution of sands between river and beach environments and it

Standard Deviation versus First Percentile

Friedman (1979) developed this bivariate plot likewise to distinguish river sand from beach sand (Fig. 10). The plots indicates that 80 % of the samples plotted within the river field sand and 20% of the samples plotted within the inland dune sand field.

showed that 100% of the studied samples plotted within the river field environment (Fig.16).



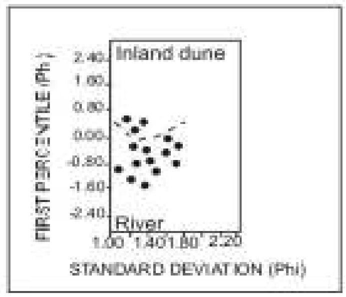
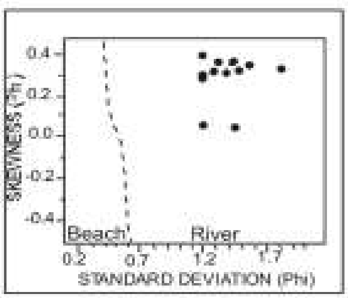


Fig.9 Bivariate plot of mean vs First percentile for whole samples (after Friedman,1979).

Fig.10 Bivariate plot of standard deviation vs First percentile for whole samples (after Friedman, 1979).



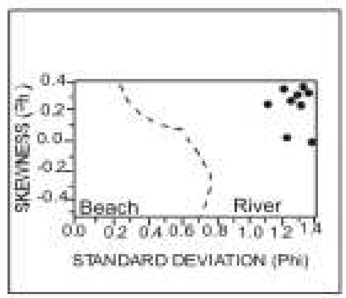


Fig.11 Bivariate plot of standard deviation vs skewness for whole samples (after Friedman, 1961).

Fig.12 Bivariate plot of standard deviation vs skewness for whole samples (after Moiola and Weiser, 1968).

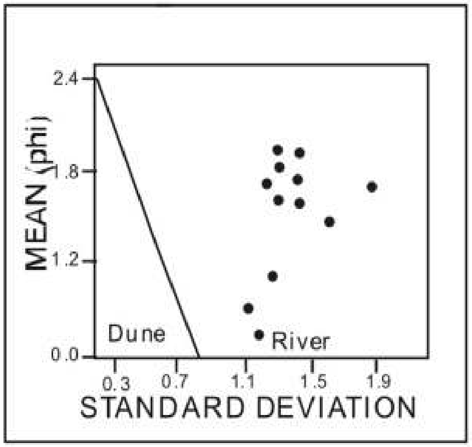


Fig.13 Bivariate plot of standard deviation vs mean for whole samples (after Moiola and Weiser, 1968).

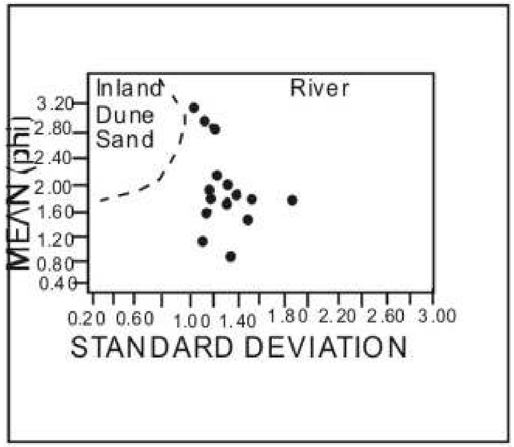


Fig.14 Bivariate plot of standard deviation vs mean for whole samples (after Friedman, 1979).

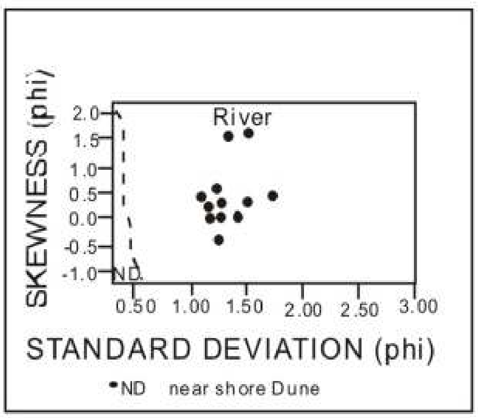


Fig.15 Bivariate plot of standard deviation vs skewness for whole samples (after Friedman, 1979).

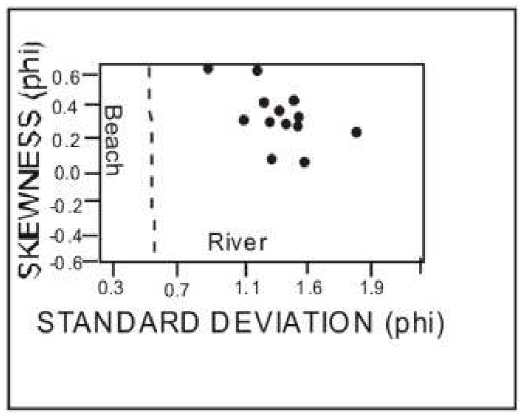


Fig.16 Bivariate plot of standard deviation vs skewness for whole samples (after Moiola and Weiser, 1968).

Standard Deviation versus Mean Size

The Moiola and Weiser (1968) plots of standard deviation versus mean size were used in delineating dune sand from river sand. 100% of the studied samples plotted within the river field (Fig. 13). The plot of standard deviation versus mean size based on Friedman (1979) also showed that 100% of the sands fell into the river sand field (Fig. 14).

Probability plots

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

Cumulative probability distribution curves (Figs. 17 and 18) of analysed samples tend to show two to three straight-line segments.

All the samples characterized by two-segment probability curves are: A1, A2, A3, B1, B2, B3, C1, C2, C3, C4, D1, D2, D3, E1 and E2. They are characterized by:

i) Poorly sorted suspension population with a slope of 5^o – 49^o that forms 2% -81% of the distribution.

ii) A well sorted saltation with a slope of 56^o – 72^o that forms 37% - 48% of the distribution.

The probability population curve shows dominances of two sand population curves and this may suggest fluvial setting owing to the fact that there are no marine indicators in the investigated samples.

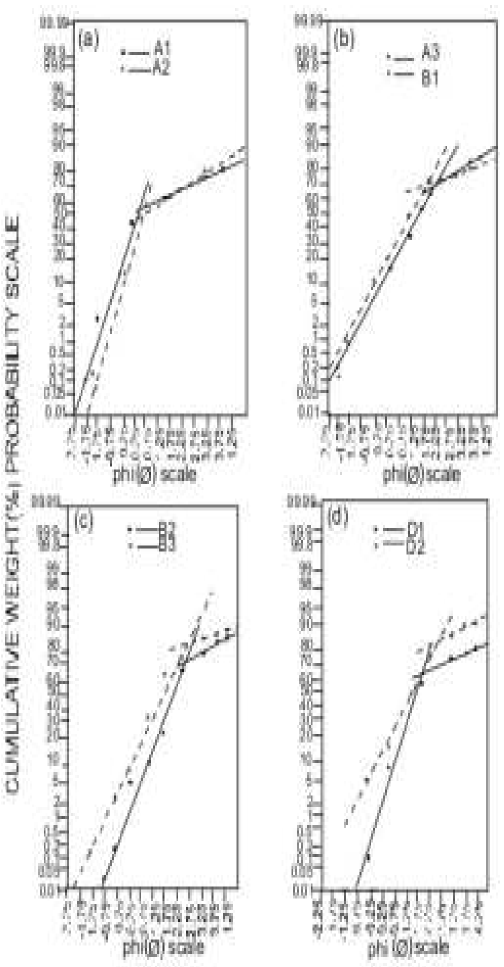


Fig.17 Sand population distribution curves based on log probability plots.

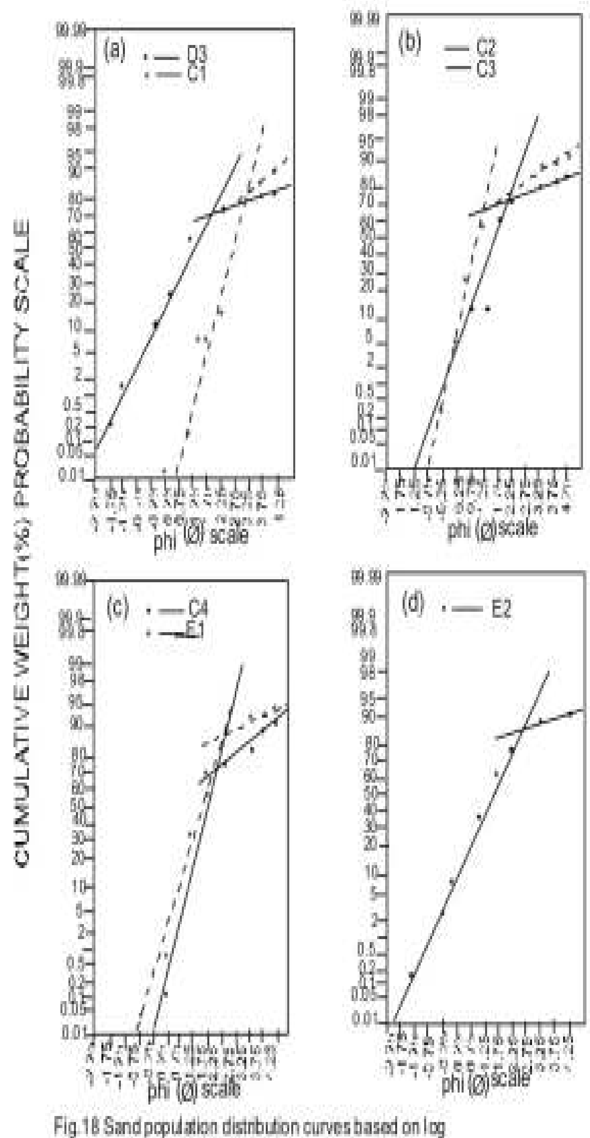


Fig.18 Sand population distribution curves based on log probability plots.

Paleocurrent analysis

Studies on paleocurrent direction usually allow for the reconstruction of the current direction through which the basin received its sediments. In this study, measurements of azimuth of cross-bedding were used in the construction of the paleocurrent direction. The beds range in thickness from 0.8m to 2m and strike at an angle 302^{o} to 047^{o}. The beds usually dip between 1^{o} to 4^{o} and the crossbeddings dip at an angle of 15^{o} to 24^{o}.

The general paleocurrent rose diagram for the Chad Formation at all the study locations (Fig. 19) yielded a unimodal trend pointing in the north-eastern direction (Fig. 19).

Generally, the current rose diagram gives an overall idea of the paleocurrent direction, while the vector mean is used to measure the average flow direction. The vector mean is determined by computing the summation of the sine and cosine for each direction of the azimuth orientation (Table 2), and the mean is the arc tan of the resulting tangent (Lindholm, 1987).In analyzing the azimuth directional data of the Chad Formation, the vector magnitude stands out at 95.77.

DISCUSSION

The graphic mean size in a deposit is largely a function of the energy of the processes controlling transport and deposition, i.e. particles are segregated according to hydrodynamic behaviors which depend on size, specific gravity and shape (Olugbemiro and Nwanjide, 1997). The graphic mean size for the various samples (Table 1) range from (0.82ø –3.22ø) i.e. coarse to very fine-grained sands with an average of (1.84ø) indicating medium grained sandstones and it is the dominating lithology. Friedman (1967) pointed out that the average mean size is not sensitive as an environmental indicator, however, since most of the samples shows unimodality of medium grained sandstones. This may suggest that deposition was in one phase with little reworking or redeposition (Kukal, 1971), hence, moderate to weak current.

Sorting depends on sediment source, grain size and depositional regime. It is indicative of hydrodynamic conditions (range of velocities and degree of turbidity) operating within the transporting medium and to some extent, it is suggestive of the distance of travel (Krumbein and Sloss, 1963; Reineck and Singh, 1973; Abdel-Wahab et al.,1992). Sorting for Chad Formation ranges from (0.99ø-1.84ø) i.e. moderate to poorly sorted, but predominantly, they are poorly sorted (Table 1). This may suggest that the sediments have a short distances of travel and were sourced in a medium prone to weak hydrodynamic conditions.

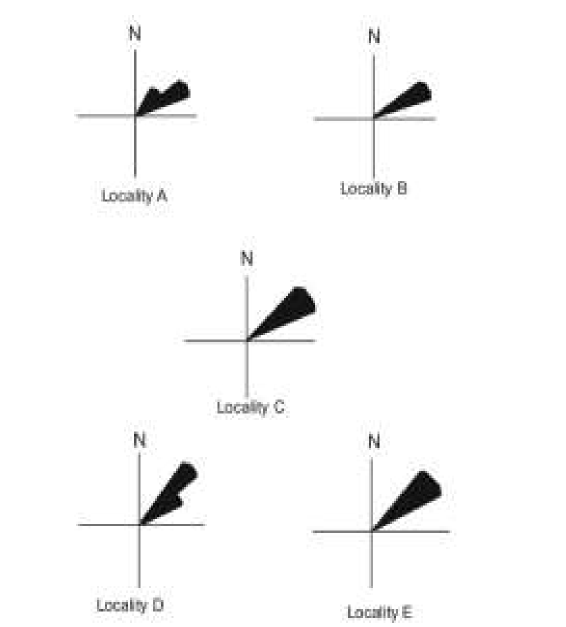
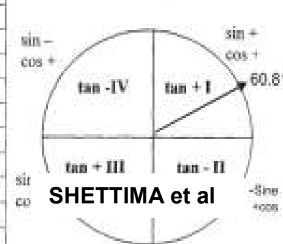


Fig. 19 Paleocurent directions of the Chad Formation at locality A,B,C,D and E.

Table 2. Paleocurrent data (Azimuth of crossbeds)

AZIMUTH	SIN X	COS X
039 (2)	1.2586	1.5543
040 (2)	1.2856	1.5321
040 (6)	3.9364	4.5283
042 (6)	4.0148	1.4863
043 (4)	2.7279	2.9254
046 (9)	6.4741	6.2519
047 (5)	3.6568	3.4099
048 (6)	4.4589	4.0148
051 (1)	0.7771	0.6293
052 (13)	10.2441	8.0036
053 (6)	4.7918	3.6108
056 (4)	3.3162	2.2368
057 (6)	5.0320	3.2678
060 (3)	2.5981	1.5000
061 (5)	4.3731	1.4544
062 (2)	1.7659	0.9389
066 (7)	6.3948	2.8472
067 (6)	5.5230	2.3444
068 (11)	10.1990	4.1297
069 (6)	5.6015	2.15021
070 (3)	2.8190	1.0261
071 (7)	6.6186	2.2789
072 (5)	4.7553	1.5451
073 (11)	10.5193	3.2161
074 (4)	3.8451	1.1026
077 (2)	1.9487	0.4499
078 (6)	5.8688	1.2475
079 (2)	1.9633	0.3816
TOTAL	**125.4078**	**70.0549**

- $Tan\,x = \frac{\Sigma n\,Sin\,x}{\Sigma n\,Cos\,x} = \frac{+125.4078}{+70.0549}$
- $Arch\ \tan = \tan^{-1}(1.7901) = 60.81$
- Vector Mean = 60.81
- $R = (\Sigma n\,Sin\,x)^2 + (\Sigma n\,Cos\,x^2)^{1/2} = 143.65$
- Vector Magnitude $\frac{R \times 100}{150} = 95.77$



CHAD FORMATION

(after, Lindholm, 1987)

Skewness is a measure of the symmetry of the distribution and it is a very useful descriptive term for the depositional processes of the sediments. The investigated samples have skewness values ranging from nearly symmetrical to very positively skewed (0.015 ø to 0.80ø) with an average of (0.36ø) very positively skewed indicating that finer materials are predominant (Table 1). River sands are generally positive skewed since most of the silt and clays are not winnowed out by current (Friedman, 1961, 1967; Agumanuu, 1993), hence, the sample may have been formed in a fluvial setting since the average skewness is (0.36ø) very positively skewed.

Kurtosis is a measure of the peak of distribution and values of kurtosis (Table 1) for the various samples range from (0.62ø to 1.56ø) i.e. very platykurtic to very leptokurtic, with an average of (0.97ø) leptokurtic. Little geologic information can be derived from values of kurtosis (Pettijohn *et al.*, 1987), however, the fluctuations of the values may suggest changes in the intensity of the depositing medium and it also largely agrees with (Abdel-Wahab, 1988) data fluvial sands.

The bivariate plots relationships of Friedman (1961, 1979) used in differentiating river sands from beach sands based skewness versus standard deviation when implored in this analysis, it generally yielded a fluvial origin for the samples plotted (Fig.11 and 13). That of Moiola and Weiser (1968) for skewness versus standard deviation and mean versus standard deviation suggest a fluvial origin for the samples studied (Fig.15 and 16). Likewise the plots based on standard deviation versus skewness, and standard deviation versus mean size (Friedman, 1967, 1979) also indicated fluvial origin for the samples (Figs.12 and 14). However, the bivariate plot of Friedman (1979) based on standard deviation versus first percentile and first percentile versus mean yielded both fluvial and coastal environments for the Chad Formation but with about 73% - 80% of the samples suggesting fluvial setting (Figs. 9 and 10).

Further evidences on the fluvial environmental interpretation for the Chad Formation is provided by the fluvial current influence on the deposition of the sediments as observed from the two-sand population segments in the log probability grain size distribution curve plots (Visher, 1969, 1972; Dike, 1972b). The two-sand population curve are characterized by a poorly sorted saltation population segment which slopes between (5^o -49^o) and makes up to about (2%-81%) of the distribution. It also has a well sorted suspension segment having a slope of (56^o – 78^o) that forms about (37% - 48%) of the distribution (fig.17 and 18). These coupled with the lack of marine indicators like phosphate concretions, marine fossils or glauconite may probably confirm the fluvial environment interpretation for the Chad Formation.

The paleocurrent rose diagram plotted for the Chad Formation yielded a unimodal trend In the northeastern direction (Fig.19) and this is in consonances with the paleocurrent direction established for the Chad Formation by Barbers and Jones (1960) which is also in the northeastern direction. This may suggest that the sediments forming this formation were possibly sourced from the southwestern direction, probably from the associated basaltic and granitic rocks of the Biu Plateau. This may further be confirmed by the paleocurrent analysis based on Lindholm (1987) which also indicated that the direction of sediment supply is in the northeast (Table 2).

CONCLUSION

The Chad Formation in the northeastern part of the Bornu Basin is composed of fine, medium, coarse grained sandstones which range from light brown to brown and grey mudstones. They are generally poorly sorted with skewness ranging from nearly symmetrical to very positively skewed and the kurtosis varies from very platykurtic to very leptokurtic.

The grain size parameters and their bivariate plots relationships have predicted that the depositional environment under which the Chad Formation got formed was generally a fluvial setting. The paleocurrent analysis also indicated that the sediments were sourced from the southwestern part of the basin most probably from the associated basaltic and granitic rocks of the Biu Plateau.

REFERENCES

Abdel-Wahab, A.,1988. Lithofacies and Diagenesis of the Nubia Formation at Central Eastern Desert, Egypt (abst.) 9th EGP. Exploration Conference Cairo, 20-23 November. IIA, 9.

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: 121-12.

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

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

Barbers, W. and Jones, D.G., 1960. The Geology and Hydrogeology of Maiduguri, Borno Province. Records of Geologic Survey of Nigeria,5-20pp.

Burke. K.C., 1976. The Chad Basin: An active intra-continental basin. Techtonophysics,36, 197-206.

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. Geological Survey Nigeria Bulletin, 30:1-99.

Dike, E.F.C., 1972. Sedimentology of the Lower Greensand of the Isle of Wight, England. Unpub. D. Phil. Thesis, University of Oxford, England, 204pp.

Du, Preez, J.W., 1949. The Maiduguri-Bama ridge and its influence on surface drainage. Unpubl. GSN. Rep., 6p

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

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

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

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

Genik, G.J., 1993. Regional framework, structural and rift aspect of petroleum basins in Niger, Chad and the Central African Republic (C.A.R.). Tectonophysics, 213, 169-185.

Hartley, R.T and Allen, P.A., 1994. Interior cratonic basins of Africa:relation to continental break-up and role of mantle convection. Basin, 2, 42.

Jones, D.K., 1959. Geology of parts of Chad Basin (Standard sheet 65AL + Gubio). Memoir of Geologic Survey of Nigeria, 8p.

Krumbien, W.C. and Sloss, L.L., 1963. Stratigraphy and Sedimentation (2nd Ed.) Freeman, San Francisco, 600pp.

Kukal, Z., 1971. Geology of Recent Sediments. Academy Press London and New York,490pp.

Lindholm, R.C., 1987. A Practical Approach to Sedimentology. Allen and Unwin, Boston, 276pp.

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

Obaje, N.G., Olu, O.K. and Petters, S.W., 1999. Biostratigraphic and geochemical controls of hydrocarbon prospect in the Benue Trough and Anambra Basin, Nigeria. Nigerian Association of Petroleum Explorationists Bulletin, 14, 1: 18-54.

Olugbemiro, R, and Nwajide, C.S., 1997. Grain size distribution and particle morphogenesis as signatures of depositional environment of Cretaceous (non ferruginous) facies in the Bida Basin, Journal of Mining and Geology, 2, 89-101.

Pettijohn, F. J., Potter, P.E. and Siever, R.,1973.Sands and Sandstones (2nd Ed). Springer-Verlag, Berlin, 407pp.

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 Geol. Helv., 79, 343-363.

Reineck, H.E and Singh, I.B., 1973. Depositional Sedimentary Environment, with References to Terrigeneous Clastics. Springer-Verlag, Berlin, 439pp.

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

Visher., G.S., 1972. Physical characteristics of fluvial deposits. Society For Sedimentary Petrologist Special Publication, 16: 84-97.