

# SEDIMENTOLOGY, PALEOENVIRONMENTS AND PROVENANCES OF THE CLASTIC SEQUENCE OF THE GOMBE SANDSTONE AROUND GOMBE AND ENVIRONS IN THE GONGOLA ARM OF THE UPPER BENUE TROUGH NIGERIA

---

B. SHETTIMA, I.Y. BUBA, A.M. KYARI, F. BUKAR

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

## ABSTRACT

The textural parameters computed from granulometric analysis for twenty-five samples of the Gombe Sandstone i.e. graphic mean size, standard deviation, skewness, and kurtosis yielded average values of 2.25 $\phi$ , 1.17 $\phi$ , 0.25 $\phi$  and 1.00 $\phi$  respectively. Both granulometric and petrographic analysis indicated that the Gombe Sandstone is dominantly poorly sorted and are mostly positively skewed. The sediments range from quartzwacke to subarkose. The bivariate plots of standard deviation vs. mean, standard deviation vs. skewness, standard deviation vs. first percentile and the C–M pattern yielded a dominance of fluvial environment, however, mean vs. first percentile showed a dominance of coastal environment. The probability curve plots showed a dominance of two sand population plots indicating prevalence of unidirectional currents.

Paleocurrent analysis has shown that the Gombe Sandstone trends in the northwestern and southeastern directions with unidirectional current systems, having unimodal distribution, indicating a source from the northeastern and southeastern direction.

**KEYWORDS:** Gombe Sandstone, Sedimentology, Provenance

## INTRODUCTION

Depositional environments control textural parameters such as size, sorting, packing, fabrics, shape and rounding owing to provenance, depositional history and dynamic processes operating within the basin which include: average energy level, maximum energy level, fluctuation in energy level, rate of dissipation of high energy level, level of biogenic activity and climate. In general, well-sorted sandstones are deposited in environments where persistently high energy levels are present, and poorly sorted sandstones are deposited in environments where energy levels are consistently low.

The imprints of these environmental factors are inscribed onto the accumulating sediments and they are being determined by suites of statistical analysis in order to determine the depositional environments under which they are formed. The depositional environment of the Campano-Maastrichtian Gombe Sandstone was investigated using the textural parameters i.e. univariate and bivariate grain size parameters. Probability curve plots were also implored in these studies so as to understand the dynamic processes operating within

the basin. Provenance studies of the formation were likewise carried out using paleocurrent analysis.

## GEOLOGIC AND STRATIGRAPHIC SETTING

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 Niger-delta in the south to the southern margin of the Chad Basin in the north (Fig. 1). The trough is a sedimentary basin containing upto 6000m of Cretaceous to Tertiary sediments associated with volcanics. It is geographically sub-divided into lower, middle and upper portion (Fig. 1). The trough was believed to have been formed from extensional process during Late Jurassic to Early Cretaceous break-up of the continents of Africa and South America (Grant, 1971), but Benkheilil (1989) suggested sinistral wrenching as the tectonic process responsible for its evolution.

The Upper Benue Trough is made 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) (Fig. 2).

---

**B. Shettima**, Department of Geology, University of Maiduguri, Borno State

**I. Y. Buba**, Ministry of Commerce, Gombe State

**A. M. Kyari**, Department of Geology, University of Maiduguri, Borno State

**F. Bukar**, Department of Geology, University of Maiduguri, Borno State

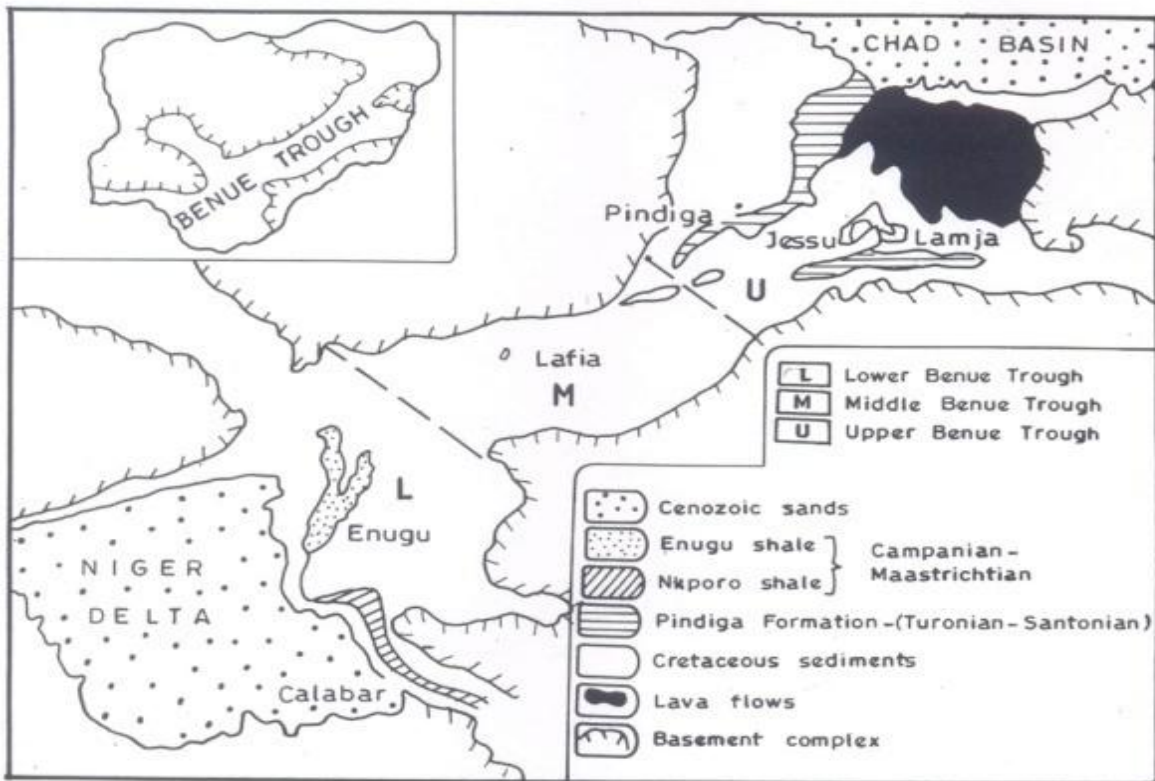


Fig. 1 Geographical subdivision of the Benue Trough (after Obaje and Lingoius, 1996)

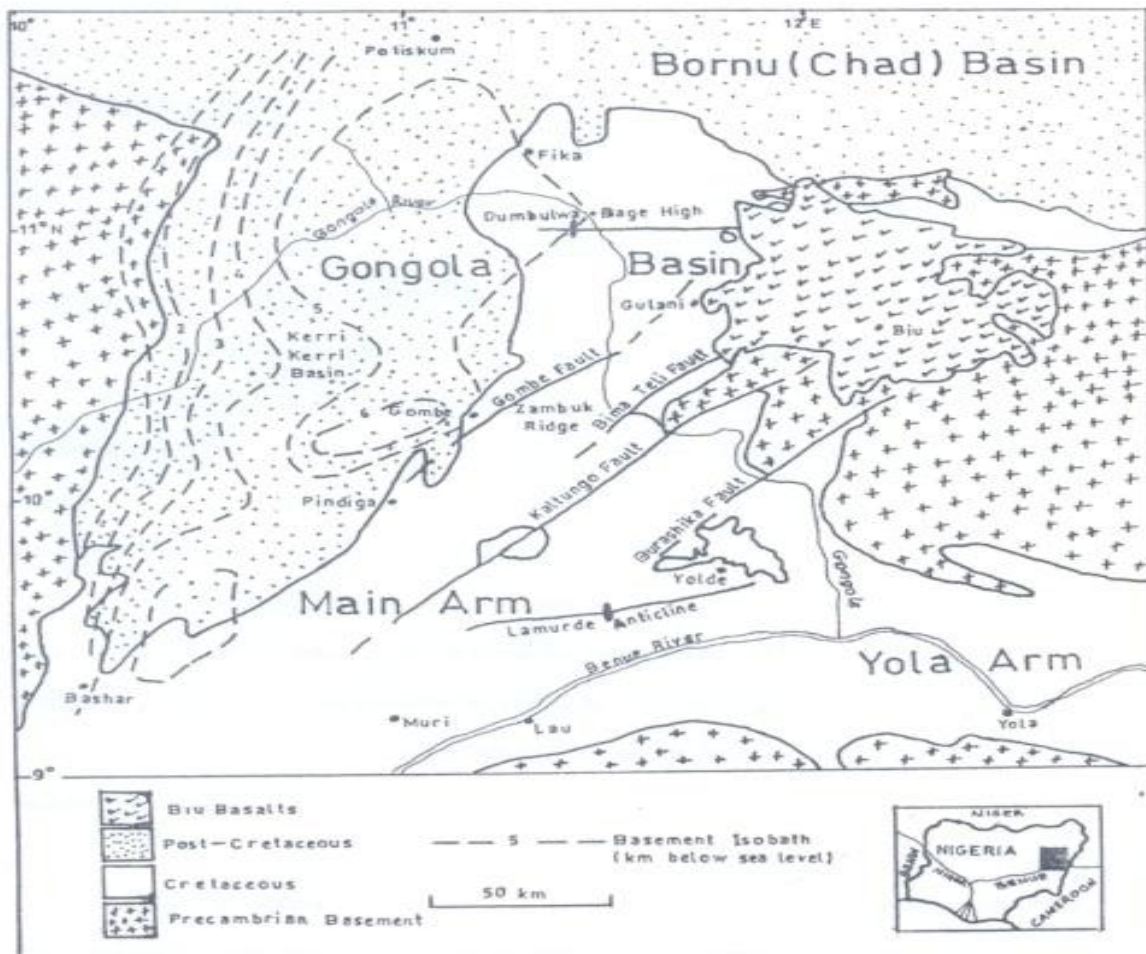


Fig. 2 Geological map of the Upper Benue Trough (after Zaborski, et al., 1997)

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) (Fig. 3).

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).

The Turonian-Santonian Pindiga Formation conformably overlies the Yolde Formation (Carter et al, 1963). It is laterally equivalent to the Gongila Formation and Fika Shales and they represent a full marine incursion into the Gongola Arm.

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 (Dike 1993).

**MATERIALS AND METHODS**

Twenty five samples of the Gombe Sandstone were collected around Gombe and environs where its thickest section occurs (Fig. 4). These samples were collected from five outcrop sections with careful attention as to avoid weathered horizons (Fig. 5, 6, 7, 8 and 9). 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), Moiola and Weiser (1968) and Passega and Bryramjee (1969) were applied to interpret the paleoenvironments of these sandstones. One hundred and forty (140) readings were measured from both declination (azimuth) and inclination of foreset planes. The obtained data were corrected for tilt so as to restore the deformed strata to its original position. The data is then grouped into appropriate class intervals from which current rose diagrams are constructed for the Gombe sandstone.

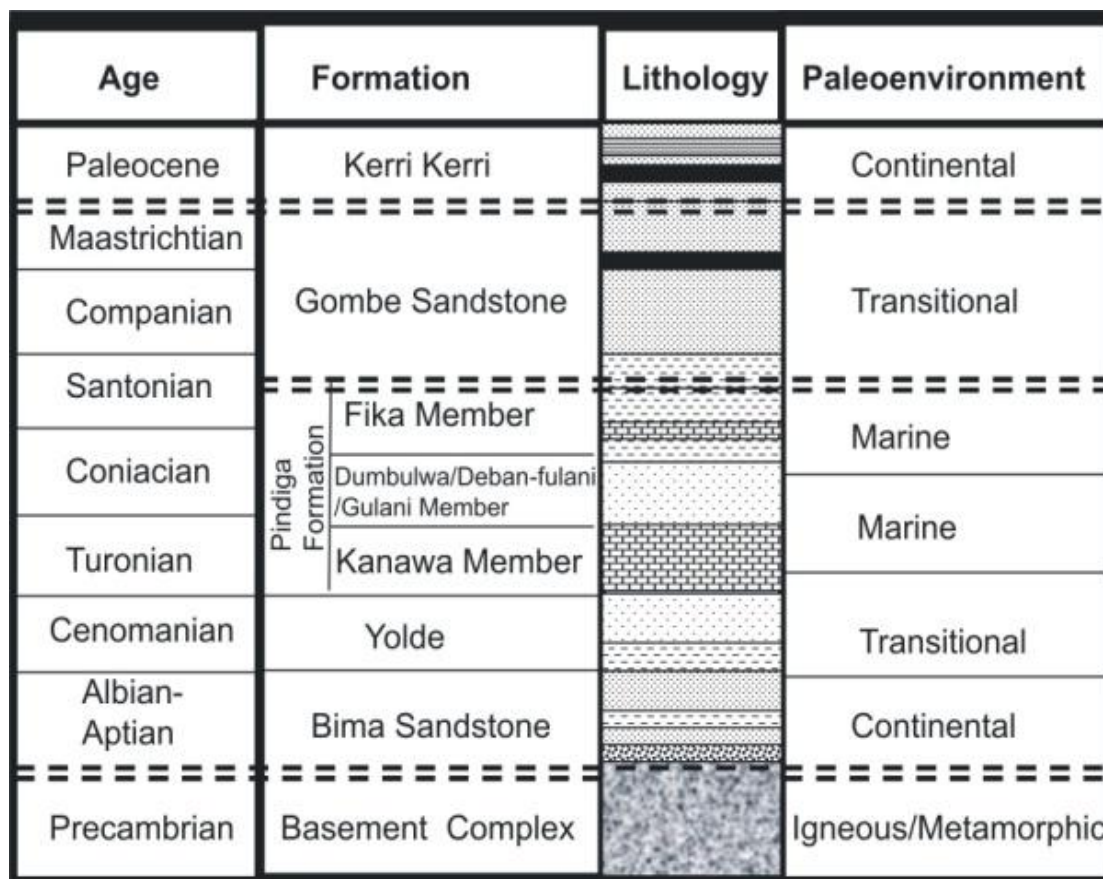


Fig.2 Stratigraphy of Gongola Basin (modified from Zaborski et al., 1997)



Table 4: Grain size distribution and qualitative parameters for the samples analyzed

SAMPLE NO.	Graphic Mean (Mz) $\Phi$	Graphic Standard Deviation (Sorting)	Graphic Skewness (Sk <sub>1</sub> ) $\Phi$	Graphic Kurtosis (Kc) $\Phi$
A4	3.11 Very fine sand	0.86 Moderately sorted	0.28 Positively skewed	0.77 Platykurtic
A5	3.05 Very fine sand	0.89 Moderately sorted	0.23 Positively skewed	0.94 Mesokurtic
A9	3.02 Very fine sand	0.97 Moderately sorted	0.15 Positively skewed	0.70 Platykurtic
A10	3.31 Very fine sand	0.77 Moderately sorted	0.18 Positively skewed	0.62 Very platykurtic
A13	2.53 Fine sand	1.21 Poorly sorted	0.36 Positively skewed	0.98 Mesokurtic
A14	2.27 Fine sand	1.32 Poorly sorted	0.41 Positively skewed	1.14 Leptokurtic
B1	3.57 Very fine sand	0.55 Moderately sorted	0.00 Symmetrical	1.34 Leptokurtic
B4	3.61 Very fine sand	0.48 Well sorted	0.11 Positively skewed	1.34 Leptokurtic
C3	2.38 Fine sand	1.44 Poorly sorted	0.12 Positively skewed	0.74 Platykurtic
C4	1.79 Medium sand	1.79 Poorly sorted	0.27 Positively skewed	0.88 Platykurtic
C5	2.06 Fine sand	1.52 Poorly sorted	0.38 Positively skewed	0.85 Platykurtic
C6	1.94 Medium sand	1.60 Poorly sorted	0.39 Positively skewed	0.88 Platykurtic
C7	1.77 Medium sand	1.83 Poorly sorted	0.32 Positively skewed	0.82 Platykurtic
C8	1.64 Medium sand	1.84 Poorly sorted	0.44 Positively skewed	1.26 Leptokurtic
C9	2.06 Fine sand	1.49 Poorly sorted	0.35 Positively skewed	0.93 Mesokurtic
C12	2.26 Fine sand	1.06 Poorly sorted	0.09 Nearly symmetrical	1.19 Leptokurtic
C18	3.16 Very fine sand	0.71 Moderately sorted	0.37 Positively skewed	0.84 Platykurtic
D2	2.92 Fine sand	0.90 Moderately sorted	-0.02 Nearly symmetrical	1.49 Leptokurtic
D3	2.76 Fine sand	0.83 Moderately sorted	-0.12 Negatively skewed	2.39 Very leptokurtic
D4	3.15 Very fine sand	0.73 Moderately sorted	0.44 Positively skewed	1.03 Mesokurtic
E5	1.24 Medium sand	2.09 Very poorly sorted	0.24 Positively skewed	1.02 Mesokurtic
E9	2.26 Fine sand	1.14 Poorly sorted	0.38 Positively skewed	1.10 Mesokurtic
E11	1.73 Medium sand	1.41 Poorly sorted	0.16 Positively skewed	1.04 Mesokurtic
E13	3.17 Very fine sand	0.78 Moderately sorted	0.33 Positively skewed	0.70 Platykurtic
E15	2.92 Fine sand	0.93 Moderately sorted	0.28 Positively skewed	1.02 Mesokurtic
Average	2.55 Fine sand	1.17 Poorly sorted	0.25 Positively skewed	1.00 Mesokurtic

## RESULTS

### Univariate grain size parameters:

The graphic mean size for the various samples (Table 1) range from 1.24 $\phi$  –3.61 $\phi$  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 well sorted (0.48 $\phi$ ) to poorly sorted (2.09 $\phi$ ) with an average of (1.17 $\phi$ ) which implies that the whole formation is poorly sorted.

The samples analysed have skewness values ranging from 0.015  $\phi$  to 0.80 $\phi$  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 0.62 $\phi$  to 2.39 $\phi$  (very platykurtic to very leptokurtic), with an average of 1.00 $\phi$  (mesokurtic).

### Bivariate grain size parameters:

#### 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). Using the bivariate plot of Friedman (1961) which distinguishes river sand from beach sand, all the studied samples plotted within the river field (Fig.10). 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. 11 and 13). The plots based on Moiola and Weiser (1968) likewise shows distribution of sands between river and beach environments and it showed that 100% of the studied samples plotted within the river field environment (Fig. 12).

#### 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. 15). 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).

#### Standard Deviation versus First Percentile

Friedman (1979) developed this bivariate plot likewise to distinguish river sand from beach sand (Fig. 16). The plots indicates that 77% of the samples plotted within the river field sand and 23% of the samples plotted within the inland dune sand field.

#### 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. 17) indicates that 52% of the samples fell into the river sand environment, while 48% plotted into the inland dune sand environment.

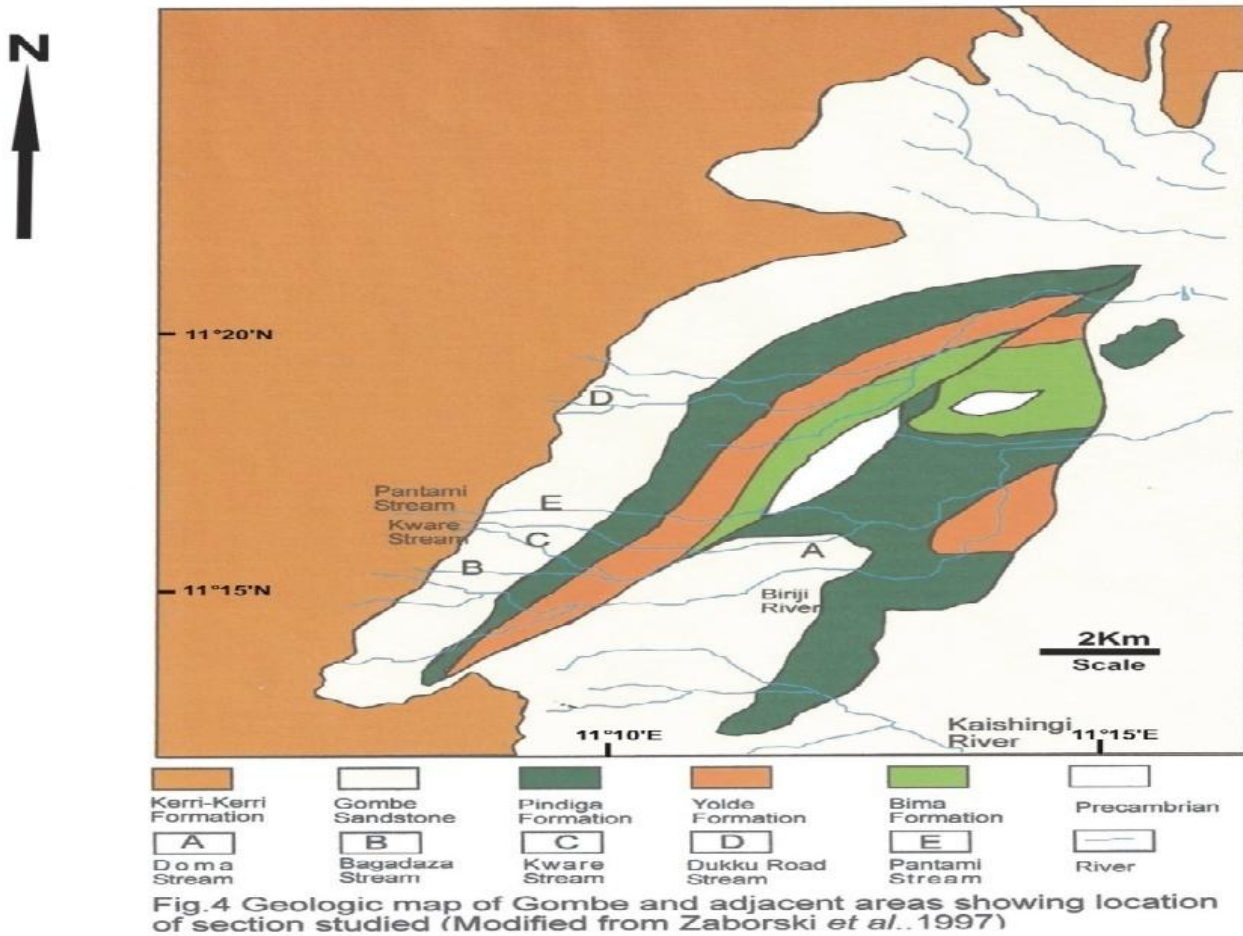
#### The C-M Pattern

The C-M pattern was introduced by Passega (1957) in an attempt to establish the relationship

between texture of sediments and processes of deposition. The C represents one percentile ( $\Phi_1$ ) diameter (in microns), and M is the fifty percentile ( $\Phi_{50}$ ) and it is also (in microns). The values of C and M were determined from the cumulative curve of individual samples in table 1 (in phi scale), and the values are

converted to microns using the Wentworth (1922) grade scale. Logarithmic scale is normally used for the construction of C – M pattern (Fig. 18).

Passega and Byramjee (1969) divided the basic C-M pattern into nine classes each reflecting



certain mode of transportation (rolling, sliding, graded suspension or saltation and uniform suspension). The samples plotted on the C-M diagram tend to occupy classes I, II IV, V, and VI. The first class suggests transportation by sliding, while the rest represents transportation by graded suspension or saltation and uniform suspension.

Passega (1957, 1964) has shown that the C-M diagram can be subdivided by points (N, O, P, Q, R and S) into segments that correspond to a particular sedimentation mechanism. The NO segment represents a deposit formed mostly by rolling, OP segment represents a mixture in variable proportion of rolling grains and suspension, where the values of C are generally higher than 800µm. Segment PQ corresponds to suspended sediment, segment QR represents deposit formed by graded suspension (saltation) and RS represents deposit formed by uniform suspension. All the investigated samples tend to occupy all the segments.

The scattered distribution pattern displayed by the investigated samples on the C-M diagram within the various fields of rolling, saltation (graded suspension) and uniform suspension tends to largely

resemble that proposed pattern for flood plain and channel deposits.

**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 Visser (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. 19 and 20) of analysed samples tend to show two to three straight-line segments.

All the samples characterized by three-segment probability curves are: A4, A5, A9, A10, C18, D3, D4 and E13. They are characterized by:

- i) Poorly sorted suspension population with a slope of 25° – 48° that forms 3% -15% of the distribution.
- ii) A well sorted saltation with a slope of 65° – 79° that forms 51% - 75% of the distribution.
- iii) A poorly sorted saltation with a slope of 25° - 47° that forms 0.5 – 12%.

The samples characterized by two segments probability curve are: A13, A14, C3, C4, C5, C7, C8, C9, C12, E5, E9, E11 and E15. They are characterized by:

- i) Poorly sorted suspension population with a slope of 8° – 40° that forms 3% - 25% of the distribution.
- ii) A well sorted saltation with a slope of 47° – 64° that forms 60%- 84% of the distribution.

However, sample D2, though it has two-sand population segment, it is characterized by:

- i) A well sorted suspension (slope, 47°) that forms 71% of the distribution and
- ii) A poorly sorted saltation (slope, 41°) that forms 17% of the distribution.

A single segment curve is characteristic of B1 and B4 and it displays:

- i) A well sorted suspension population with a slope of 72-75° that forms 79-82% of the distribution.

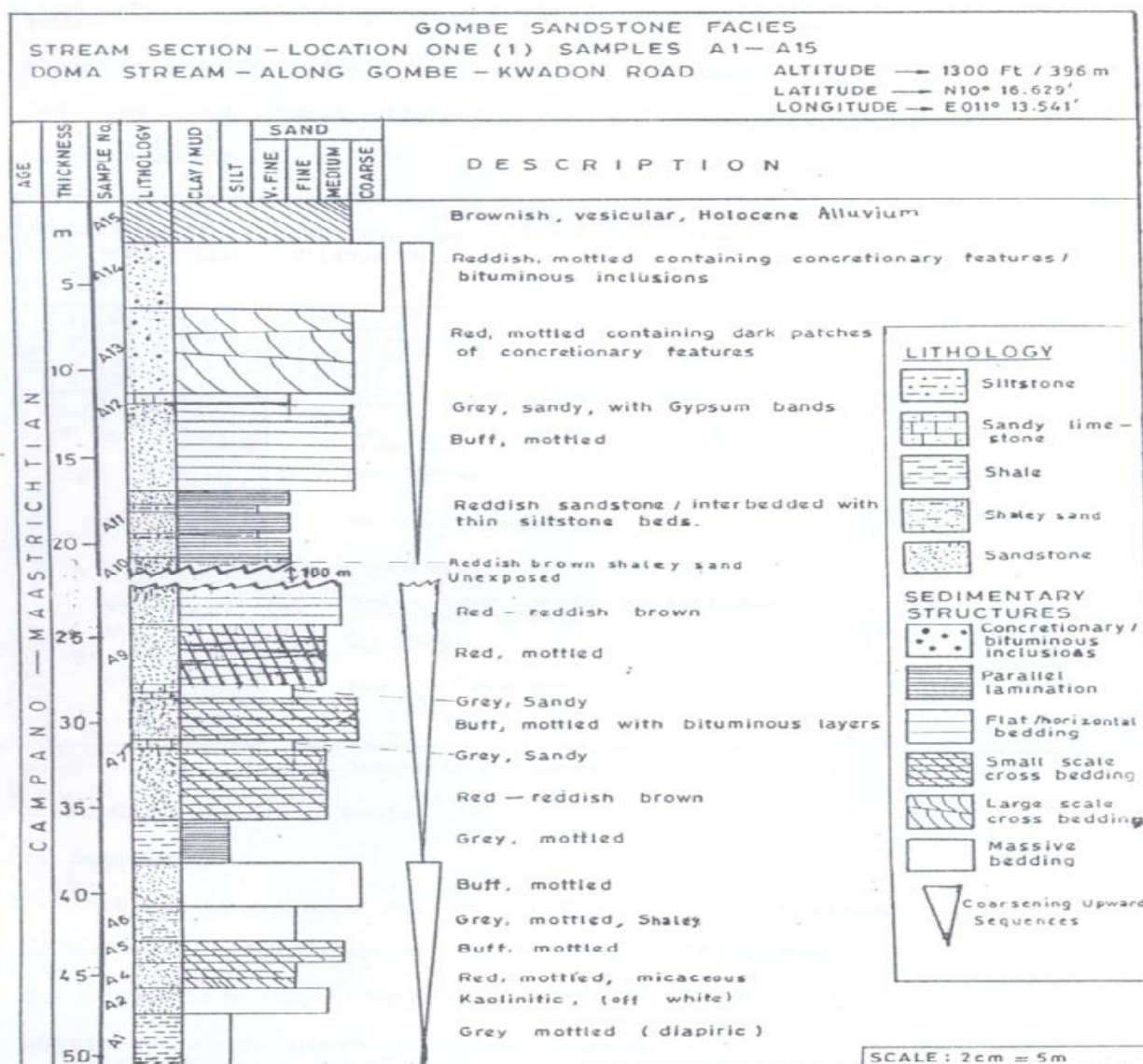


Fig.5 Section of Gombe Sandstone at Doma stream



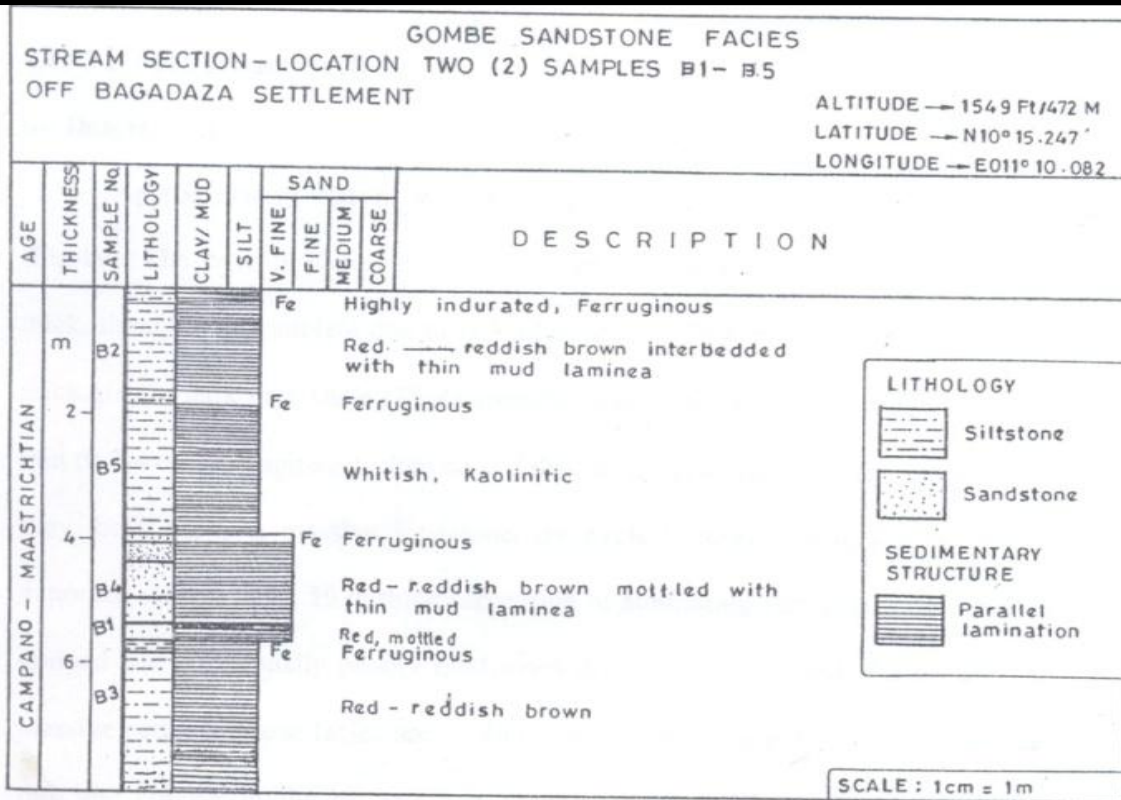


Fig.6 Section of Gombe Sandstone at Bagadaza stream

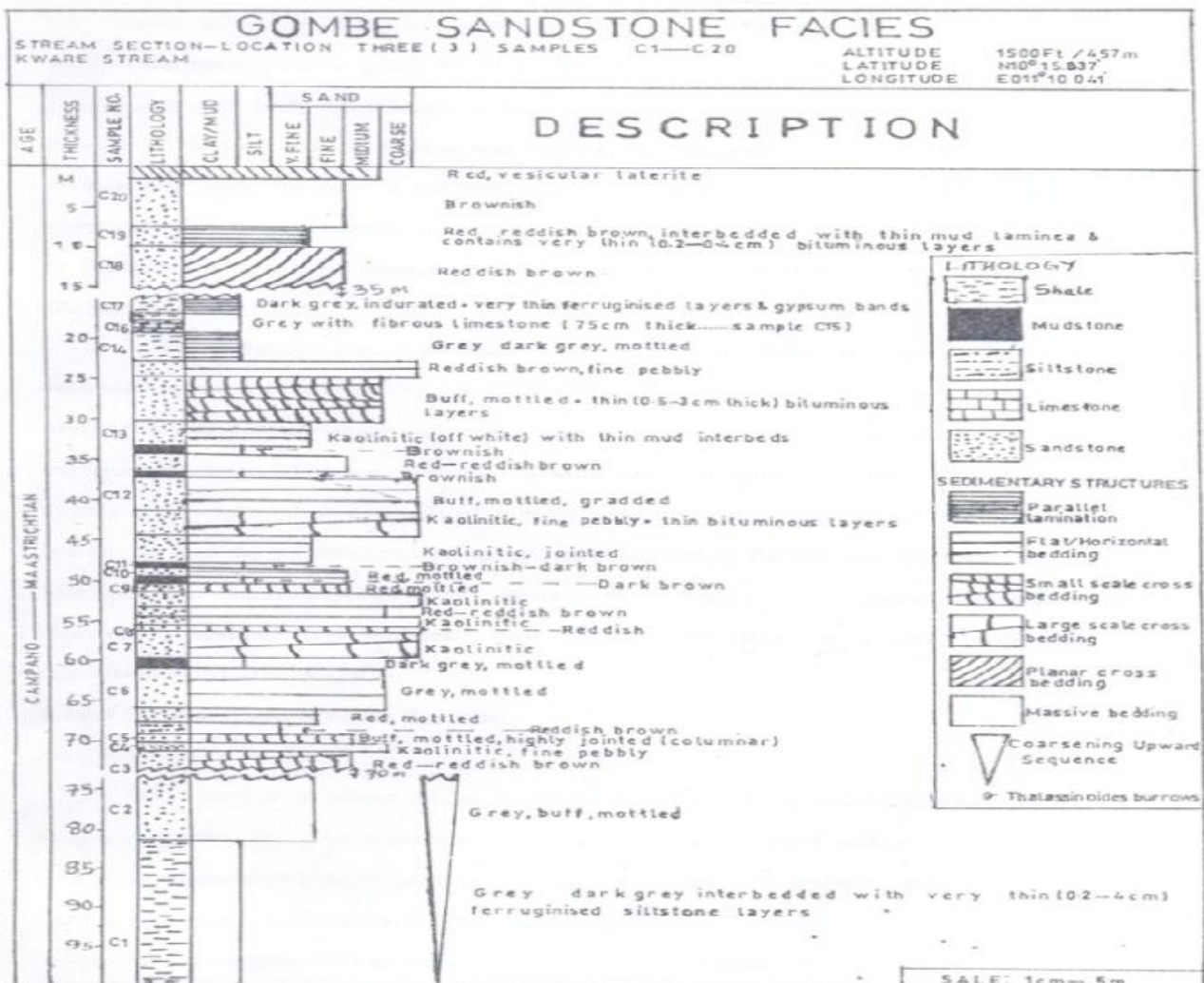


Fig.7 Section of Gombe Sandstone at Kware stream

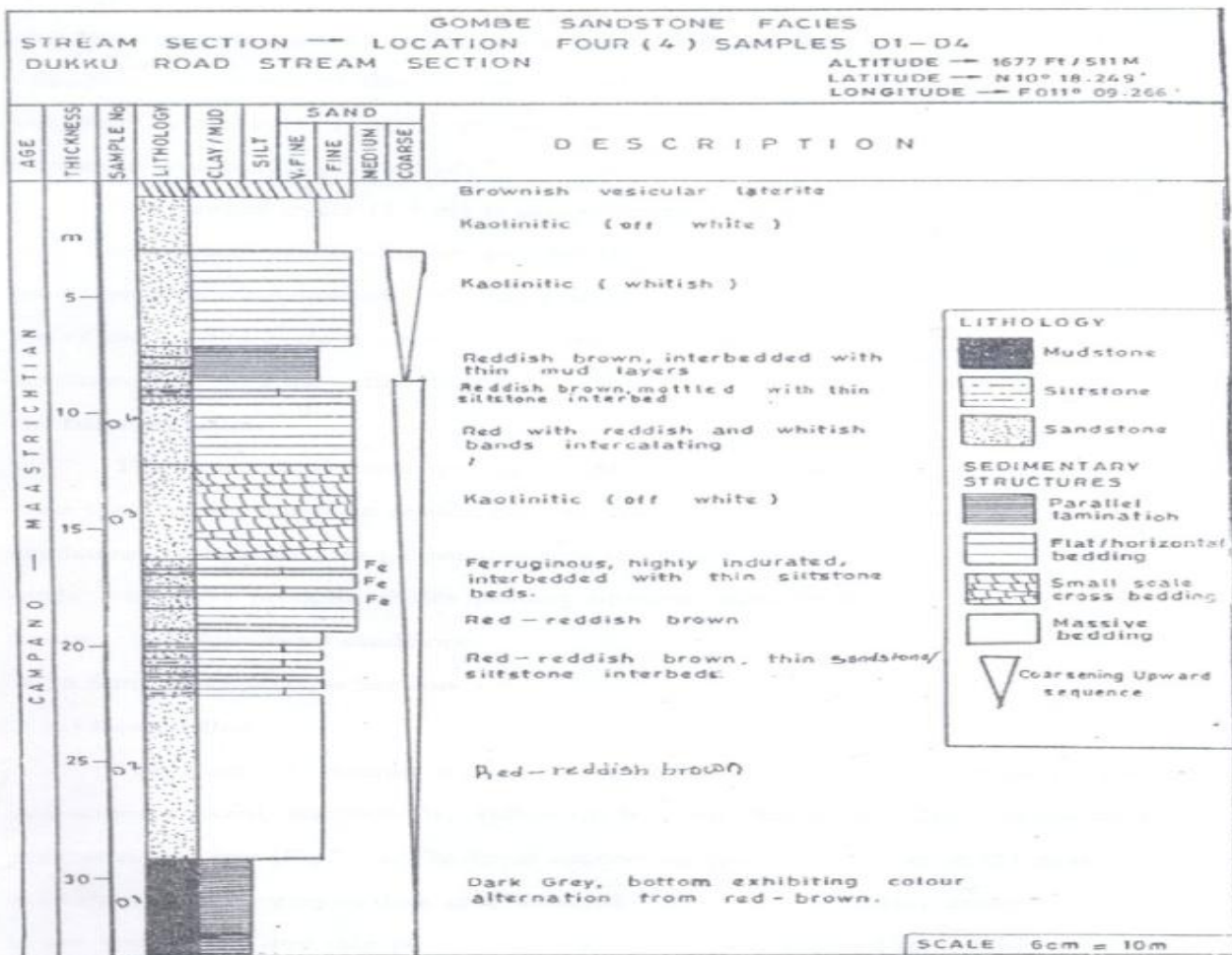


Fig.8 Section of Gombe Sandstone along Dukku road

### Paleocurrents

Studies on paleocurrent direction allow for the reconstruction of the current system and this research, azimuths of crossbeds from five sample point were measured. The beds are of varying thickness and strike in a general NW direction (N48W-N56W) and dip at angles between 7° and 10° (average 9°) and the cross beds dip at angles between 8° and 30° (average 15°). The azimuths were however not subjected to tilt correction because tectonic dip does not exceeds 10°. Apart from the paleocurrent rose diagram of the Pantami stream section which indicated a single major trend in the northwestern direction (Fig.21 d), all the other study locations i.e. Doma stream, Kware stream and Dukku road sections (Fig.21 a, b and c) have a minor trend in the southwestern direction apart from the major northwestern trend. The composite paleocurrent rose diagram for the whole study locations showed both the major northwestern and minor southwestern trends (Fig.21 e) and this may indicate that the sediment forming the Gombe Sandstone were dominantly sourced from the southeastern direction with minor contribution from the northeastern direction.

Although the current rose diagram gives an overall idea of the paleocurrent direction, the average flow direction is determined from the vector mean. The vector mean is determined by computing the summation of the sine and cosine for each direction of the azimuth orientation and the mean is the arc tan of the resulting tangent.

In analyzing the azimuth directional data, the dispersion of the data is given by the vector magnitude, it is also known as the consistency ratio (Lindholm, 1987).

High value usually indicates high dispersion, in this analysis the vector mean for the Gombe Sandstone is 80.50, while the vector magnitude stands out of 97.98 (Table 2). The vectors mean indicate that the flow direction was in northwestern direction.



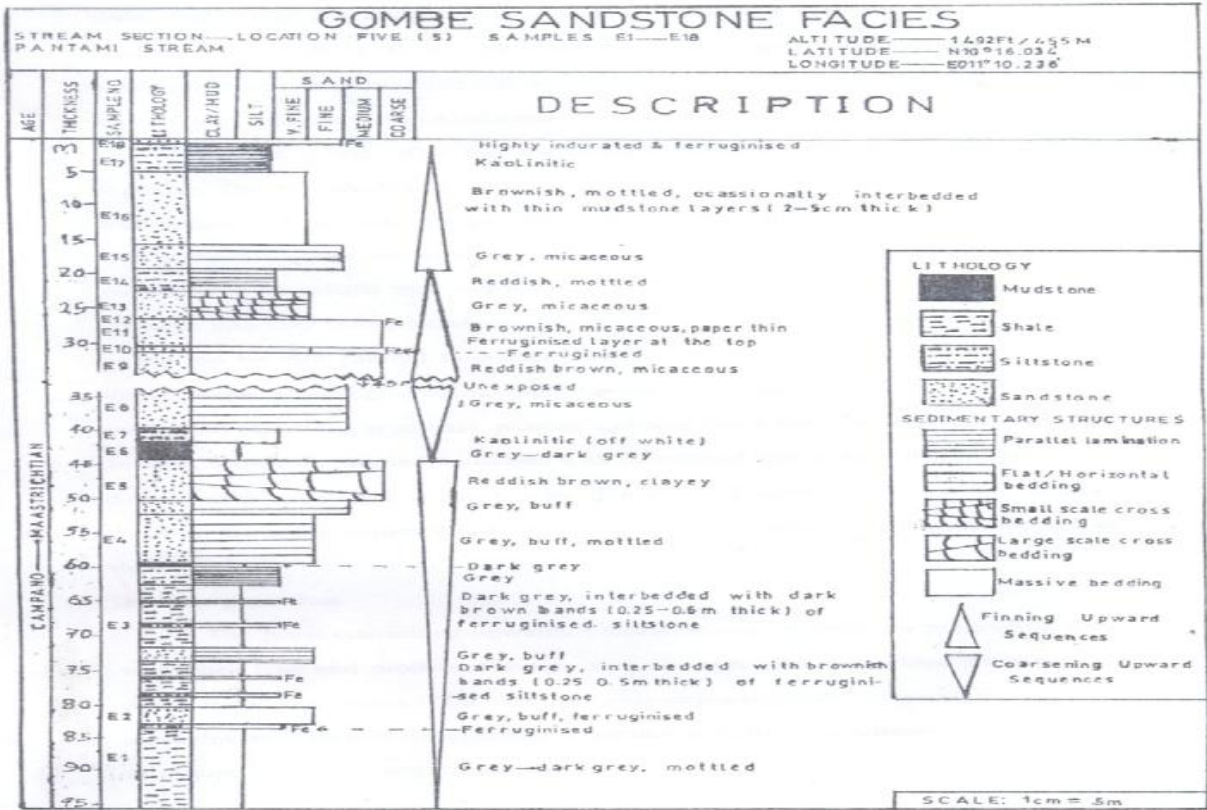


Fig.9 Section of Gombe Sandstone at Pantami stream

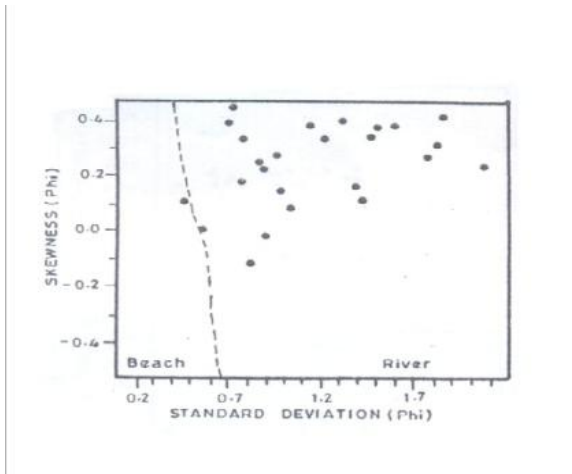


Fig.10 Bivariate plot of skewness vs standard deviation (after Friedman, 1961)

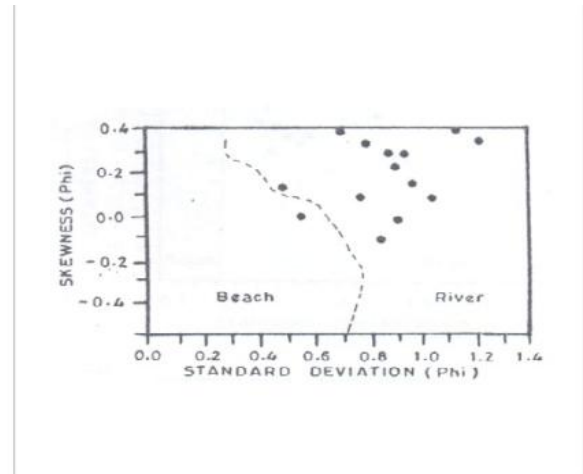


Fig.11 Bivariate plot of skewness vs standard deviation (after Friedman, 1967)

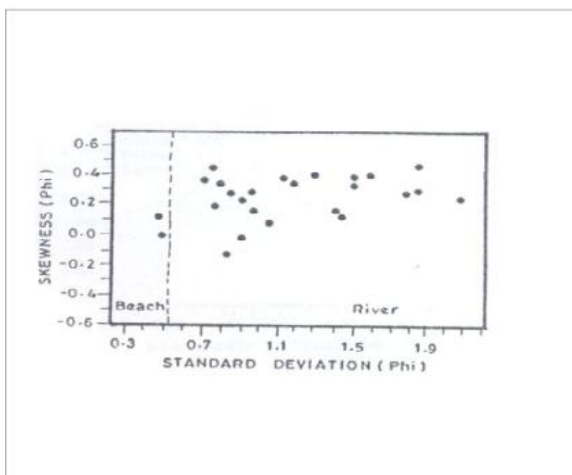


Fig.12 Bivariate plot of skewness vs standard deviation (after Moiola and Wieser, 19676)

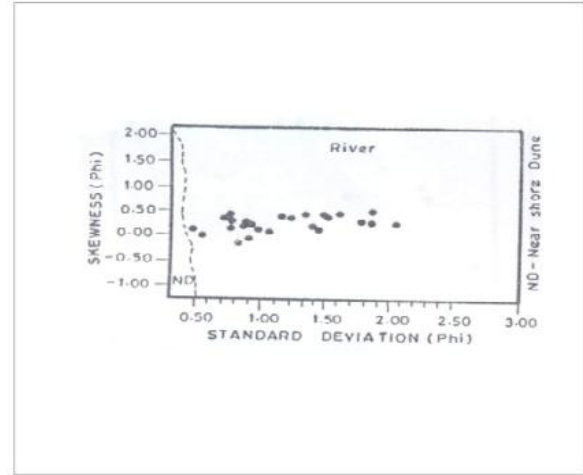


Fig.13 Bivariate plot of skewness vs standard deviation (after Friedman, 1979)

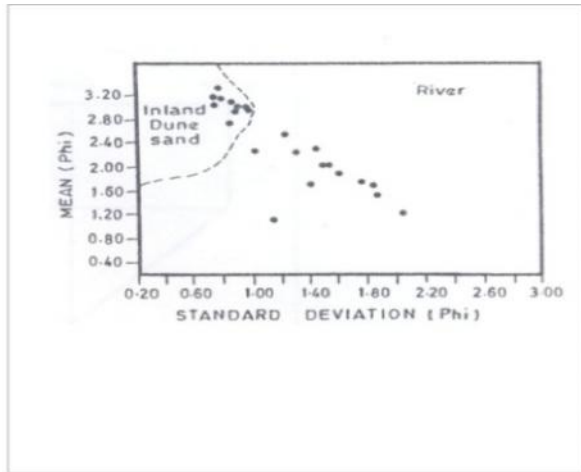


Fig. 14 Bivariate plot of mean vs standard deviation (after Friedman, 1961)

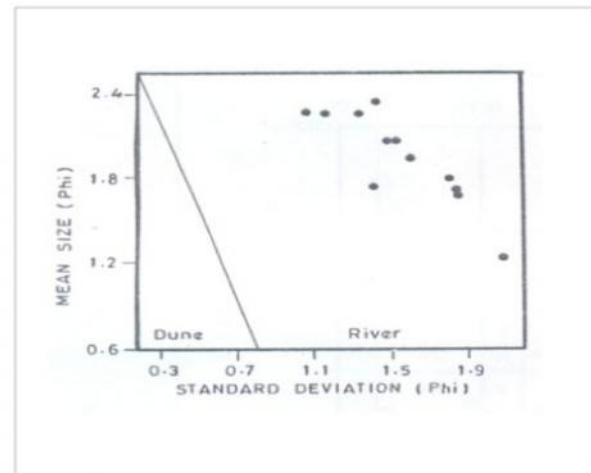


Fig. 15 Bivariate plot of mean vs standard deviation (after Friedman, 1961)

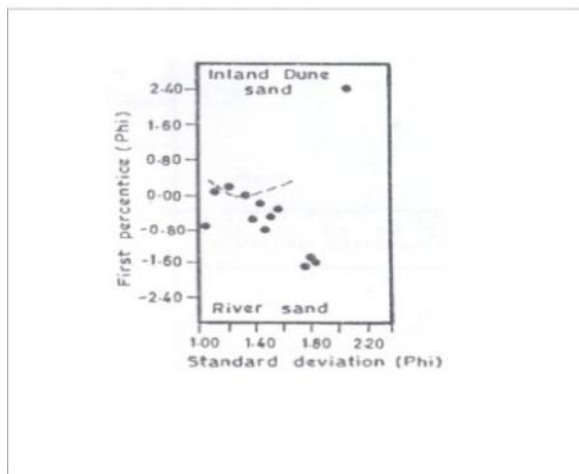


Fig. 16 Bivariate plot of standard deviation vs first percentile (after Friedman, 1979)

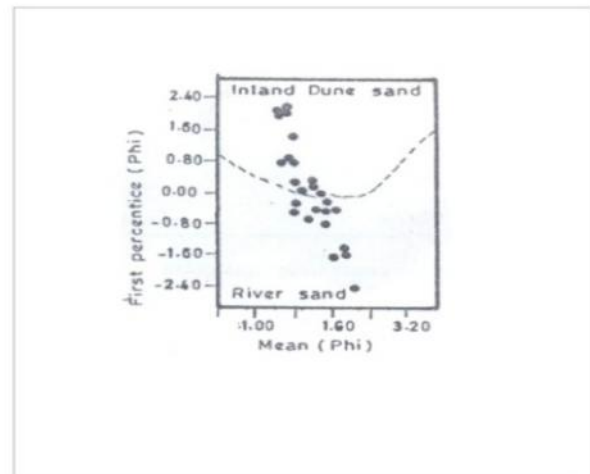


Fig. 17 Bivariate plot of mean vs first percentile (after Friedman, 1979)

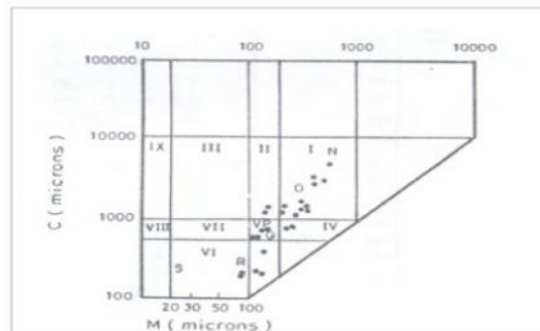


Fig. 18 C-M diagram of Gombe Sandstone (after Passega, 1957 and Passega and Byramjee, 1969)

## 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 Gombe Sandstone ranges from  $(1.24\phi-3.61\phi)$  i.e. very to medium grained sandstones with an average of  $(2.55\phi)$  indicating fine grained sandstone and it is the dominating lithology (Table 1). Friedman 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 in one phase with little reworking or redeposition (Kukul, 1971). Hence, the deposition of the Gombe Sandstone is probably 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). Sorting for the Gombe Sandstone ranges from  $(0.48\phi-2.09\phi)$  i.e. well sorted to very poorly sorted, with a mean value of  $(1.17\phi)$  indication poor sorting (Table 1). The poor to well sorting of the sandstones of this formation (Table 1) may suggest that the transportation responsible for its deposition is quick and rapid. It is also suggestive of short distances of transportation and nearness of sediment source.

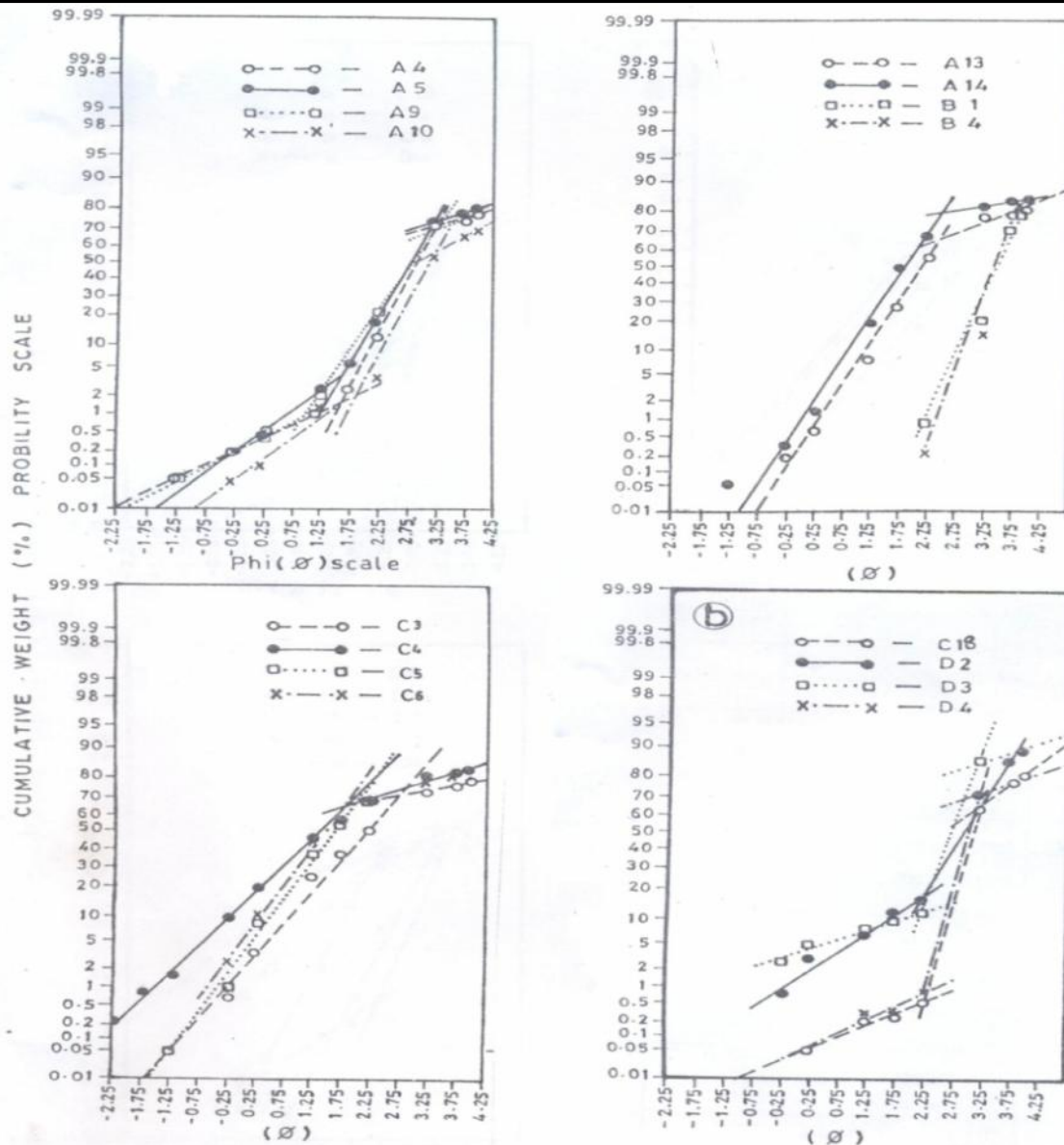


Fig.19 Sand population distribution curve based on log probability plots

Skewness is the measure of the symmetry of the distribution and it is a very useful descriptive term from the depositional processes of the sediment. The samples analysed ranged from  $(-0.12\phi - 0.44\phi)$  i.e. negatively skewed to positively skewed (Table 1). These investigated samples are dominantly positive skewed, indicating that finer materials predominates. River sands are generally positively skewed since most of the silts and clays are not removed by current (Friedman, 1961, 1967), therefore, the samples may have been formed in a fluvial setting since the average skewness is  $(0.36\phi)$  i.e. very positively skewed.

Kurtosis is the measure of the peak of distribution and for the Gombe Sandstone it ranges from  $(0.62\phi - 2.39\phi)$  i.e. very 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 plots relationships of Friedman (1961, 1967) used for differentiating river sands from beach sands based on skewness versus standard deviation when implored in this analysis indicated both fluvial and marine setting for the samples analysed, but with fluvial influence dominating most (Figs.10 and 11). Likewise that of Moliola and Weiser (1968) also indicated both fluvial and beach setting but with fluvial dominating (Fig.12). However, that of Friedman (1979) generally suggested a fluvial environment (Fig.13). The plots based on mean versus standard deviation of Friedman (1979) suggested a dominant fluvial setting with little marine influence (Fig.14), but for Moliola and Weiser (1968) it generally indicated a fluvial setting (Fig.15). Furthermore, the bivariate plots of Friedman (1979) based on first percentile versus standard deviation and first percentile versus mean yielded both



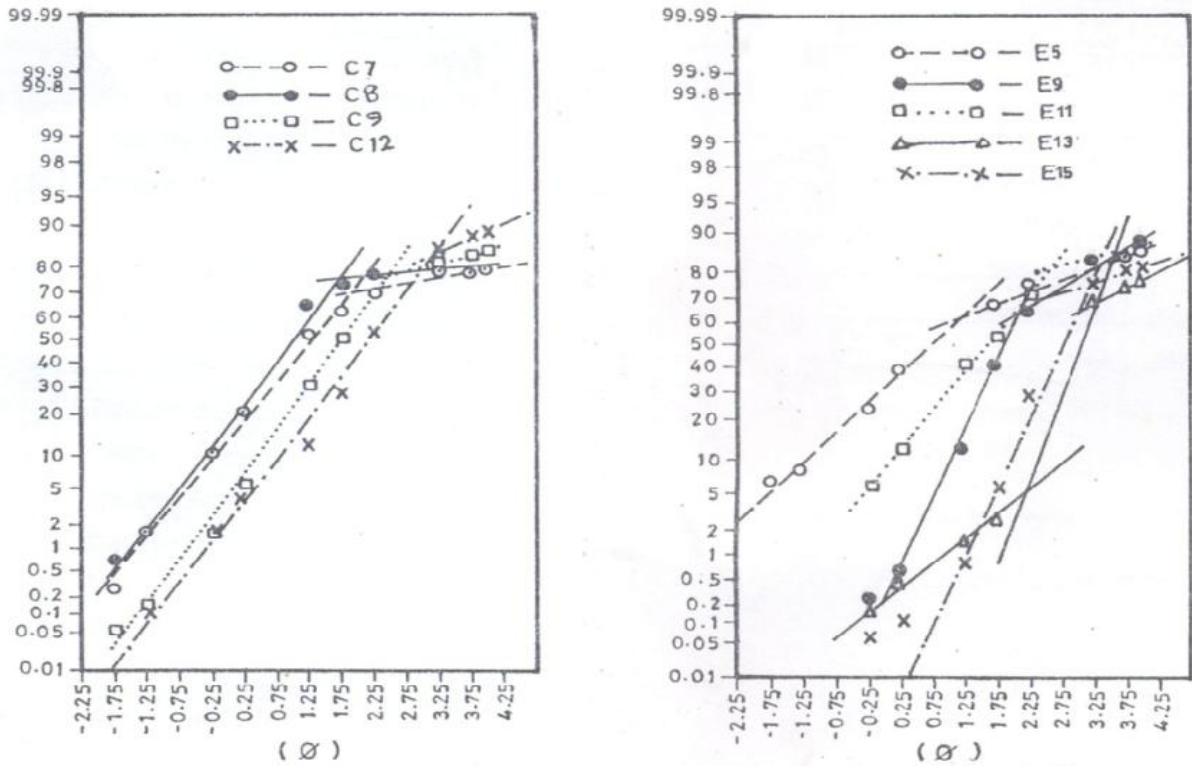


Fig..20 Sand population distribution curve based on log probability plots

Table 2 Trigonometrical methods for calculating vector mean and vector magnitude

Azimuth	Sin x	Cos x
260 (4)*	-3.939	-0.695
262 (13)	-2.971	-0.418
265 (8)	-7.970	-0.697
267 (8)	-7.989	-0.419
270 (13)	-13.000	0.000
272 (12)	-11.993	0.419
275 (12)	-11.954	1.046
277 (4)	-3.970	0.487
278 (4)	-3.961	0.557
282 (12)	-11.738	2.495
285 (17)	-16.421	4.400
290 (3)	-2.819	1.026
300 (1)	-0.866	0.500
301 (1)	-0.857	0.515
302 (10)	-8.480	5.299
305 (7)	-5.734	4.015
308 (1)	-0.788	0.616
Σn	-135.146	22.619

- $\tan x = \frac{\sum n \sin x}{\sum n \cos x} = \frac{-135.146}{22.619} = -5.975$
- $\text{Arch tan} = \tan^{-1} -5.975 = 80.50$
- Vector mean = 80.50
- $R = ((\sum n \sin x)^2 + (\sum n \cos x)^2)^{1/2} = 137.026$
- Vector magnitude =  $\frac{R \times 100}{140} = 97.88$

Gombe Formation

\*No readings

(After Lindholm, 1987)

fluvial and coastal environments for the Gombe Sandstones (Figs. 16 and 17), but, in the former fluvial environments predominates while the latter indicates prevalence of coastal setting. In addition to this, the C-M pattern of Passega and Byramjee (1968) also suggested a fluvial setting for the Gombe Sandstone (Fig.18). Probability curve plots for the investigated samples tends to display three and two sand population curves with the two sand population curve significantly dominating (Figs.19 and 20). Visher (1969) indicated that three sand population curves are associated with wave zones and two sand population curves are associated with fluvial setting. Therefore, this may suggest that the Gombe Sandstone may have formed in both fluvial and marine settings but with much greater contribution from fluvial environment. Dike (1972) that the two sand population curves are associated with unidirectional current system, therefore, such plots could be generated in tidal deltas, tidal channels etc. but owing to the lack of marine indicators (like phosphate concretions, marine fossils or glauconite) in the investigated samples, this may further confirm the fluvial interpretation for the two-sand population curves.

The paleocurrent rose diagrams for the Gombe Sandstones yielded a dominant unimodal pattern and these patterns are characteristics of fluvial setting. This unimodal pattern trends in the northwestern direction with a slight deviation pointing towards the southwest (Fig.21). Therefore, materials forming the Gombe Sandstone may have been dominantly sourced from the southeastern direction, probably from the eastern Precambrian Basement Complex. This may be confirmed by the paleocurrent analysis based on Lindholm (1987) which also indicates that the direction of sediment supply is in the southeast (Table 2).

## CONCLUSION

The univariate and bivariate grains size relationships and probability curve plots has indicated that the Gombe Sandstone was probably formed under an environmental setting that to comprises of fluvial and marine contributions but in which the fluvial conditions are more prevalent.

The unimodal pattern obtained from paleocurrent studies indicates the dominance of fluvial environment and the sediments forming the Gombe Sandstone may have been sourced from the southeastern direction probably from the eastern Nigeria Precambrian Basement Complex.

## REFERENCE

- Abdel-Wahab, A, 1988. Lithofacies and diagenesis of the Nubia Formation at Central eastern desert, Egypt (abst.) 9<sup>th</sup> EGP. Expl. Conf., Cairo,20-23 Nov. 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.
- Abubakar, M.B., Obaje, N.G., Luterbacher, H.P., Dike, E.F.C. and Ashraf, A.R, 2006. A report on the occurrence of Albian-Cenomanian elater-bearing pollen in the Narawa-1 Well, Upper Benue Trough, Nigeria: Biostratigraphy and palaeoclimatological implication. *Journal of African Earth Sciences*, 45, 347-354.
- Benkhelil, J. 1989. The origin and evolution of the Cretaceous Benue Trough (Nigeria). *Journal African Earth Sciences* ,8, 251-282.
- Dike, E.F.C., 1972. Sedimentology of the Lower Greensand of the Isle of Wight, England. Unpub. D. Phil. Thesis, University of Oxford, England, 204.
- Dike, E.F.C. ,1993. The Statigraphy and structure of the Kerri-Kerri Basin Northeastern Nigeria. *Journal Mining and Geology*,29, 2, 77-93.
- Dike, E.F.C. , 2002. Sedimentation and tectonic evolution of the Upper Benue Trough and Bornu Basin, Northeastern Nigeria. *Nig. Min. Geosci. Soc. 38<sup>th</sup> Annual and international confer. Port Harcourt 2002 (NMGS/ELF award wining paper) Abstr.*,47,
- 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.
- Grant, N.K., 1971. The south Atlantic Benue Trough and Gulf of Guinea Cretaceous Tripple. *Geological. Society of American Bulletin*, 82, 2295-2298.
- Guiraud. M., 1990. Tectono-sedimenatry framework of the Early Cretaceous continental Bima Formation (Upper Benue Trough N.E. Nigeria). *Journal African Earth Sciences*, 10, 341-353.
- Kukal, Z., 1971. Geology of recent sediments. Academy Press London and New York, 490pp.
- Lawal, O. and Moullade,M., 1986. Palynological biostratigraphy of Cretaceous sediments in the Upper Benue Basin N.E. Nigeria. *Revue Micropaleotologie*, 29, 61-83.
- Lindholm, R.C., 1987. A practical approach to sedimentology. Allen and Unwin, Boston, Sydney, Wellington (1<sup>st</sup> Ed), 276pp.

- Ola, R.J. and Weiser, D., 1968. Textural parameters: An evaluation. *Journal of Sedimentary Petrology*, 38, 45-53.
- Moss, A.J., 1963. The Physical nature of common sandy and pebbly deposit part 2. *American Journal of Science*, 261, 297-343.
- Obaje, N.G. and Lingous, B., 1996. Petrographic evaluation of the depositional environments of the Cretaceous Obi/Lafia coal deposit in the Benue Trough of Nigeria. *Journal African Earth Sciences*, 22, 159-171.
- Passega, R., 1957. Texture as characteristics of clastic deposition American Association of Petroleum Geologists Bulletin, 41, 1952 – 1984.
- Passega, R., 1964. Grain size characteristics by C-M pattern as a tool. *Journal of Sedimentary Petrology*, 34,233-847.
- Passega, R. and Byramjee. R., 1969. Gran size image of clastic deposits. *Sedimentology*, 13, 233-252.
- Pettijohn, F. J., Potter, P.E. and Siever, R., 1987. *Sand and Sandstones* (2<sup>nd</sup> Ed). Springer-Verlag, 407p.
- Reineck, H.E and Singh, I.B., 1980. *Depositional Sedimentary Environment, with References to Terrigenous Clastics*. Springer-Verlag, Berlin, 439p.
- Shettima, B, 2005. *Sedimentology and reconstrucion of the depositional environments of the Yolde Formation in the Gongola Arm of the Upper Benue Trough (N.E.Nigeria)* MSc. Thesis (unpublished), ATBU, pp.84.
- Visher., G.S., 1969. Grain-size distribution and depositional processes. *Journal of Sedimentary Petrology*, 39, 1074-1106.
- Wentworth, C.K., 1922. A scale of grade and class terms for clastic sediments. *Journal of Geology*, 30, 377-392.
- Zaborski, P., Ugodulunwa, F., Idornigie, A., Nnabo, P. and Ibe, K., 1997. Stratigraphy, Structure of the Cretaceous Gongola Basin, Northeastern Nigeria. *Bulletin Centre Research Production Elf Aquitaine*, 22, 153-185.