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DEPOSITIONAL ENVIRONMENT OF THE GOMBE FORMATION IN THE GONGOLA SUB-BASIN OF THE NORTHERN BENUE TROUGH: USING GRAIN SIZE PARAMETERS

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ABSTRACT

The depositional environment of the Gombe Formation was determined using grain size parameters in which sixteen sandstone samples and ninety nine pebbles were subjected to granulometric and pebbles morphometric analysis respectively. The granulometric analysis for the sixteen (16) samples of the Gombe Formation show an average graphic mean of 2.51ϕ (fine grained sandstone), mean standard deviation of 0.58ϕ (moderately well sorted sandstone), mean skewness value of 0.09ϕ (nearly symmetrical) and mean kurtosis value of 0.89ϕ (platykurtic). The Bivariate plot of standard deviation vs. skewness indicated dominance of fluvial environment. While the probability curves plots showed a dominance of three sand populations indicating influence of marine processes. Environmental discrimination formulae for Y1, Y2 and Y3 indicated dominance of Aeolian, shallow agitated marine environment and shallow marine environment respectively. The plots of Y2 vs.Y1 and Y3 vs. Y2 showed a dominance shallow marine environment. The morphometric analysis indicates both fluvial and beach environment with dominance of fluvial environment.

KEYWORDS: Gombe Formation, Gongola Sub-Basin, Pebbles Morphology, Granulometric analysis, grain size

INTRODUCTION

The Benue Trough trends NE - SW for about 1000 km in length and 150 km width. It formed during early Cretaceous rifting and strike slip movement of central West African Basement (Benkhelil, 1989). Benue Trough is bounded by Niger-Delta Basin at the southern end and by Chad Basin to the North (Fig. 1) (Zaborski 1998). The trough is a sedimentary basin containing up to 6000 m of Cretaceous-Tertiary sediments associated with volcanic. The Benue Trough of Nigeria is part of the West and Central African Rift System (WCARS); formed during separation of the African and South American plates during the Early Cretaceous (Fitton, 1983; Genik, 1992).

The Benue Trough is divided into Lower, Middle, and Upper (Fig.1) by Zaborski (1998) while Nwajide (2013) subdivided it into Southern, Central and Northern (this subdivision was used in this study). The Northern Benue Trough is made up of two major sub-basins: the N-S trending Gongola Sub-basin and E-W trending Yola sub-basin (Nwajide, 2013). The Geology and stratigraphy of Northern Benue Trough was described in detail by Carter el al. (1963), Offodile (1976), Benkhelil (1989), Zaborski et al. (1997), Abubakar (2006) and Tukur et al. (2015). The stratigraphic succession in the Gongola sub-basin of the Northern Benue Trough comprises the Aptian-Albian Continental Bima Formation, The Cenomanian transitional-marine Yolde Formation, the Cenomanian-Santonian marine Pindiga Formation, the Campano-Maastrichtian Deltaic Gombe Formation (the formation of interest in this study) and Tertiary Continental Keri-Keri Formation (Fig. 2).

In the study area the environment of deposition of Gombe Formation was interpreted as fluvial dominated delta by Carter el al. (1963) and Abubakar (2006). Shetima et al. (2012) regarded the environment of deposition of the formation as marginal marine based on textural and lithologic analysis. Hamidu (2012) regarded red sandstone facies, bedded facies and interbedded facies of Zaborski et al. (1997) as alluvial, beach, shoreface, and sublitoral environment respectively.

The study area is located mainly at Gombe and Environs in the Gongola sub-basin. The purpose of this study is to use pebble morphometric analysis and Sahu (1964) method in addition to granulometric analysis used by Shetima et al. (2012) to interpret the depositional environment of Campano-Maastrichtian Gombe Formation.

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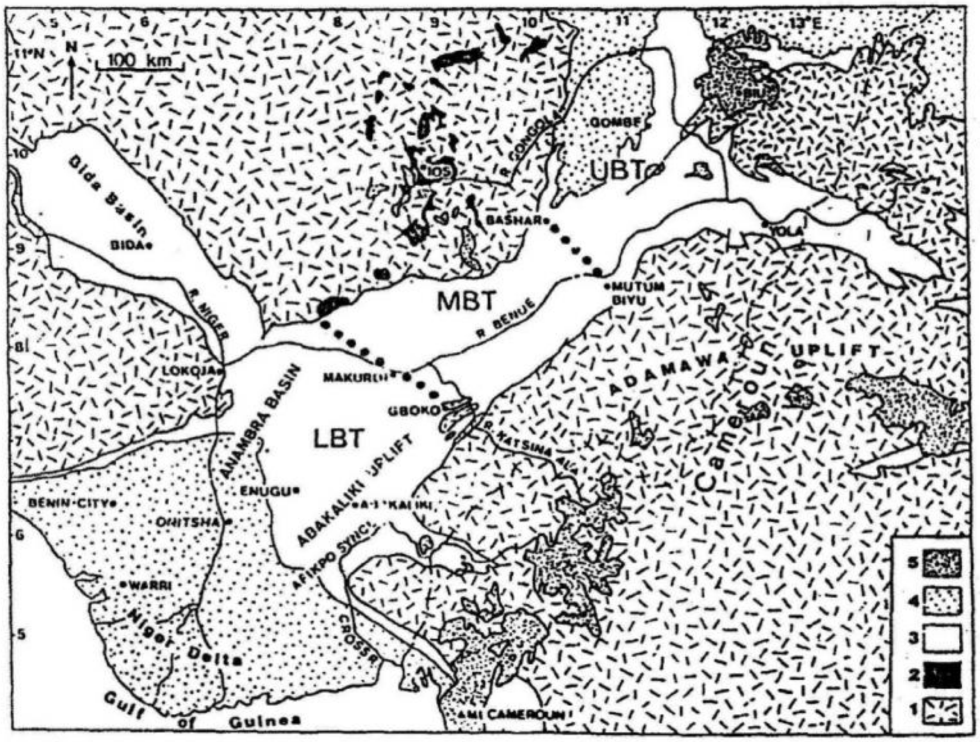

Figure 1: Outline of Geological Map of the Benue Trough and adjacent areas. LBT Lower Benue Trough; MBT Middle Benue Trough; UBT Upper Benue Trough. 1. Precambrian. 2. Jurassic "Younger Granites" 3. Cretaceous 4. Post Cretaceous sediments 5. Cenozoic Recent basalts including those of Cameroon Line (after Zaborski, 1998).

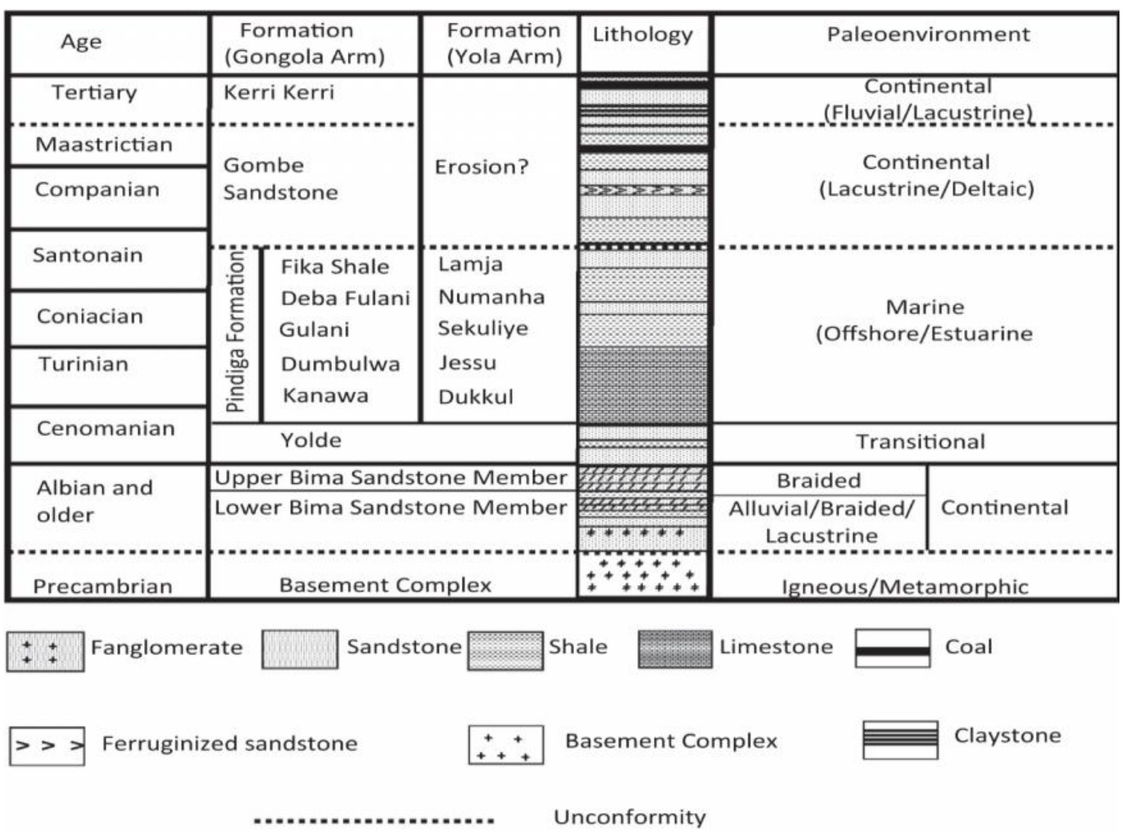

Figure 2: Stratigraphy succession of Benue Trough (Tukur et al. 2015)

GEOLOGICAL SETTING

The Gombe Formation is the youngest Cretaceous lithostratigraphic unit in the N-S trending Gongola sub-basin of the Northern Benue Trough (Popoff et al. 1986 and Nwajide 2013). It unconformably overlies Fika Shale and is overlain by Palaeocene Keri-Keri Formation. The lithologic units of the Gombe Formation are divided into three (Zaborski et al. 1997): basal interbedded unit, middle bedded facie and upper red sandstone facies. The basal unit comprise alternating thin beds of silty shalves, with some plant remains and fine to medium grained sandstone intercalated with flaggy ironstones. The middle part consists of regularly horizontally bedded, fine to medium grained quartz arenite, interbedded with Silts, Silty Clays and ironstones while, the upper part of the Formation consists of brick red coloured sandstone. The grain sizes range from pebble to medium grained sandstones with trough, tabular, and planar cross-bedding. The Gombe Formation is regarded as Maastrichtian in age (Carter et al. 1963; Kogbe 1976; Popoff et al. 1986).

METHODS

Sixteen (16) sandstones samples and ninety nine pebbles were collected from four outcrop sections of Gombe Formation for granulometric analysis and pebble morphometric study respectively. Samples obtained from Arawa stream, Pantami stream and Mallam Sidi road cut setion were sieved using Folk and Ward (1957) method. The graphical parameters of graphic mean, standard deviation, skewness, and kurtosis were calculated using Folk and Ward (1957) formula. The calculated graphical parameters were used for palaeoenvironment discrimination using the method proposal by Sahu (1964). The following Sahu (1964) formulae were used for palaeoenvironmental discrimination;

$$Y_1 = -3.5688\ MZ + 3.7016\ \delta_1^2 - 2.0766\ SK_1 + 3.1135\ KG$$

$$Y_2 = 15.6534\ MZ + 65.7091\ \delta_1^2 + 18.1071\ SK_1 + 18.5043\ KG$$

$$Y_3 = 0.2852\ MZ - 8.7604\ \delta_1^2 - 4.8932\ SK_1 + 0.0482\ KG$$

Where MZ: mean value, δ_1^2: standard deviation, SK1: Skewness and KG: kurtosis

The bivariate plots of Friedman (1979), Sahu (1964) and Visher (1969) sand population were applied to interpret the depositional environments of Gombe Formation.

In pebbles morphometric analysis, the long axis (a), the intermediate axis (b) and the short axis (c) were measured with vernier calliper according to Wentworth (1922) method. The values obtained were used for computing the statistical parameters based on Zingg (1935), Wentworth (1922) and Dobkins and Folks (1970). Axial ration were calculated according to Zingg (1935). Maximum projection sphericity and coefficient of flatness were calculated according to the method of Dobkins and Folks (1970) and Stratten (1974) respectively.

RESULTS

The granulometric analysis results of percentile value for the sixteen sandstone samples of Gombe Formation are presented in Table 1. The graphic mean, Standard deviation, skewness, kurtosis of the analysed samples are presented in Table 2.

The graphic mean for the various samples ranges from 0.8ϕ to 3.1ϕ with an average of 2.5ϕ (fine grained sandstone) (Table 2) which indicate coarse to very fine grained sandstone. The standard deviation values range from $0.4\phi - 1.0\phi$ (Table 2) with average of 0.6ϕ (moderately well sorted sandstone), which indicate well to poorly sorted. However, moderately sorted to well sorted values predominate. The values for the skewness range from -0.3ϕ to 0.4ϕ (Table 2) which indicate negative skewed to positive skewed. However the positive skewed values predominate. The values of Kurtosis for the various sample range from 0.6ϕ to 2.1ϕ (very platykurtic to very leptokurtic) with an average of 1.3ϕ (leptokurtic). The Bivariate plot of standard deviation vs. skewness indicated dominance of fluvial environment (fig.3). While the probability curves plots showed a dominance of three sand populations and subordinate results of two sand populations (figs. 4). The results obtained from environmental discrimination functions (Y1, Y2 and Y3) of Sahu (1964) are presented in Table 3. The values of maximum projection sphericity and coefficient of flatness obtained are shown in Table 4, 5 and 6.

Table 1: Percentile value from cumulative curve plots of sandstone samples analyzed.

Samples	ϕ5	ϕ16	ϕ 25	ϕ 50	ϕ 75	ϕ 84	ϕ 95
1	1.4	2.7	2.8	3.1	3.3	3.5	3.8
2	2.0	2.2	2.3	2.6	3.1	3.3	4.3
3	1.0	2.0	2.2	2.4	2.7	3.0	3.5
5	2.0	2.1	2.2	2.4	2.7	3.0	3.5
6	2.0	2.1	2.2	2.4	2.6	2.8	3.3
7	2.0	2.2	2.3	2.6	3.1	3.3	3.6
9	2.0	2.2	2.2	2.5	2.9	3.1	3.5
10	2.1	2.3	2.5	2.9	3.3	3.4	3.7
11	2.0	2.3	2.5	3.0	3.4	3.5	3.9
12	1.0	2.7	2.8	3.1	3.3	3.4	3.8
13	2.0	2.2	2.3	2.6	3.0	3.2	3.4
14	1.0	2.8	2.8	2.9	3.3	3.5	3.8
15	2.1	2.3	2.5	2.9	3.2	3.3	3.5
16	1.2	1.3	1.9	2.3	2.7	3.0	3.6
17	0.5	0.0	0.3	0.8	1.4	1.6	2.0
18	0.0	0.0	0.7	1.3	1.9	2.2	3.0

Table 2 Grain size distribution and quantitative parameters for the sandstone samples analyzed

Samples Id	Mean	Standard Deviation (Sorting)	Skewness (SK1)	Kurtosis (KG)
1	3.10 Very fine sand	0.54 Moderately well sorted sand	-0.21 Positive skewed	2.05 Very leptokurtic
2	2.70 Fine sand	0.64 Moderately well sorted sand	0.35 Strong Positive skewed	1.11 Mesokurtic
3	2.50 Fine sand	0.61 Moderately well sorted sand	0.09 Near symmetrical	1.86 Very leptokurtic
5	2.50 Fine sand	0.45 Well sorted	0.40 Strong Positive skewed	1.23 Leptokurtic
6	2.43 Fine sand	0.37 Well sorted	0.26 Positive skewed	1.33 Leptokurtic
7	2.69 Fine sand	0.52 Moderately well sorted sand	0.25 Positive skewed	0.82 Platykurtic
9	2.58 Fine sand	0.47 Well sorted	0.30 Positive skewed	0.90 Platykurtic
10	2.87 Fine sand	0.52 Moderately well sorted sand	-0.05 Near Symmetrical	0.86 Platykurtic
11	2.93 Fine sand	0.59 Moderately well sorted sand	-0.11 Negative skewed	0.87 Platykurtic
12	3.08 Very fine sand	0.59 Moderately well sorted sand	-0.31 Strong negative skewed	2.27 Very leptokurtic
13	2.67 Fine sand	0.46 Well sorted	0.19 Positive skewed	0.79 Platykurtic
14	3.03 Very fine sand	0.59 Moderately well sorted sand	0.26 Positive skewed	2.39 Very leptokurtic
15	2.85 Fine sand	0.48 Well sorted	-0.15 Negative skewed	0.83 Platykurtic
16	2.20 Fine sand	0.80 Moderately sorted sand	-0.06 Negative skewed	1.26 Leptokurtic
17	0.80 Coarse sand	0.63 Moderately well sorted sand	0.30 Positive skewed	0.56 Very platykurtic
18	1.17 Medium sand	1.01 Poorly sorted	-0.02 Negative skewed	1.03 Mesokurtic

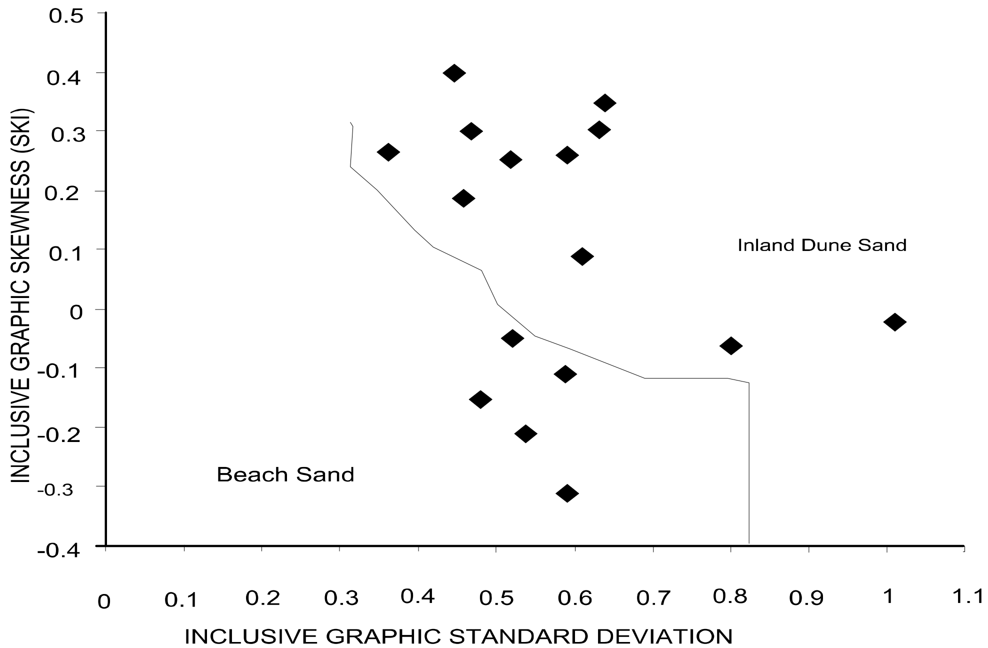

Figure 3: Bivariate plot of skewness vs. standard deviation (after Friedman, 1979)

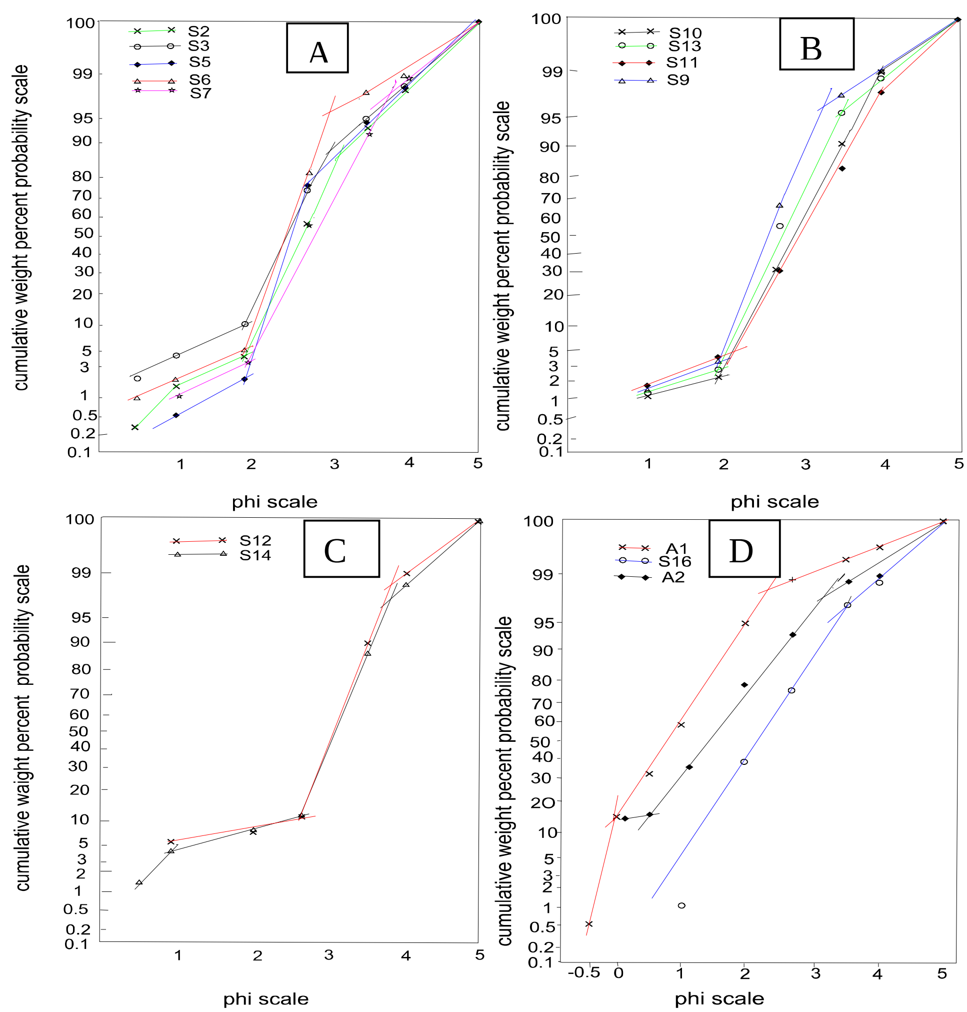

Figure 4: Sand population distribution curves based on log probability plots

Table 3: The discriminate function and environment of deposition

Sample no.	Y1	Y2	Y3
1	-6.75 Aeolian	80.54 shallow agitated marine	-0.60 shallow marine
2	-5.32 Aeolian	95.74 shallow agitated marine	-4.48 shallow marine
3	-1.94 Beach	99.63 shallow agitated marine	-2.897 shallow marine
5	-5.17 Aeolian	82.44 shallow agitated marine	-2.96 shallow marine
6	-4.57 Aeolian	76.35 shallow agitated marine	-1.71 shallow marine
7	-6.57 Aeolian	79.58 shallow agitated marine	-2.79 shallow marine
9	-6.21 Aeolian	76.99 shallow agitated marine	-2.62 shallow marine
10	-6.46 Aeolian	77.67 shallow agitated marine	-1.25 shallow marine
11	-6.23 Aeolian	82.84 shallow agitated marine	-1.63 shallow marine
12	-1.99 Beach	107.48 shallow agitated marine	-0.56 shallow marine
13	-6.68 Aeolian	73.76 shallow agitated marine	-1.98 shallow marine
14	-2.62 Beach	119.24 shallow agitated marine	-3.34 shallow marine
15	-6.42 Aeolian	72.39 shallow agitated marine	-0.43 shallow marine
16	-1.44 Beach	98.72 shallow agitated marine	-4.63 shallow marine
17	-0.27 Beach	54.40 Beach	-4.69 shallow marine
18	2.86 Beach	103.97 shallow agitated marine	-8.44 Fluvial

Table 4: Summary of pebble morphometric analysis results at 10^0 24′ 174″ N and 11^0 14′ 757″ E

S/No	a (cm)	B (cm)	c (cm)	Axial ratio c/a	Maximum projection Sphericity $(c^2/ab)^{1/3}$	Coefficient Flatness $(^c/_a)$ x100
1	2.9	2.2	1.2	0.4	0.6	41.4
2	2.1	1.8	1.4	0.7	0.8	66.7
3	2.2	1.6	0.9	0.4	0.6	40.9
4	2.0	1.8	1.0	0.5	0.7	50.0
5	2.6	2.3	1.1	0.4	0.2	42.3
6	2.2	1.8	0.8	0. 4	0.5	36.4
7	2.0	1.4	1.3	0.7	0.8	65.0
8	1.9	1.5	1.3	0.7	0.6	68.4
9	2.1	1.4	1.1	0.5	0.7	53.4
10	2.5	2.0	1.5	0.6	0.8	60.0
11	1.8	1.3	1.1	0.6	0.1	61.0
12	1.8	1.7	1.2	0.7	0.8	66.6
13	3.0	2.3	1.2	0.4	0.6	40.0
14	2.3	1.5	1.2	0.5	0.7	52.2
15	1.8	1.6	0.8	0.4	0.6	44.4
16	1.7	1.4	1.0	0.6	0.7	58.8
17	1.6	1.4	1.0	0.6	0.8	62.5
18	2.5	1.7	1.5	0.6	0.8	60.0
19	2.3	2.0	1.2	0.6	0.7	52.2
20	1.5	1.2	1.1	0.7	0.9	73.3
21	2.0	1.5	1.2	0.6	0.9	60.0
22	2.0	1.2	0.8	0.4	0.5	40.0
23	1.9	1.5	0.8	0.4	0.6	42.1
24	2.0	1.5	0.7	0.4	0.5	35.0
25	1.9	0.8	0.6	0.3	0.6	31.6
26	1.7	1.2	1.0	0.6	0.8	58.8
27	1.6	1.1	0.7	0.4	0.3	43.8
28	1.4	1.2	0.5	0.4	0.5	35.7
29	1.7	1.4	1.1	0.67	0.8	64.7
30	1.9	1.6	1.2	0.6	0.8	63.2
31	2.0	1.5	0.7	0.4	0.5	35.0
32	1.8	1.3	0.8	0.4	0.6	44.4
33	1.5	1.4	1.0	0.77	0.7	66.7
Mean					0.7	52.0

Table 5: Summary of Pebble Morphometric Analysis Results at $10^0\ 24'\ 59.6$ N″ and $11^0\ 14'\ 07.2''$ E

S/No	A (cm)	B (cm)	c (cm)	Axial ratio c/a	Maximum projection sphericity $(c^2/ab)^{1/3}$	Coefficient Flatness $(^c/_a)$ x100
1	1.9	1.5	0.9	0.5	0.7	47.4
2	2.2	1.7	1.0	0.5	0.6	45.5
3	2.1	1.9	0.9	0.4	0.6	42.9
4	1.7	1.5	0.8	0.5	0.6	47.1
5	2.5	2.0	1.2	0.5	0.6	48.0
6	2.4	1.5	1.2	0.5	0.7	50.0
7	1.6	1.2	0.7	0.4	0.6	43.8
8	2.1	1.5	1.0	0.5	0.7	47.6
9	1.2	0.9	0.6	0.5	0.7	50.0
10	2.7	1.2	0.9	0.3	0.6	33.3
11	2.5	1.2	0.8	0.3	0.6	32.0
12	1.8	1.2	0.7	0.4	0.6	38.9
13	1.7	1.1	0.4	0.3	0.4	23.5
14	1.6	1.1	0.7	0.4	0.7	43.8
15	1.7	1.0	0.6	0.4	0.6	35.3
16	1.8	1.4	1.0	0.6	0.7	55.6
17	2.6	1.9	1.0	0.4	0.6	38.5
18	1.8	1.3	0.8	0.4	0.6	44.4
19	2.1	1.2	0.9	0.4	0.7	42.9
20	2.1	1.2	1.0	0.4	0.7	47.6
21	2.0	1.3	1.1	0.6	0.7	55.0
22	1.7	1.2	1.0	0.6	0.8	58.8
23	2.0	0.9	0.5	0.3	0.5	25.0
24	1.8	1.3	0.6	0.3	0.5	33.3
25	2.2	1.6	1.1	0.5	0.3	50.0
26	1.9	1.4	0.7	0.4	0.5	39.8
27	1.4	1.0	0.8	0.6	0.8	57.1
28	1.6	0.9	0.6	0.4	0.6	37.5
29	1.7	1.1	0.5	0.3	0.5	29.4
30	1.8	1.5	0.8	0.4	0.6	44.4
31	1.8	1.3	1.0	0.6	0.8	55.6
32	2.0	1.2	0.7	0.4	0.6	35.0
33	2.6	1.7	0.8	0.3	0.5	30.8
Mean					0.6	42.7

Table 6: Summary of Pebble Morphometric Analysis Results 10^0 23′ 53.8 ″ N and 11^0 14′ 52.1″ E

S/No	a (cm)	B (cm)	c (cm)	Axial ratio $^c/_a$	Maximum projection Sphericity $(c^2/ab)^{1/3}$	Coefficient Flatness $(^c/_a)$ x100
1	3.2	2.5	1.2	0.4	0.6	37.5
2	2.2	1.8	0.9	0.4	0.6	40.9
3	1.7	1.5	1.0	0.6	0.7	58.8
4	2.1	1.6	0.9	0.4	0.6	42.8
5	1.5	1.2	0.6	0.4	0.6	40.0
6	1.8	1.5	1.2	0.7	0.8	66.7
7	2.0	1.4	0.7	0.3	0.6	35.0
8	1.7	1.3	0.7	0.4	0.6	41.2
9	2.1	1.5	1.0	0.5	0.7	47.6
10	1.7	1.2	1.0	0.6	0.8	58.8
11	1.8	1.4	0.8	0.4	0.6	44.4
12	1.8	0.9	0.6	0.3	0.6	33.3
13	1.6	1.2	1.0	0.6	0.8	62.5
14	1.8	0.9	0.6	0.3	0.6	33.4
15	1.6	1.0	0.8	0.5	0.7	50.0
16	2.1	0.9	0.6	0.3	0.4	28.5
17	2.4	0.7	0.5	0.2	0.5	20.8
18	2.0	1.6	1.2	0.6	0.7	60.0
19	1.6	1.2	0.9	0.6	0.6	56.3
20	2.3	1.4	0.8	0.4	0.7	34.8
21	1.6	1.4	0.9	0.6	0.8	56.3
22	1.6	1.2	1.0	0.6	0.6	62.5
23	2.0	1.5	0.9	0.5	0.9	45.0
24	1.8	1.1	0.8	0.4	0.6	44.4
25	2.1	1.6	0.9	0.4	0.7	42.8
26	2.0	1.5	1.0	0.5	0.5	50.0
27	1.7	1.5	0.6	0.5	0.6	35.3
28	2.0	1.2	0.7	0.5	0.7	35.0
29	1.7	1.1	1.0	0.6	0.8	58.8
30	1.5	1.0	0.9	0.6	0.7	60.0
31	2.2	1.5	0.8	0.4	0.6	36.4
32	1.8	1.3	0.7	0.4	0.7	38.9
33	1.9	1.2	1.0	0.9	0.8	52.6
Mean					0.7	45.8

DISCUSSION

Univariate grain size parameters

The graphic mean size for the various sample of Gombe Formation range from 0.8ϕ to 3.1ϕ, which indicate coarse to very fine grained. Freidman (1967) pointed out that grained size distributions are controlled by processes rather than environment. Therefore the fluctuations in mean values suggest change in energy of the depositional conditions. Sorting is important factor that is use for environmental analysis. It is very significant in differentiating between fluvial and wave deposits (Freidman 1967). Sorting for various samples of the Gombe Formation range from 0.37ϕ to 1.01ϕ, this indicates well to poorly sorting. However moderately to well sorted values predominate. The well to moderately sorted nature of Gombe Formation may suggest reworking by wave activities, which removed clay material from the sand (Mason and Folk 1958; Freidman 1967).

The values of skewness for various samples range from 0.31ϕ to 0.4ϕ which indicates negative skewed to positive skewed. However the positive skewed values predominate. The predominance of positive skewed in coarsening upward deposit of Gombe Formation suggest transitional environment. This interpretation is supported by the work of Freidman (1967 and1979), in which he suggested positive skewed for deeper part of the continental shelf/lagoon and beach where abundance of fine exceeds the energy available for dispersing them. The values for kurtosis from various sample range from 0.56ϕ to 2.05ϕ (very platykurtic to very leptokurtic) with an average of 1.3ϕ (leptokurtic). Kurtosis has little Geologic information that could be obtained (Boggs 2006), however, the fluctuation in values may suggest change in energy of depositional medium (Abdel-Wahab 1988, Shetima et al., 2012).

For the discrimination between aeolian and littoral (intertidal zone) environments, the Y1equation is used. Sahu (1964) suggest that when Y1 is less than – 2.7411 it is an Aeolian deposit whereas if Y1 is greater than – 2.7411 a beach environment is suggested. A Aeolian environment was infer, since 62.5% of the values of Y1 are greater than – 2.7411 (Table 3). This may suggest aeolian deposits associated with bar deposit. For the discrimination between beach (back-shore) and shallow agitated marine environments (sub-tidal environment) the Y2 equation is used. If the value of Y2 is less than 65.3650 a beach deposition is suggested, whereas if it is greater than 65.3650, a shallow agitated marine environment is inferred. Shallow agitated marine environment is suggested since 93.25% values of Y2 calculated are greater than 65.3650 (Table 3). This agitated marine environment may be taken to be a deltaic realm, where Gombe Formation is inferred as fluvial-deltaic in nature. For discrimination between shallow marine and the fluvial environments, the discrimination equation of Y3 is used. If Y3 is less than -7.419 the sample is identified as a fluvial deposits whereas if Y3 is greater than -7.419 the sample is identified as a shallow marine deposit. The analyzed results showed 93.75% of the plotted Y3 values from the total number of samples has values more than -7.419, suggestive of shallow marine environment while 6.25 % has Y3 less than -7.419 inferring fluvial setting (Table 3).

The result obtained from Y2, Y3 and probability plot have supported the earlier interpretation of the positive skewed values as transitional environment rather than fluvial environment.

Bivariate grain size parameters

The bivariate plots of standard deviation vs. skewness is based on Friedman (1979) which distinguishes Inland Dune Sand from Beach Sand, the plots indicates that 68.75% of the samples plotted within the river field and 31.25% of the samples plotted within the Beach Sand field (Fig. 3). The dominance of samples within Inland Dune field was due to river pumps of tremendous load of fines into the nearshore environment and the available energy was unable to remove them (Friedman, 1967)

Plotting of the three discriminate functions (Y1, Y2 and Y3) as bivariate scatter plots was used to improve the success rate and refinement of the discrimination of the depositional environment. A bivariate plot of Y1 and Y2 (Fig. 5) show most samples to be littoral or shallow agitated marine environment. A bivariate plot of Y2 and Y3 (Fig.6) show that most samples are of fluvial/deltaic environment.

Probability plots

According to Visher (1969) different sand population are of environmental value. The sand population curves are characteristic of either fluvial, beach or wave zone. Two sand populations are characteristic of fluvial setting, while three sand populations are characteristic of shallow marine setting. Probability plots of samples from bedded facies of Gombe Formation (Figs. 4A, B and C) show three sand populations which indicate deposit of shallow marine environment. Samples of red sandstone facie show two sand populations which suggest fluvial environment (Fig.4D).

Fourteen samples obtained from coarsening upward units have three sand populations. Eleven of the samples have saltation population from 2.0 to 3.5 and little suspension population (Fig. 4A and B) similar to Visher (1969) figure 9A. This type of curves were interpreted as marine sand from wave zone, while sample 12 and 14 have saltation population between 2.7 to 3.9 and 10 percent surface creep (Fig.4C) similar to Visher (1969) figure 13A which was interpreted as offshore marine sand in the area of tidal delta at depth of 3.05 to 12.2 m.

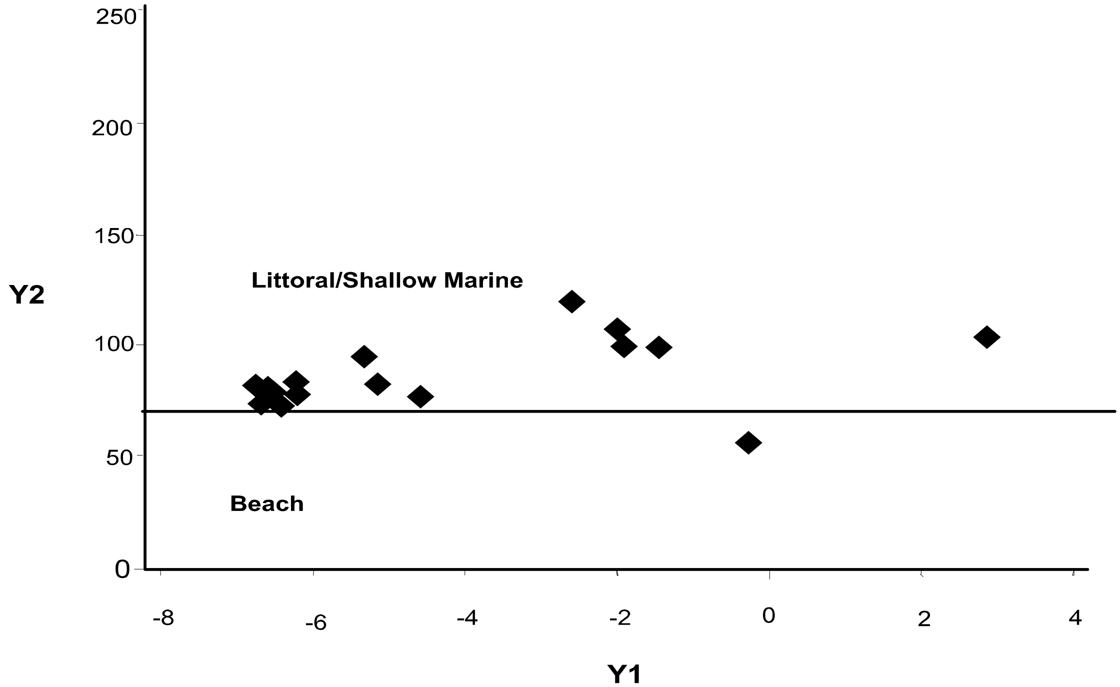

Figure 5: Bivariate plot of Y2 Vs Y1 (after Sahu 1964)

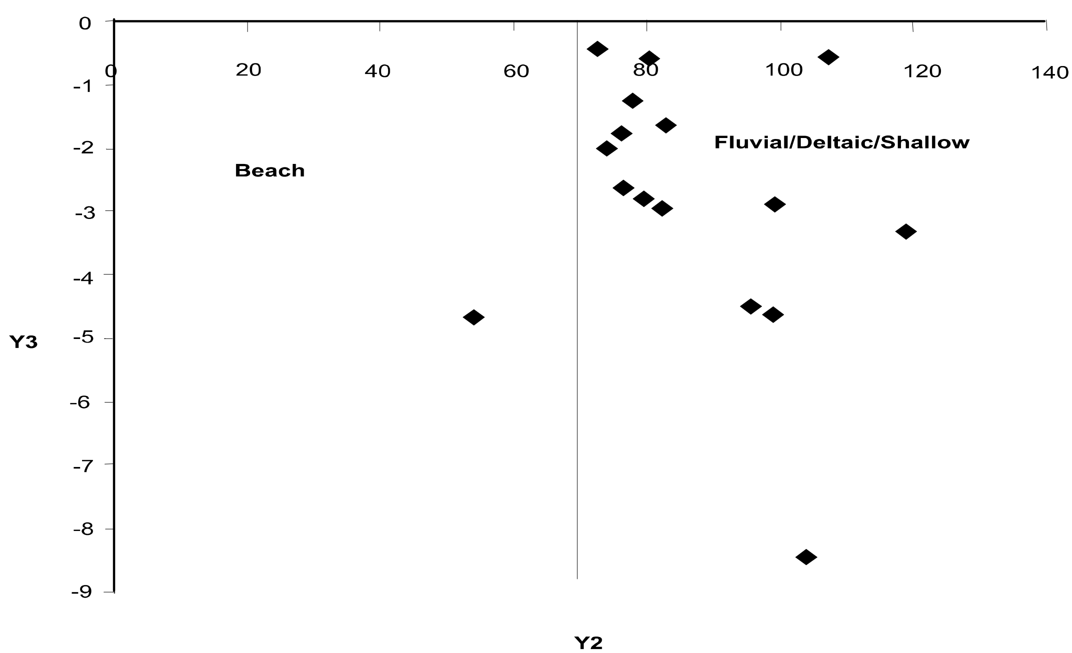

Figure 6: Bivariate plot of Y3 Vs Y2 (after Sahu 1964)

Pebbles morphometric

Maximum projection sphericity and coefficient of flatness are environmentally diagnostic (Stratten 1974). Pebbles from Gombe Formation were measured and the value of maximum projection sphericity and coefficient of flatness were calculated to determine its depositional environment. The pebbles have mean maximum projection sphericity of 0.646, 0.627 and 0.667 table 4, 5 and 6 respectively and mean coefficient of flatness of 52.013, 42.714 and 45.796 table 4, 5 and 6 respectively.

Sphericity is a measure of the approach of a pebble to sphere. It can be measured in different ways (Krumbein, 1941, Sneed and Folk 1958). In this study the maximum projection sphericity of Sneed and Folk has been used. The maximum projection sphericity values for range from 0.4 to 0.9 with mean value of 0.65. The average value of maximum projection sphericity is exactly at a line of separation between beach and fluviatile of Stratten (1974), indicating beach environment.

The Coefficient Flatness values range from 20.8 to 73 with mean value of 46.8. The average value of coefficient flatness is slightly above the 45 coefficient flatness line of Stratten (1974), indicating fluvial environment.

Each individual pebble sample studied here was plotted on a Sneed and Folk (1958) (Fig. 7) diagram using the "TRI – PLOT" programme (Graham and Midgley, 2000) and the average percentages of the form classes were calculated and shown in Table 7. The study of form indices has shown the dominance of the following form classes Bladed, Compact – Bladed, Compact – Elongated and Platy. According to Dobkins and Folk (1970) Compact, Compact – Bladed and Compact – Elongated forms are indicative of fluvial action. Blades are common on both beach and fluvial environment. The study of the form indices has shown that pebbles of the Gombe Formation were shaped in a fluvial environment.

Table 7: Percentages of pebbles forms class categories

	Count	Percent (%)
Compact	1	1.0
Compact-Platy	5	5.1
Compact-Bladed	16	16.2
Compact-Elongate	12	12.1
Platy	11	11.1
Bladed	38	38.4
Elongate	11	11.1
Very-Platy	0	0.0
Very-Bladed	2	2.0
Very-Elongate	3	3.0

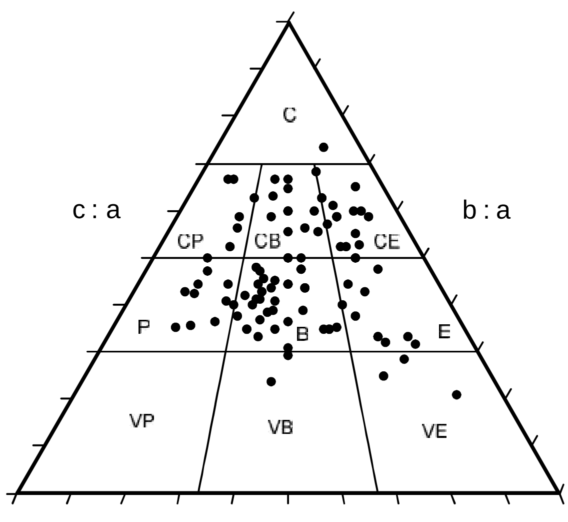

Figure 7: Sneed and Folk (1958) diagram showing shape based on the parameters C = Compact, CP = Compact - Platy, CB = Compact - Bladed, CE = Compact - Elongate, P = Platy, B = Bladed, E = Elongate, VP = Very Platy, VB = Very Bladed, VE = Very Elongate.

CONCLUSION

The numerical values used in an analysis of all studied granulometric parameters, pebble morphometric parameters and bivariate plots as well as sand population all point to a series of related subenvironment in transitional environment with subordinate results of fluvial setting. The various characteristic of the sediment as fine grain, very fine grain positive skewness and well sorted nature of Gombe Formation are in agreement with early studied by Shetima et al. (2012)

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