Granulometric Analysis Of Bima Sandstone Around Chekole In Gombe Sub-Basin Of The Upper Benue Trough, Nigeria

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Abstract—The study investigates the grain size distribution of Bima sandstone formation exposed around Chekole in North-eastern Nigeria and determines the condition of their deposition. This has been achieved by collecting sediment samples from the exposed outcrops of Bima sandstone formation in various locations across the study area. The granulometric analyses suggest that the texture of the Albian sedimentary formation ranged from gravely to coarse grained sand. Other components include medium and fine grained sands. Statistical parameters indicate that the sorting of these sediments ranged between moderate and poorly-sorted, the skewness values show that over 90% the samples analysed are positively skewed. Kurtosis values ranged from platykurtic to leptokurtic.

Keywords: Granulometric analysis, Bima sandstone, Upper Benue Trough, Nigeria

1 INTRODUCTION

Bima sandstone is the name given to the continental Intecalaire in the Chad Basin and Upper Benue Trough of Nigeria. It is the oldest sedimentary deposit in these regions. The composition of Bima sandstone, mainly Arkose to quartz arenite and its depositional structures have generated wide speculations as to the source and environment of deposition. This sandstone consist unit consists of alternating layers of poorly to moderately consolidated fine to coarse grained sandstones, clay-shales, siltstone and mudstone with an average thickness of more than 200m as seen from their outcrops in the field. This geologic formation reaches hundreds of meters in thickness is of significant interest in the Chad basin as it is assumed to be the potential reservoir rock for petroleum storage and it is of hydrogeological significance in the upper Benue trough. From field observations, exposures of Bima Sandstone in the study area is light brown to reddish brown in colour, felspathic and fine to coarse grained in texture. It is highly indurated and cemented in some places especially east of Briyel town. Grain size analysis is a vital component of sedimentary petrology investigations from which the nature and processes of erosion, transportation, and deposition of sedimentary rocks can be deduced. In particular, the dynamic mechanisms of transportation and deposition of the constituent grains of sediments are usually drawn from their size distribution. Also, information about the transport and deposition processes can be obtained from statistical parameters of a given grain-size distribution such as mean, median, kurtosis and skewness. This study investigates the grain size distribution of the Bima Formation (Oldest stratigraphic unit of the Chad basin and Upper Benue Basin) as exposed in Chekole and Dadinkowa areas on the basis of their physical characteristics and determines the condition of their deposition. This provides a better understanding of the petrological and hydrogeological characteristics of the sedimentary environment.

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1.1 Study area

The study area is located about 10 kilometres east of Briyel town in Borno state which corresponds to latitudes 10° 20’ and 10° 24’ North and longitudes 11° 37’ and 11° 40’ East (Figure 1). The area falls in the (Gombe sub-basin) upper margins of the upper Benue Trough. It is characterised by undulating terrain with few flat plains.The climate is semi-arid with three distinct seasons: a long hot dry season from April to May. Day time temperatures are in the range of 36 to 40°C and night time temperatures fall to 10 to 17°C. This is followed by a short rainy season from May to September with a daily minimum temperature of 20°C and a maximum of 31°C with relative humidity of 40 to 60% and annual rainfall from 860 to 900 mm. Finally, the cold (harmattan) season runs from October to March when temperatures fall to about 20°C and a dry dusty wind blows from the Sahara desert [1, 2].

1.2 Geology of the area

The origin and evolution of the Benue Trough have been various described by many workers [3, 4, and 5]. Benue Trough is widely held to have originated as a tectonic trough whose origin was closely related with the separation of African and South American Continents during the Mesozoic [6 and 5].
The Upper Benue Trough is made up of two arms, the Gongola Arm and the Yola Arm (Obaje, 2009). However, some authors have sub-divided the Upper Benue Trough to include a third central Lau-Gombe sub-basin [7]. In both arms of the basin, the Albian Bima Sandstone lies unconformably on the Pre-cambrian Basement.This formation was deposited under continental conditions (fluvial, deltaic, lacustrine) and is made up of coarse to medium grained sandstones, intercalated with carbonaceous clays, shales, and mudstones. The Bima Sandstone was subdivided by [3] into a Lower, Middle and Upper Bima. The Middle Bima is reported to be shaley in most parts with some limestone intercalations and was assumed to be deposited under a more aqueous anoxic condition (lacustrine, brief marine). Consequently, marine transgression episode caused the deposition of Yolde, Dukul, Jessu, Sekule and Numanha sedimentary formations, which are found in the Upper Benue Trough.

2 MATERIALS AND METHODS

2.1 Sediment sample collection

Six sampling points were selected for this study using the geological map (using the geological map (sheet 153 NW) covering Wuyo, Chekole, and Dadinkowa area of Borno and Gombe states. The various locations were selected due to the excellent exposure of the Bima sandstone. In each area, detailed field observations, measurements of dips and strikes of the outcrops were made. Representative sediment samples that constitute the Bima sandstone formation were systematically collected from the exposed outcrops across the study area. In each location, the coordinates were taken using a hand held GPS (Garmin eTrex 20). Simple hand held sampling tools such as shovel, digger, plastic bucket, polyethylene bags, and measuring tape were used. Digging of outcrops was carried out at systematic depth not exceeding 2 metres to obtain fresh sample of Bima sandstone in the selected locations; the samples were poured into a properly labelled plastic bag in each case. All the samples were transported to the sedimentary petrology laboratory of the Geology department, University of Maiduguri for granulometric analyses.

2.2 Granulometric analysis

The portion of sediment sample retained on the No. 10 sieve is tested for grain size distribution by passing the sample through a number of sieves of different size openings as outlined by [8]. The sieves are stacked in order, with the sieve with 2mm aperture size at the top. The sieves are agitated by mechanical means for about 10 minutes. When this mechanical process is completed, the weight of the particles retained in each sieve is determined using the Ohaus (Model T31P) digital balance, from which the individual and cumulative percentage weights were computed. Grain size statistical parameters such as graphic mean (Mz), inclusive graphic skewness (SK), and graphic kurtosis (KG) were determined using the SPSS statistical software package.

3 RESULTS AND DISCUSSIONS

Results of the granulometric analyses show that the Bima sandstone sample in location 1 is wholly composed of gravel (2mm), coarse sand (1mm), and fine sand (710µm) particles constituting about 27%, 26%, and 12.5% of the sediment sample separately. Other components of this out crop includes fine sand (150 µm) and coarse silt (63 µm) representing about 4% and 2% of the total weight percentage respectively (Figure 1 a). The out crop in location 2 is mainly composed of gravel (29%), varying coarse sands; 1mm particles constituting 21.6%, 850 µm (6.7%), and 710 µm (9%) of the total weight percentage correspondingly. Others are medium sand (500 µm) and fine sand (425 µm) which constitute about 11 and 6.9% of the sediment sample individually (Figure 1 b). Sample 3 is dominated chiefly by gravel (23%), coarse sand (21%), and coarse-medium sand (11%). Other components are medium sand (9%), fine sand (7%), and coarse siltstone (4.9%). Similarly, the Bima sandstone sample in location 4 is wholly composed of gravel (29%), coarse sand (19%), and coarse-medium sand (15%). Other component of this out crop includes medium sand (8%) and fine sand constituting about 7.7%. Figure 2 (a) and (b). Furthermore, sample 5 is dominated primarily by gravel (13%), coarse sand (11.13%), and medium-fine sand (12.11%). Other components are coarse siltstone (7.98%) and fine siltstone (5.33%). The exposed out crop in location 6 is dominated by gravel (15.17%), varying coarse sands; 1mm particles constituting 26.06%, 850 µm (6.72%), and 710 µm (9.12%). Others are medium sand (500 µm) and fine sand (425 µm) which constitute about 18.55 and 5.51% of the sediment sample individually. Figure 3 (a) and (b).

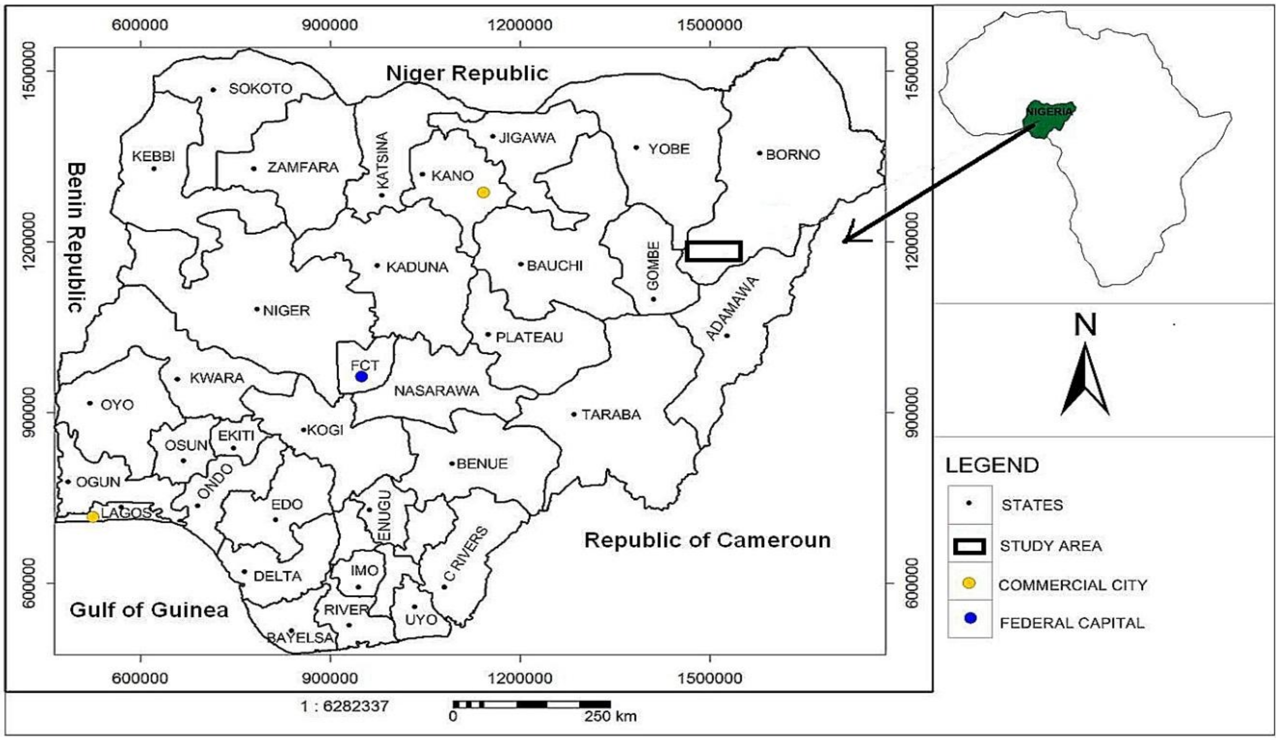


Figure 1 Map showing the location of study area

Table 1 Characteristics of samples selected for granulometric analyses

Stratigraphy	Sample number	Geomorphology	Lithology	Origin	Location
Bima formation	1	River bank	Gravely sand	Continental/ marine	N10°20.122' E11°37.003'
Bima formation	2	Out crop	Coarse sand	Continental/ marine	N10°21.002' E11°39.113'
Bima formation	3	Slope of Valley	Slightly gravely sand	Continental/ marine	N10°24.031' E11°38.078'
Bima formation	4	Out crop	Gravely sand	Continental/ marine	N10°22.106' E11°37.313'
Bima formation	5	Out crop	Coarse sand	Continental/ marine	N10°23.077' E11°38.001'
Bima formation	6	Out crop	Coarse sand	Continental/ marine	N10°24.613' E11°40.093'

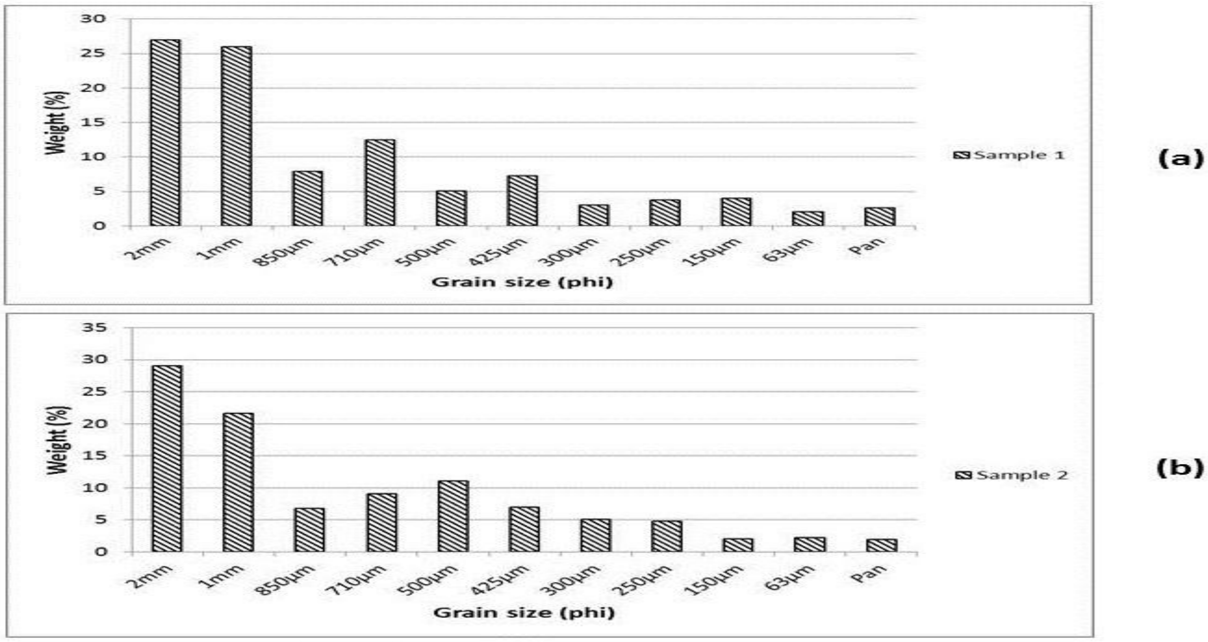


Figure 1 (a) and (b) grain size distribution of samples 1 and 2

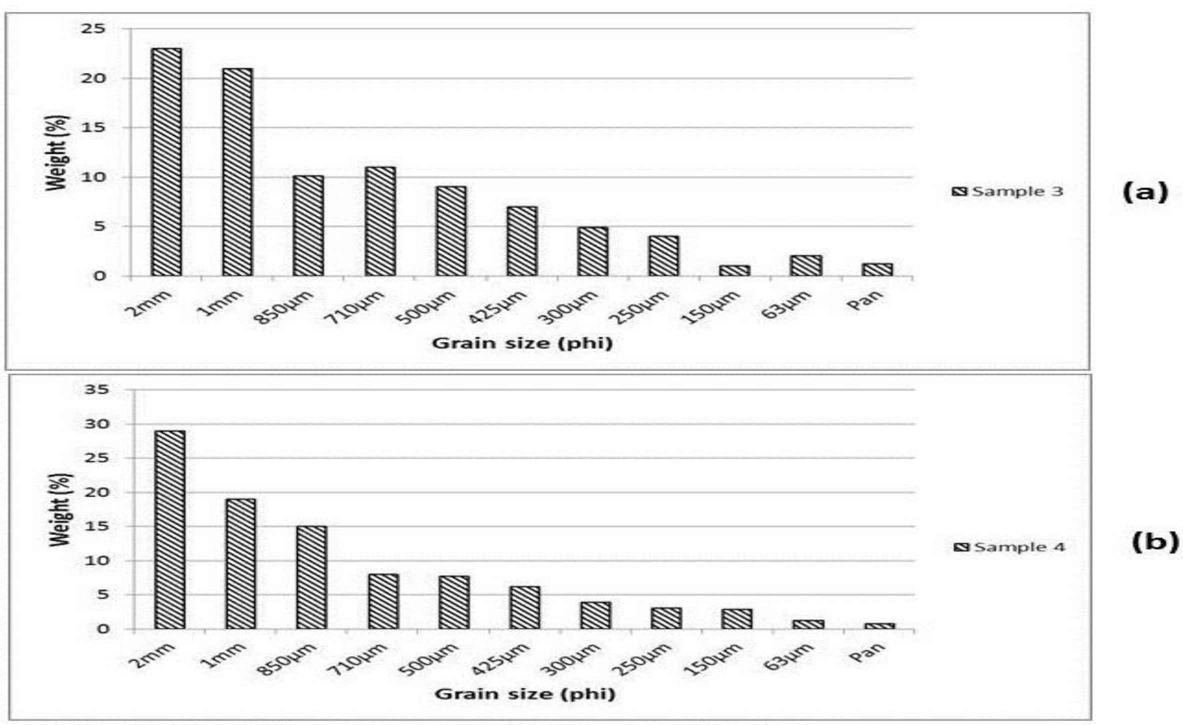
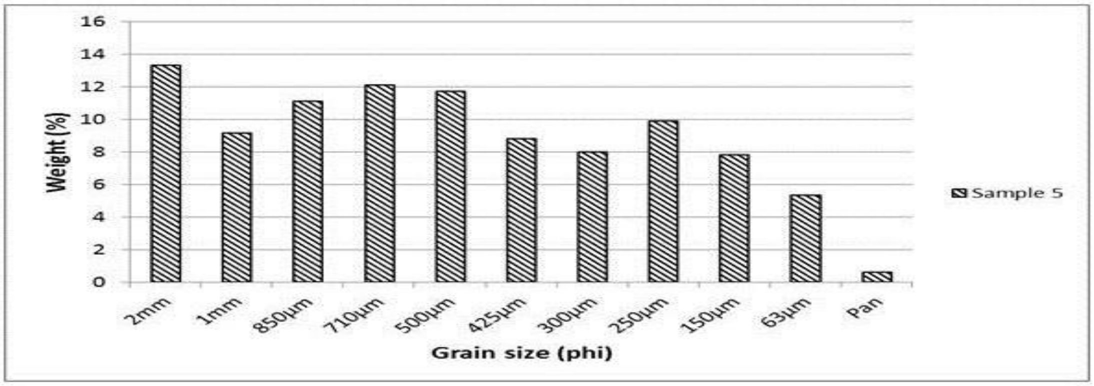


Figure 2 (a) and (b) grain size distribution of samples 3 and 4



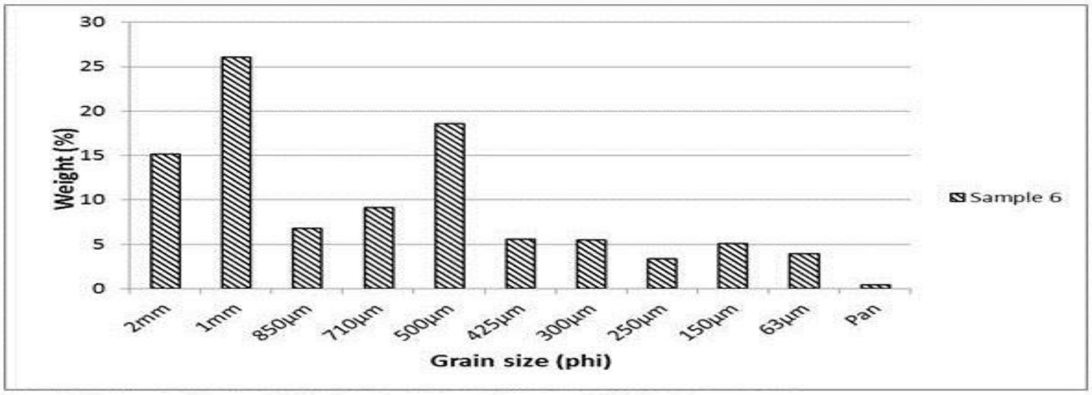


Figure 3 (a) and (b) grain size distribution of samples 5 and 6

Table 2 summary of statistical result of Bima sandstone samples analysed

Sample	Mean	Sorting	Skewness	Kurtosis
1	0.1	0.95	0.15	3.71
2	0.68	1.6	0.37	0.89
3	0.2	1.54	0.15	1.4
4	0.63	1.20	0.28	1.12
5	0.4	0.89	0.18	1.39
6	0.53	1.16	0.14	1.06

The summary of the statistical results of the sediment analysed (Table 2) suggest that the sandstone sample in location 1 is coarse grained (mean 0.1), extremely skewed and very leptokurtic (kurtosis 3.71). Similarly, the sandstone sample obtained in location 2 is also coarse grained (mean 0.68), poorly sorted (1.6), positively skewed (0.37), and platykurtic (0.89) in nature. Also, the Bima sandstone sample obtained in location 3 suggests that it is coarse grained (mean 0.2), poorly sorted (sorting 1.6), and finely skewed (0.15) and it is leptokurtic in nature (kurtosis 1.4). Furthermore, Bima sandstone sample of location 4 show that it is coarse grained (mean 0.63), poorly sorted (1.20), strongly fine skewed (skewness 0.28), and leptokurtic in nature (kurtosis 1.12). The same sandstone in location 5 show that it is coarse grained (mean 0.4), moderately sorted (sorting 0.89), strongly fine skewed (skewness 0.18), and leptokurtic (kurtosis 1.39). Lastly, Bima sandstone sample in location 6 revealed that the sample is coarse grained (mean 0.53), poorly sorted (sorting 1.16), finely skewed (skewness 0.14), and leptokurtic in nature (kurtosis 1.06). Textural attributes of sediments such as mean (Mz), sorting (SD), skewness (Ski) and kurtosis (KG) are widely used to reconstruct the depositional environment of sediments [9]. The mean is the arithmetic average of the particle size in the samples. The graphic mean calculated is very valuable, because it reflects the energy of the depositional medium and may be controlled by the availability of particles of a particular size [10]. Sorting is the standard deviation calculated as the measure of the range of the grain sizes present and the magnitude of the spread of these sizes around the mean size [10]. Skewness is the degree of asymmetry of a frequency curve. Kurtosis is the degree of peakedness or aperture from the normal cumulative or frequency curve. It measures the degree of sorting in the centre of a curve compared to sorting at its tails. Although this is calculated for samples, the interpretation of its meaning is unknown because it varies between different authors [11]. From the foregoing graphical representation of the samples analysed, they suggest a unimodal distribution of sediments from a single source. Also, the coarse nature of the sediments indicates fast rate of sedimentation under high energy condition. In this regard, [12] argue that coarser particles can be more mobile than finer particles if the speed of the transporting medium is higher than the threshold value of the sediment particles. This could result in an increased grain size in the direction of transport. Furthermore, the fine grained sediments contained in the samples indicate slight reduction of energy level of the transporting medium. This probably explains the leptokurtic nature of the sediments in the area which suggests relative short distance of transportation from a nearby provenance. Consequently, correlation between sediment size parameters and transportation/depositional mechanism of sediments has been established by exhaustive studies from many modern and ancient sedimentary environments [13 and 14]. Also, [15] is of the view that sediment grain size and sorting patterns are likely to evolve in the direction of transport and this depends on the relative proportions of potential saltation, suspension and creep population in the source sediments. Likewise, [16] suggest that the extreme high or low values of kurtosis imply that part of sediment achieved its sorting elsewhere in high-energy environment. Variation in the kurtosis values is a reflection of the flow characteristic of the depositing medium [17 and 18].

4 CONCLUSIONS

The result of the granulometric analysis indicates that the grain size of the Bima formation is continental in origin which is dominated by coarse grains and some fine to medium grains which indicates an evidence of change in depositional energy medium from moderate to high. The positive skewness values indicate fluvial process under high energy condition. The sandstone has high storage capacities for hydrocarbon accumulation, good aquifer characteristics and excellent economic value as aggregates for construction.

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