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Classification and Nomenclature of the Sandstones of the Bama Ridge, Bornu Sub Basin, North Eastern Nigeria

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Abstract: ***The Bama Ridge is a long, narrow and prominent morphological feature lying roughly NW to SE on top of the Quaternary Chad Formation in the Bornu sub basin. Section logging revealed the predominance of sandstone lithofacies, from which samples were obtained for nomenclature. Granulometric analyses of samples analysed show an overwhelming degree of textural maturation, characterized by extremely low percentages of matrix. Thin section microscopy and quantitative estimation by point counting indicate Quartz richness with significant amount of feldspar. However, rock fragment and other mineralogical suites are insignificant. Thus, these sandstones are Quartzose and mineralogically immatured. Nomenclature plots, employing the schemes of Mc Bride (1963) and Dott (1964) indicate that the sandstones of the facies of the Bama Ridge are predominantly Arkosic Arenites: sandstones which are texturally matured but mineralogically immatured.***

Keywords: Bama Ridge, Granulometry, Thin section Microscopy, Classification, Arkosic Arenit

1. Introduction

The Bama Ridge is a sand ridge that is long and narrow. It is a prominent morphological feature lying on top of the Quaternary Chad Formation in Northeastern part of Nigeria (Fig 1) and represents the ancient shoreline of the Mega Lake Chad (Durand, 1982). It was considered to have been formed during the late Pleistocene when it was left as a distinct feature as the Mega Chad receeded (Grove, 1959).

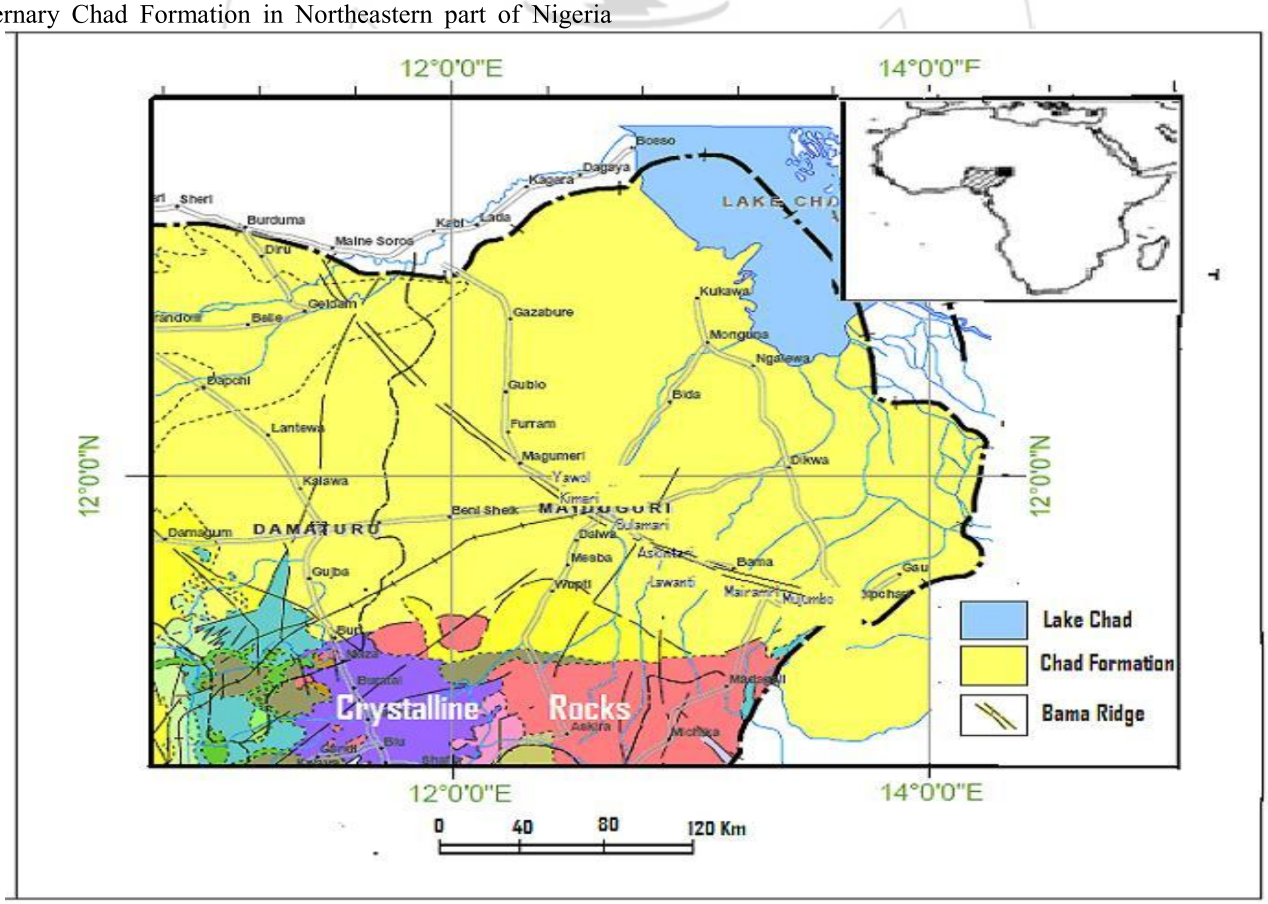

Figure 1: Map of north eastern Nigeria showing the Bama Ridge

Regionally, this sand ridge trends roughly NW-SE in a somewhat discontinuous manner for about 160km.It covers parts of the Cameroun plains, extending through the northern tip of the Mandara Hills in Nigeria, passing through Bama in Borno State to Gashua and Nguru in Yobe State. It ultimately flattens out beneath the sand dunes of the Republic of Niger. The relief surrounding the Bama Ridge (which rises for some 12m) is relatively a flat plain (Seneviratae, 1983).

The Bama Ridge is thus a unique, interesting and significant feature, being the only ridge noticeable on the plains in Borno. Further, it serves as a source of sand for construction works.

2. The Bama Ridge in perspective

Geological literature on the Bama Ridge is quite scanty and discussions on its formation have been relative and passive, focusing mostly on the Mega Lake Chad. Therefore, no detailed geological research has been focused on the Bama Ridge with regards to its evolution.
Survey of existing literature underlines the widely held view that the Bama Ridge is a beach ridge formed along the south western shores of the Mega Lake Chad. Several authors, Grove and Warren, 1968; Bawden, 1972 and Servant-Vildary, 1977 among others, agree that during a peak water level of the Mega Lake Chad at about 320 masl, storm waves of the lake formed the Bama Ridge along its shores. There is however differences on the times of attainment of these peak levels during the Holocene, varying from 5400 years B.P - 21,800 years B.P.

Some deviation from an entirely beach process building up the ridge was presented by Iwuagwu (1991) who undertook a lithofacies analyses and though attributed to beach process, the analyses did not reveal a typical beach sand characteristics, thereby questioning the beach origin widely ascribed to it.

Durand (1982) and Ostaficzuk (1985) hypothesized the ridge to have formed along a neotectonic fault, the probable fault line trending NNW-SSE guided the initial accumulation of sediments along the SW shores of the mega Lake Chad.

Works departing from beach origin and concluding on fluvial origin are scanty. Agbo and Goni (1995) on the basis of grain size analyses at the lake Alau Dam project excavation site, few kilometers SE of Maiduguri found the sediments to be averagely coarse and poorly sorted and along side other statistical parameters of grain size,they concluded deposition under a high energy fluvial environment. Obi (1996) undertook quartz pebble morphometric study of the Bama Ridge and by measuring the long,intermediate and short axes of pebbles and a consideration of maximum projection sphericity,oblate-prolate index and elongation ratios,he obtained results suggesting that the pebbles of the Bama Ridge were shaped in a fluvial environment. Similarly, Bristow et al (2008) logged sections near fogori village at both sides of the River Ngadda and concluded that the sedimentological interpretations of exposed quarries and sand pits show fluvial stratigraphy.

3. Materials and Methods

Reconaissance
This stage was used as an aid to locate suitable sites for the field studies and also to determine the accessibility of the study area by locating foot and truck paths. The Nigerian Federal Survey topographic map sheet 90 (Maiduguri / Mafa) and the Agric, Livestock and Technical Services (ALTS, 1976) topographic map of the Ngadda and Yedzaram catchments were used.

Section measurement and description
This exercise was aimed at studying the outcrops in detail by measuring and recording all features of geologic interest such as strikes and dips, sedimentary structures and the azimuths of directional structures. Logging of each section was based on recognition and subdivision of lithologic units such as clay, silt, sandstone and granulestone. This follows the style of Tucker, (1982, 1991, and 2003). After identification of the lithologies, bed thicknesses were measured and details of the attributes were recorded in the field note book.

Sampling
Systematic sampling of studied sections was undertaken for each bed of each section, and additionally from areas of subtle changes in colour and or texture within beds. This was done mostly in accordance with Folk (1980) spot sampling technique, which favours the determination of the origin and sedimentological conditions of the sediments.

Thus, samples comprising of i) sands and sandstones that are unconsolidated, weakly consolidated and consolidated ii) laminated silty clays of various shades of colours ranging from light to dark grey and iii) granulestones which are mostly consolidated were obtained for further studies on the ridges textural and mineralogical attributes.
Sieve analyses

About 100 grammes each of the disaggregated samples were sieved through a set of sieves of various mesh sizes. Sieving was performed using the automatic electric shaker at 15 minutes preset time. After sieving, the fraction retained on each sieve mesh was carefully weighed. The weight of each retained fraction was converted to weight percentage and from the individual weight percentages, cumulative weight percentages were determined.
Thin section Microscopy

Representative sandstone samples were carefully selected for thin section studies. Most of these samples were friable while few were indurated. The friable samples were impregnated using araldite and epoxy resin while the indurated samples were directly cut and mounted on glass slides.

The impregnation stage was followed by proper thinning achieved in accordance with Kerr's (1970) method. Mounting on the slides was performed by mostly using araldite (though in few cases Canada balsam was used instead). Finally the

glass slides were covered and labeled before the microscopic studies.
Thin sections of the samples were studied with a petrographic microscope under plane and crossed polarized lights. Reference to McKenzie and Guilford (1980) was frequently made for proper mineral identification.

The relative frequencies of mineral grains were estimated using a point counter. The proportion of grid intersections that fall on a specified mineral is assumed to be equivalent to the volumetric ratio of that mineral in the bulk specimen.

4. Results

The resulting data of mechanical sieve analyses is as presented as appendix 1. Although a number of secondary data and plots have arisen from the raw data, emphasis is here laid only on that which has a direct bearing on the matrix content of samples analysed. Mineralogical compositions studied under the petrologic microscope (Table 1) indicate that quartz is the dominant mineral of the sands of the Bama Ridge. Three types have been recognized based on the number of crystals per grain and nature of extinction. The polycrystalline quartz grains are composite and are formed of 2 or more crystal units. This constitutes 10.75 %. Monocrystalline quartz that shows undulatory extinction constitutes 66.98 % while monocrystalline quartz that shows non undulatory extinction has a relative abundance of 22.27%.

Other minerals occurring in subordinate amounts include feldspar, iron oxide, an assemblage of heavy minerals (which includes haematite, zircon, hornblende and garnet) and some rock fragments, constituting a minor percentage.

The data generated from each thin section also include an estimation of the modal components according to the volumetric ratios of framework minerals present in the rock (Table 1).

Table 1: Modal composition of framework minerals of the Bama Ridge

S.No	Quartz			Feldspar			Rock Fragment		
	Sample ID	Modal Value	Percent Modal Value	Potassium	Plagioclase	Percent Modal Value	Modal Value	Percent Modal Value	Q/F/L
1	L1S1	54	59.34	31	0	34.07	6	6.59	59/34/7
2	L2S1	59	63.44	29	4	35.48	1	1.08	63/36/1
3	L6S1	67	72.82	18	0	19.56	7	7.61	73/19/8
4	L6S4	54	60	31	0	34.44	5	5.56	60/34/6
5	L9S3	60	68.18	28	0	31.82	0	0	68/32/0
6	L14S1	55	61.11	26	5	34.43	4	5	61/34/5
7	L15S4	55	63.22	26	0	29.89	6	6.9	63/30/7
8	L12S3	61	66.3	26	0	28,26	5	5.43	66/28/5
9	L3S6	60	65.22	23	4	29.34	5	5.43	65/29/5
10	L4S3	66	71.74	22	0	23.91	4	4.35	72/24/4
11	L4S5	62	66.67	28	0	30.11	3	3.23	67/30/3
12	L7S3	66	70.97	19	5	25.81	3	3.23	71/26/3
13	L8S1	62	63.27	32	0	32.65	4	4.08	63/33/4
14	L8S6	63	67.02	27	0	28.72	4	4.26	67/29/4
15	L9S6	65	72.22	24	0	26.67	1	1.11	72/27/1
16	L11S1	61	62.24	30	0	30.61	7	7.14	62/31/7
17	L3S4	55	59.78	29	0	31.52	8	8.7	59/32/9
18	L6S6	57	64.77	31	0	35.23	0	0	65/35/0
19	L2S6	58	60.42	32	0	33.33	6	6.25	60/33/6
20	L13S5	66	70.21	28	0	29.79	0	0	70/30/0
21	L5S3	63	69.23	24	0	26.37	4	4.4	69/26/4
22	L17S2	56	65.12	24	0	27.91	6	6.98	65/28/7
23	**Average**		**66**			**29**		**5**	

5. Discussions

Numerous classifications of clastics, especially sandstones, have been proposed over the years with the majority based on two parameters: mineralogy and/or texture. Those classifications that are used today employ the same aspects of composition and texture. According to Dike (*Personal Discussion*), it is best to employ at least two schemes so that the inadequacies of one can be handled by the other.

Sandstones are extremely interesting group of rocks because the variety of textures and compositions inherent in these rocks provide a wealth of information about their parent rocks, transport and depositional history (Maigari, 2010). Most sandstone are made up of mixtures of a small number of dominant components. According to Dickinson (1985), Quartz (including chert), feldspars, rock fragments and matrix materials are the only constituents commonly abundant enough to be of significance in sandstone classification. These are therefore employed in the classification of the sandstones of the Bama Ridge. The first three constituents form the framework elements and are also referred to as the QFR constituents (Dott, 1964 and Dickinson, 1985). In this classification, these three constituents are plotted as end members on a triangular diagram in McBride (1963) and Dott (1964) schemes as Figures 2 and 3 respectively. Quartz is recognized and plotted in the Q-pole, feldspars in the F-pole and all forms of rock fragments in the R-pole. Several sandstone classification schemes are available but one of the most widely used is that of Dott's (1964), where sandstones with insignificant matrix (<15%) are classified as arenites and those with appreciable matrix (>15%) are recognized as wackes. However, Mc Bride (1963) classification scheme was also used in this study for the purpose of comparison (Fig. 3).

Under both schemes, most samples plotted on the Quartz arenite quadrants, with some falling under the subarkose. It may be postulated therefore that the sandstones of the Bama Ridge in the investigated area are dominantly Arkosic arenites, grading to subarkose.

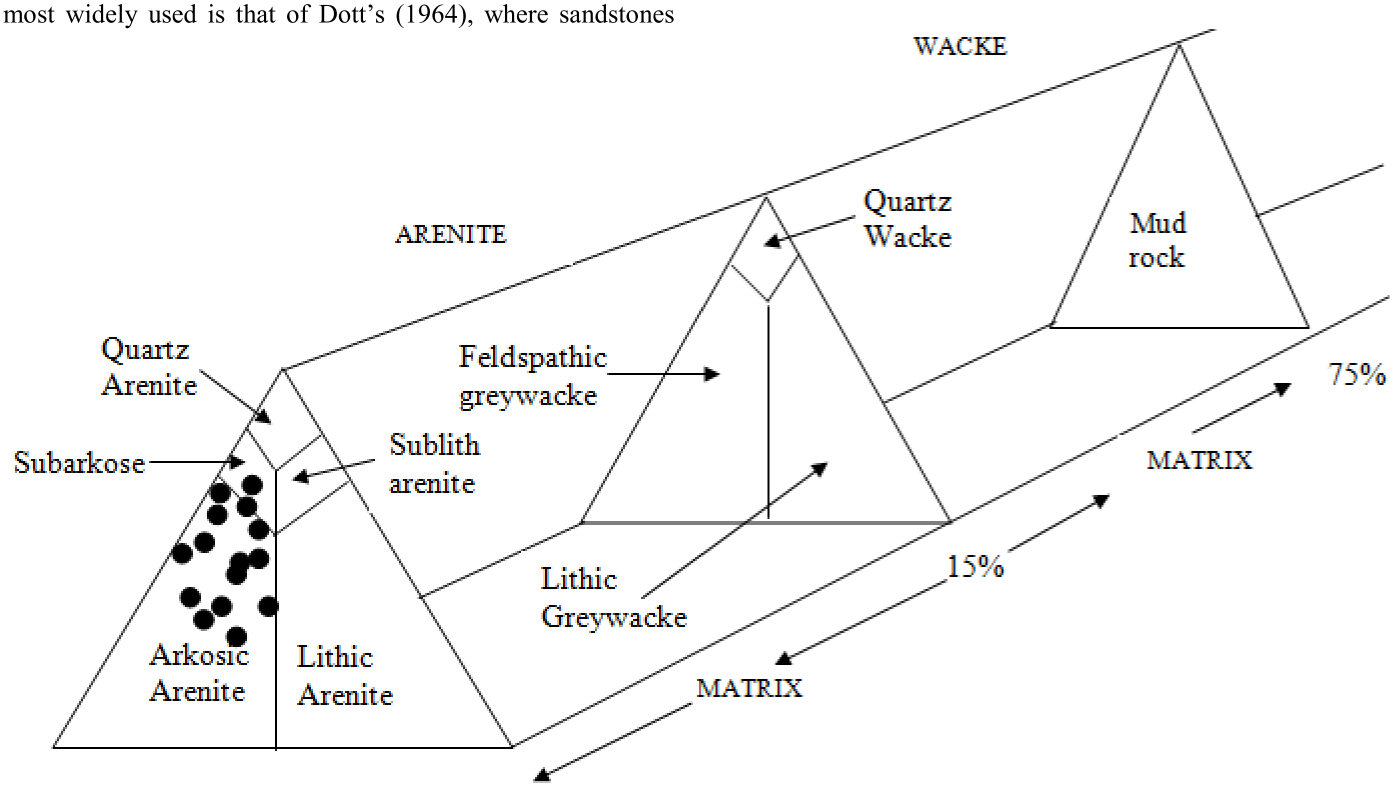

Figure 2: Classification of the Bama Ridge Sandstone (Based on Dott, 1964 nomenclature)

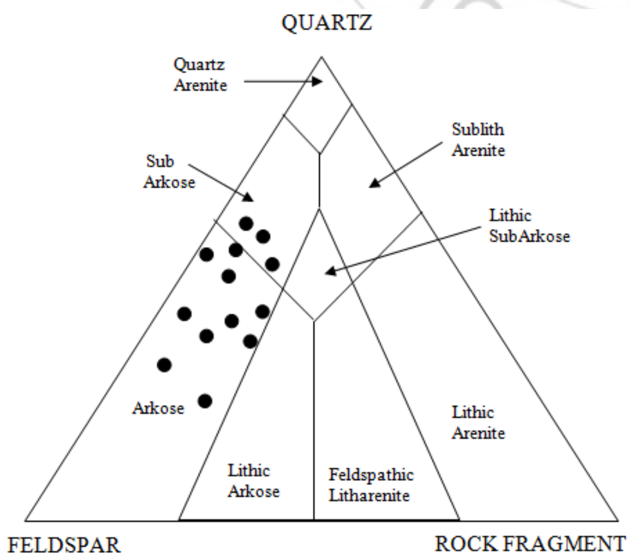

Figure 3: Classification of the Bama Ridge Sandstone (Based on Mc Bride, 1963 nomenclature)

6. Summary and Cnclusion

Section logging of the Bama Ridge revealed the predominance of sandstone lithofacies, the samples of which were used for classification and nomenclature. Grain size analyses of the samples indicate textural maturation, characterized by extremely low percentages of matrix. Thin section microscopy and quantitative estimation by point counting further rindicate Quartz richness, though with significant amount of feldspar. However, rock fragment and other mineralogical suites are insignificant. Thus, these sandstones are Quartzose and mineralogically immatured.

Nomenclature plot based on the classification schemes of Mc Bride (1963) and Dott (1964) both indicate that the sandstones of the Bama Ridge facies are predominantly texturally matured but mineralogically immatured and are considered Arkosic Arenites.

Appendix 1: Data of Mechanical Sieve Analyses

Sample 1: L1S1

Mesh No.	Mesh Diametre		Weight Retained	Cumulative Weight	Weight %	Cumulative Weight %
	Phi	mm				
1	-2.00	4.00	0.4	0.4	0.40	0.40
2	-1.50	2.83	1.2	1.6	1.21	1.61
3	-1.00	2.00	5.3	6.9	5.35	6.96
4	-0.50	1.41	8.5	15.4	8.59	15.55
5	0.00	1.00	23.2	38.6	23.43	38.98
6	0.50	0.71	20.6	59.2	20.81	59.79
7	1.00	0.50	18.3	77.5	18.48	78.27
8	1.50	0.35	7.4	84.9	7.47	85.74
9	2.00	0.25	5.6	90.5	5.66	91.40
10	2.50	0.177	2.4	92.9	2.42	93.82
11	3.00	0.125	0.3	93.2	0.30	94.12
12	3.25	0.105	2.0	95.2	2.02	96.14
13	3.50	0.088	1.4	96.6	1.41	97.55
14	3.75	0.074	1.1	97.7	1.11	98.66
15	4.00	0.063	0.7	98.4	0.71	99.37
16	4.25	0.053	0.4	98.8	0.40	99.77
Pan	-	-	0.2	99.0	0.20	99.97

Sample 2: L2S1

Mesh No.	Mesh Diametre		Weight Retained	Cumulative Weight	Weight %	Cumulative Weight %
	Phi	mm				
1	-2.00	4.00	0.0	0.0	0.00	0.00
2	-1.50	2.83	0.0	0.0	0.00	0.00
3	-1.00	2.00	0.7	0.7	0.70	0.70
4	-0.50	1.41	1.4	2.1	1.41	2.11
5	0.00	1.00	1.9	4.0	1.91	4.02
6	0.50	0.71	3.3	7.3	3.32	7.34
7	1.00	0.50	5.8	13.1	5.83	13.17
8	1.50	0.35	7.7	20.8	7.74	20.91
9	2.00	0.25	10.9	31.7	10.96	31.87
10	2.50	0.177	15.4	47.1	15.48	47.35
11	3.00	0.125	20.1	67.2	20.20	67.55
12	3.25	0.105	14.6	81.8	14.67	82.22
13	3.50	0.088	8.2	90.0	8.24	90.46
14	3.75	0.074	6.4	96.4	6.43	96.89
15	4.00	0.063	2.6	99.0	2.61	99.50
16	4.25	0.053	0.5	99.5	0.50	100
Pan	-	-	-	-	-	-

Sample 3:L6S1

Mesh No.	Mesh Diametre		Weight Retained	Cumulative Weight	Weight %	Cumulative Weight %
	Phi	mm				
1	-2.00	4.00	0.0	0.0	0.00	0.00
2	-1.50	2.83	32.1	32.1	32.26	32.26
3	-1.00	2.00	18.7	50.8	18.79	51.05
4	-0.50	1.41	9.2	60.0	9.25	60.30
5	0.00	1.00	6.4	66.4	6.43	66.73
6	0.50	0.71	8.3	74.7	8.34	75.07
7	1.00	0.50	5.7	80.4	5.73	80.80
8	1.50	0.35	3.6	84.0	3.62	84.42
9	2.00	0.25	3.5	87.5	3.52	87.94
10	2.50	0.177	2.8	90.3	2.81	90.75
11	3.00	0.125	2.0	92.3	2.01	92.76
12	3.25	0.105	2.4	94.7	2.41	95.17
13	3.50	0.088	1.7	96.4	1.71	96.88
14	3.75	0.074	1.3	97.7	1.31	98.19
15	4.00	0.063	0.9	8.6	0.90	99.09
16	4.25	0.053	0.6	99.2	0.60	99.69
Pan	-	-	0.3	99.5	0.30	99.99

Sample 4:L6S4

Mesh No.	Mesh Diametre		Weight Retained	Cumulative Weight	Weight %	Cumulative Weight %
	Phi	mm				
1	-2.00	4.00	0.0	0.0	0.00	0.00
2	-1.50	2.83	0.6	0.6	0.60	0.60
3	-1.00	2.00	0.7	1.3	0.70	1.30
4	-0.50	1.41	1.5	2.8	1.50	2.80
5	0.00	1.00	2.3	5.1	2.31	5.11
6	0.50	0.71	4.2	9.3	4.21	9.32
7	1.00	0.50	7.1	16.4	7.11	16.43
8	1.50	0.35	13.3	29.7	13.33	29.76
9	2.00	0.25	17.4	47.1	17.43	47.19
10	2.50	0.177	16.6	63.7	16.63	63.82
11	3.00	0.125	11.1	74.8	11.12	74.94
12	3.25	0.105	8.3	83.1	8.33	83.27
13	3.50	0.088	6.7	89.8	6.71	89.98
14	3.75	0.074	4.8	94.6	4.81	94.79
15	4.00	0.063	2.1	96.7	2.10	96.89
16	4.25	0.053	2.7	99.4	2.71	99.60
Pan	-	-	0.4	99.8	0.40	100

Sample 5:L9S3

Mesh No.	Mesh Diametre		Weight Retained	Cumulative Weight	Weight %	Cumulative Weight %
	Phi	Mm				
1	-2.00	4.00	1.2	1.2	1.20	1.20
2	-1.50	2.83	33.6	34.8	33.73	34.93
3	-1.00	2.00	22.3	57.1	22.39	57.32
4	-0.50	1.41	6.5	63.6	6.53	63.85
5	0.00	1.00	6.4	70.0	6.43	70.28
6	0.50	0.71	3.6	73.6	3.61	73.89
7	1.00	0.50	3.3	76.9	3.31	77.20
8	1.50	0.35	3.1	80.0	3.11	80.31
9	2.00	0.25	2.9	82.9	2.91	83.22
10	2.50	0.177	5.2	88.1	5.22	88.44
11	3.00	0.125	3.3	91.4	3.31	91.75
12	3.25	0.105	2.7	94.1	2.71	94.46
13	3.50	0.088	1.8	95.9	1.81	96.27
14	3.75	0.074	1.5	97.4	1.51	97.78
15	4.00	0.063	1.2	98.6	1.20	98.98
16	4.25	0.053	0.7	99.3	0.70	99.68
Pan	-	-	0.3	99.6	0.30	99.98

Sample 6:L14S1

Mesh No.	Mesh Diametre		Weight Retained	Cumulative Weight	Weight %	Cumulative Weight %
	Phi	mm				
1	-2.00	4.00	0.0	0.0	0.00	0.00
2	-1.50	2.83	3.6	3.6	3.64	3.64
3	-1.00	2.00	8.0	11.6	8.09	11.73
4	-0.50	1.41	12.3	23.9	12.44	24.17
5	0.00	1.00	17.8	41.7	17.99	42.16
6	0.50	0.71	22.4	64.1	22.65	64.81
7	1.00	0.50	12.2	76.3	12.34	77.15
8	1.50	0.35	8.7	85.0	8.80	85.95
9	2.00	0.25	7.2	92.2	7.28	93.23
10	2.50	0.177	3.6	95.8	3.64	96.87
11	3.00	0.125	1.5	97.3	1.52	98.39
12	3.25	0.105	0.6	97.9	0.61	99.00
13	3.50	0.088	0.4	98.3	0.40	99.40
14	3.75	0.074	0.3	98.6	0.30	99.70
15	4.00	0.063	0.3	98.9	0.30	100
16	4.25	0.053	0.0	0.0	0.0	0.0
Pan	-	-	-	-	-	-

Sample 7:L15S4

Mesh No.	Mesh Diametre		Weight Retained	Cumulative Weight	Weight %	Cumulative Weight %
	Phi	mm				
1	-2.00	4.00	0.4	0.4	0.41	0.41
2	-1.50	2.83	1.2	1.6	1.22	1.63
3	-1.00	2.00	5.1	6.7	5.17	6.80
4	-0.50	1.41	11.9	18.6	12.06	18.86
5	0.00	1.00	16.0	34.6	16.21	35.07
6	0.50	0.71	20.6	55.2	20.87	55.94
7	1.00	0.50	17.3	72.5	17.53	73.47
8	1.50	0.35	9.4	81.9	9.52	82.99
9	2.00	0.25	5.3	87.2	5.37	88.36
10	2.50	0.177	3.2	90.4	3.24	91.60
11	3.00	0.125	1.8	92.2	1.82	93.42
12	3.25	0.105	2.3	94.5	2.33	95.75
13	3.50	0.088	1.4	95.9	1.42	97.17
14	3.75	0.074	1.2	97.1	1.22	98.39
15	4.00	0.063	1.0	98.1	1.01	99.40
16	4.25	0.053	0.6	98.7	0.61	100.01
Pan	-	-	0.0	0.0	0.0	0.00

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Sample 8:L12S3

Mesh No.	Mesh Diametre		Weight Retained	Cumulative Weight	Weight %	Cumulative Weight %
	Phi	mm				
1	-2.00	4.00	0.3	0.3	0.30	0.30
2	-1.50	2.83	19.4	19.7	19.52	19.82
3	-1.00	2.00	22.7	42.4	22.84	42.66
4	-0.50	1.41	10.3	52.7	10.36	53.02
5	0.00	1.00	8.2	60.9	8.25	61.27
6	0.50	0.71	6.1	67.0	6.14	67.41
7	1.00	0.50	6.3	73.3	6.34	79.75
8	1.50	0.35	6.8	80.1	6.84	80.59
9	2.00	0.25	4.4	84.5	4.43	85.02
10	2.50	0.177	4.1	88.6	4.12	89.14
11	3.00	0.125	3.3	91.9	3.32	92.46
12	3.25	0.105	2.5	94.4	2.52	94.98
13	3.50	0.088	2.1	96.5	2.11	97.09
14	3.75	0.074	1.7	98.2	1.71	98.80
15	4.00	0.063	0.7	98.9	0.70	99.50
16	4.25	0.053	0.4	99.3	0.40	99.90
Pan	-	-	0.1	99.4	0.10	100

Sample 9:L3S6

Mesh No.	Mesh Diametre		Weight Retained	Cumulative Weight	Weight %	Cumulative Weight %
	Phi	mm				
1	-2.00	4.00	0.0	0.0	0.00	0.00
2	-1.50	2.83	0.0	0.0	0.00	0.00
3	-1.00	2.00	0.4	0.4	0.40	0.40
4	-0.50	1.41	1.2	1.6	1.20	1.60
5	0.00	1.00	2.8	4.4	2.81	4.41
6	0.50	0.71	5.6	10.0	5.62	10.03
7	1.00	0.50	7.8	17.8	7.84	17.87
8	1.50	0.35	9.4	27.2	9.44	27.31
9	2.00	0.25	11.3	38.5	11.34	38.65
10	2.50	0.177	15.4	53.9	15.46	54.11
11	3.00	0.125	16.2	70.1	16.27	70.38
12	3.25	0.105	10.6	80.7	10.64	81.02
13	3.50	0.088	7.7	88.4	7.73	88.75
14	3.75	0.074	4.3	92.7	4.32	93.07
15	4.00	0.063	4.0	96.7	4.02	97.09
16	4.25	0.053	2.4	99.1	2.41	99.50
Pan	-	-	0.5	99.6	0.50	100

Sample 10:L4S3

Mesh No.	Mesh Diametre		Weight Retained	Cumulative Weight	Weight %	Cumulative Weight %
	Phi	mm				
1	-2.00	4.00	0.0	0.0	0.0	0.00
2	-1.50	2.83	0.0	0.0	0.0	0.00
3	-1.00	2.00	0.0	0.0	0.0	0.00
4	-0.50	1.41	0.5	0.5	0.50	0.50
5	0.00	1.00	0.7	1.2	0.71	1.21
6	0.50	0.71	6.4	7.6	6.45	7.66
7	1.00	0.50	6.8	14.4	6.85	14.51
8	1.50	0.35	9.3	23.7	9.37	23.88
9	2.00	0.25	15.3	39.0	15.42	39.30
10	2.50	0.177	20.8	59.8	20.98	60.28
11	3.00	0.125	11.5	71.3	11.59	71.87
12	3.25	0.105	13.4	84.7	13.51	85.38
13	3.50	0.088	7.7	92.4	7.76	93.14
14	3.75	0.074	4.2	96.6	4.23	7.37
15	4.00	0.063	1.8	98.4	1.81	99.18
16	4.25	0.053	0.8	99.2	0.81	99.99
Pan	-	-	-	-	-	-

Sample 11:L4S5

Mesh No.	Mesh Diametre		Weight Retained	Cumulative Weight	Weight %	Cumulative Weight %
	Phi	mm				
1	-2.00	4.00	0.4	0.4	0.40	0.40
2	-1.50	2.83	17.7	18.1	17.81	18.21
3	-1.00	2.00	18.2	36.3	18.31	36.52
4	-0.50	1.41	15.6	51.9	15.69	52.21
5	0.00	1.00	8.7	60.6	8.75	60.96
6	0.50	0.71	7.3	67.9	7.34	68.30
7	1.00	0.50	6.0	73.9	6.04	74.34
8	1.50	0.35	4.5	78.4	4.53	78.87
9	2.00	0.25	3.7	82.1	3.72	82.59
10	2.50	0.177	3.2	85.3	3.22	85.81
11	3.00	0.125	2.6	87.9	2.62	88.43
12	3.25	0.105	2.9	90.8	2.92	91.35
13	3.50	0.088	3.1	93.9	3.12	94.47
14	3.75	0.074	2.6	96.5	2.62	97.09
15	4.00	0.063	1.7	98.2	1.71	98.80
16	4.25	0.053	0.8	99.0	0.80	99.60
Pan	-	-	0.4	99.4	0.40	100

Sample 12:L7S3

Mesh No.	Mesh Diametre		Weight Retained	Cumulative Weight	Weight %	Cumulative Weight %
	Phi	mm				
1	-2.00	4.00	0.0	0.0	0.00	0.00
2	-1.50	2.83	0.0	0.0	0.00	0.00
3	-1.00	2.00	0.5	0.5	0.50	0.50
4	-0.50	1.41	0.8	1.3	0.81	1.31
5	0.00	1.00	2.2	3.5	2.22	3.53
6	0.50	0.71	4.7	8.2	4.74	8.27
7	1.00	0.50	8.3	16.5	8.38	16.65
8	1.50	0.35	10.5	27.0	10.60	27.25
9	2.00	0.25	9.6	36.6	9.69	36.94
10	2.50	0.177	12.7	49.3	12.82	49.76
11	3.00	0.125	17.0	66.3	17.15	66.91
12	3.25	0.105	13.4	79.7	13.52	80.43
13	3.50	0.088	7.7	87.4	7.77	88.20
14	3.75	0.074	6.2	93.6	6.26	94.46
15	4.00	0.063	3.4	97.0	3.43	97.89
16	4.25	0.053	1.6	98.6	1.61	99.50
Pan	-	-	0.5	99.1	0.50	100

Sample 13:L8S1

Mesh No.	Mesh Diametre		Weight Retained	Cumulative Weight	Weight %	Cumulative Weight %
	Phi	mm				
1	-2.00	4.00	0.0	0.0	0.0	0.00
2	-1.50	2.83	3.8	3.8	3.82	3.82
3	-1.00	2.00	8.8	12.6	8.85	12.67
4	-0.50	1.41	8.6	21.2	8.65	21.32
5	0.00	1.00	13.4	34.6	13.48	34.80
6	0.50	0.71	16.1	50.7	16.20	51.00
7	1.00	0.50	7.3	58.0	7.34	58.34
8	1.50	0.35	10.3	68.2	10.26	68.60
9	2.00	0.25	8.4	76.6	8.45	77.05
10	2.50	0.177	6.5	83.1	6.54	83.59
11	3.00	0.125	4.6	87.7	4.63	88.22
12	3.25	0.105	2.8	90.5	2.82	91.04
13	3.50	0.088	1.5	92.0	1.51	92.55
14	3.75	0.074	3.4	95.4	3.42	95.97
15	4.00	0.063	2.0	97.4	2.01	97.98
16	4.25	0.053	1.6	99.0	1.61	99.59
Pan	-	-	0.4	99.4	0.40	99.99

Sample 14:L8S6

Mesh No.	Mesh Diametre Phi	Mesh Diametre mm	Weight Retained	Cumulative Weight	Weight %	Cumulative Weight %
1	-2.00	4.00	1.3	1.3	1.30	1.30
2	-1.50	2.83	20.4	21.7	20.44	21.74
3	-1.00	2.00	12.8	34.5	12.83	34.57
4	-0.50	1.41	7.6	42.1	7.62	42.19
5	0.00	1.00	7.4	49.5	7.41	49.60
6	0.50	0.71	6.8	56.3	6.81	56.41
7	1.00	0.50	6.5	62.8	6.51	62.92
8	1.50	0.35	6.2	69.0	6.21	69.13
9	2.00	0.25	6.0	75.0	6.01	75.14
10	2.50	0.177	6.3	81.3	6.31	81.45
11	3.00	0.125	5.4	86.7	5.41	86.86
12	3.25	0.105	4.5	91.2	4.51	91.37
13	3.50	0.088	2.9	94.1	2.91	94.28
14	3.75	0.074	2.4	96.5	2.40	96.68
15	4.00	0.063	1.7	98.2	1.70	98.38
16	4.25	0.053	1.3	99.5	1.30	99.68
Pan	-	-	0.3	99.8	0.30	99.98

Sample 15:L9S6

Mesh No.	Mesh Diametre Phi	Mesh Diametre mm	Weight Retained	Cumulative Weight	Weight %	Cumulative Weight %
1	-2.00	4.00	0.0	0.0	0.0	0.00
2	-1.50	2.83	0.0	0.0	0.0	0.00
3	-1.00	2.00	0.8	0.8	0.8	0.80
4	-0.50	1.41	4.0	4.8	4.02	4.82
5	0.00	1.00	5.3	10.1	5.33	10.15
6	0.50	0.71	5.8	15.9	5.84	15.99
7	1.00	0.50	7.8	23.7	7.85	23.84
8	1.50	0.35	11.0	34.7	11.07	34.91
9	2.00	0.25	11.7	46.4	11.77	46.68
10	2.50	0.177	13.2	59.6	13.28	59.96
11	3.00	0.125	11.7	71.3	11.77	71.73
12	3.25	0.105	10.6	81.9	10.66	82.39
13	3.50	0.088	6.8	88.7	6.84	89.23
14	3.75	0.074	4.3	93.0	4.33	93.56
15	4.00	0.063	3.5	96.5	3.52	97.08
16	4.25	0.053	2.9	99.4	2.92	100
Pan	-	-	-	-	-	-

Sample 16:L11S1

Mesh No.	Mesh Diametre Phi	Mesh Diametre Mm	Weight Retained	Cumulative Weight	Weight %	Cumulative Weight %
1	-2.00	4.00	0.0	0.0	0.00	0.00
2	-1.50	2.83	0.0	0.0	0.00	0.00
3	-1.00	2.00	0.3	0.3	0.30	0.30
4	-0.50	1.41	0.8	1.1	0.80	1.10
5	0.00	1.00	2.1	3.2	2.12	3.22
6	0.50	0.71	2.2	5.4	2.22	5.44
7	1.00	0.50	3.5	8.9	3.54	8.98
8	1.50	0.35	3.5	12.4	3.54	12.52
9	2.00	0.25	7.2	19.6	7.27	19.79
10	2.50	0.177	8.5	28.1	8.59	28.38
11	3.00	0.125	9.1	37.2	9.19	37.57
12	3.25	0.105	11.4	48.6	11.52	49.09
13	3.50	0.088	7.6	66.2	17.78	66.87
14	3.75	0.074	22.3	88.5	22.53	89.40
15	4.00	0.063	8.2	96.7	8.28	97.68
16	4.25	0.053	2.3	99.0	2.32	100
Pan	-	-	-	-	-	-

Sample 17:L3S4

Mesh No.	Mesh Diametre		Weight Retained	Cumulative Weight	Weight %	Cumulative Weight %
	Phi	Mm				
1	-2.00	4.00	0.0	0.0	0.0	0.0
2	-1.50	2.83	1.3	1.3	1.30	1.30
3	-1.00	2.00	5.4	6.7	5.42	6.72
4	-0.50	1.41	9.2	15.9	9.24	15.96
5	0.00	1.00	18.7	34.6	18.78	34.74
6	0.50	0.71	21.8	56.4	21.89	56.63
7	1.00	0.50	17.4	73.8	17.47	74.10
8	1.50	0.35	8.6	82.4	8.63	82.73
9	2.00	0.25	7.2	89.6	7.23	89.96
10	2.50	0.177	3.5	93.1	3.51	93.47
11	3.00	0.125	2.2	95.3	2.21	95.68
12	3.25	0.105	1.8	97.1	1.81	97.49
13	3.50	0.088	1.3	98.4	1.31	98.80
14	3.75	0.074	0.7	99.1	0.70	99.50
15	4.00	0.063	0.3	99.4	0.30	99.80
16	4.25	0.053	0.2	99.6	0.20	100
Pan	-	-	-	-	-	-

Sample 18:L6S6

Mesh No.	Mesh Diametre		Weight Retained	Cumulative Weight	Weight %	Cumulative Weight %
	Phi	mm				
1	-2.00	4.00	0.0	0.0	0.00	0.00
2	-1.50	2.83	0.0	0.0	0.00	0.00
3	-1.00	2.00	0.5	0.5	0.50	0.50
4	-0.50	1.41	0.8	1.3	0.80	1.30
5	0.00	1.00	0.4	1.7	0.40	1.70
6	0.50	0.71	1.5	3.2	1.51	3.21
7	1.00	0.50	2.9	6.1	2.91	6.12
8	1.50	0.35	8.4	14.5	8.43	14.55
9	2.00	0.25	17.6	32.1	17.68	32.23
10	2.50	0.177	21.7	53.8	21.79	54.02
11	3.00	0.125	19.3	73.1	19.38	73.40
12	3.25	0.105	11.2	84.3	11.24	84.64
13	3.50	0.088	6.4	90.7	6.43	91.07
14	3.75	0.074	4.9	95.6	4.92	95.99
15	4.00	0.063	2.6	98.2	2.61	98.60
16	4.25	0.053	1.0	99.2	1.00	99.60
Pan	-	-	0.4	99.6	0.40	100

Sample 19:L2S6

Mesh No.	Mesh Diametre		Weight Retained	Cumulative Weight	Weight %	Cumulative Weight %
	Phi	mm				
1	-2.00	4.00	0.2	0.2	0.20	0.20
2	-1.50	2.83	19.3	19.5	19.42	19.62
3	-1.00	2.00	18.7	38.2	18.81	38.43
4	-0.50	1.41	10.8	49.0	10.87	49.30
5	0.00	1.00	9.8	58.8	9.86	59.16
6	0.50	0.71	8.3	67.1	8.35	67.51
7	1.00	0.50	7.8	74.9	7.85	75.36
8	1.50	0.35	4.8	79.7	4.83	80.19
9	2.00	0.25	3.7	83.4	3.72	83.91
10	2.50	0.177	3.3	86.7	3.32	87.23
11	3.00	0.125	3.8	90.5	3.82	91.05
12	3.25	0.105	3.0	93.5	3.02	94.07
13	3.50	0.088	2.6	96.1	2.62	96.69
14	3.75	0.074	2.1	98.2	2.11	98.80
15	4.00	0.063	0.9	99.1	0.90	99.70
16	4.25	0.053	0.3	99.4	0.30	100
Pan	-	-	0.0	0.0	0.00	0.00

Sample 20:L13S5

Mesh No.	Mesh Diametre		Weight Retained	Cumulative Weight	Weight %	Cumulative Weight %
	Phi	Mm				
1	-2.00	4.00	1.4	1.4	1.40	1.40
2	-1.50	2.83	27.3	28.7	27.39	28.79
3	-1.00	2.00	18.5	47.2	18.56	47.35
4	-0.50	1.41	7.6	54.8	7.62	54.97
5	0.00	1.00	7.4	62.2	7.42	62.39
6	0.50	0.71	8.3	70.5	8.33	70.72
7	1.00	0.50	6.5	77.0	6.52	77.24
8	1.50	0.35	6.3	83.3	6.32	83.56
9	2.00	0.25	4.2	87.5	4.21	87.77
10	2.50	0.177	3.6	91.1	3.61	91.38
11	3.00	0.125	2.9	94.0	2.91	94.29
12	3.25	0.105	1.2	95.2	1.20	95.49
13	3.50	0.088	1.7	96.9	1.71	97.20
14	3.75	0.074	1.4	98.3	1.40	98.60
15	4.00	0.063	1.0	99.3	1.00	99.60
16	4.25	0.053	0.4	99.7	0.40	100
Pan	-	-	-	-	-	-

Sample 21:L5S3

Mesh No.	Mesh Diametre		Weight Retained	Cumulative Weight	Weight %	Cumulative Weight %
	Phi	Mm				
1	-2.00	4.00	0.0	0.0	0.00	0.00
2	-1.50	2.83	0.0	0.0	0.00	0.00
3	-1.00	2.00	0.0	0.0	0.00	0.00
4	-0.50	1.41	0.5	0.5	0.50	0.50
5	0.00	1.00	1.3	1.8	1.31	1.81
6	0.50	0.71	2.4	4.2	2.41	4.22
7	1.00	0.50	4.3	8.5	4.32	8.54
8	1.50	0.35	8.2	16.7	8.23	16.77
9	2.00	0.25	10.4	27.1	10.44	27.21
10	2.50	0.177	17.2	44.3	17.27	44.48
11	3.00	0.125	19.4	63.7	19.48	63.96
12	3.25	0.105	13.9	77.6	13.96	77.92
13	3.50	0.088	8.6	86.2	8.63	86.55
14	3.75	0.074	5.9	92.1	5.92	92.47
15	4.00	0.063	3.7	95.8	3.71	96.18
16	4.25	0.053	2.0	97.8	2.01	98.19
Pan	-	-	1.8	99.6	1.81	100

Sample 22:L17S2

Mesh No.	Mesh Diametre		Weight Retained	Cumulative Weight	Weight %	Cumulative Weight %
	Phi	Mm				
1	-2.00	4.00	0.0	0.0	0.0	0.00
2	-1.50	2.83	0.0	0.0	0.0	0.00
3	-1.00	2.00	0.5	0.5	0.50	0.50
4	-0.50	1.41	1.4	1.9	1.40	1.90
5	0.00	1.00	1.7	3.6	1.71	36.10
6	0.50	0.71	4.4	8.0	4.41	8.02
7	1.00	0.50	6.2	14.2	6.22	14.24
8	1.50	0.35	8.5	22.7	8.53	22.77
9	2.00	0.25	11.2	33.9	11.23	34.00
10	2.50	0.177	13.0	46.9	13.04	47.04
11	3.00	0.125	20.4	67.3	20.46	67.50
12	3.25	0.105	12.3	79.6	12.34	79.84
13	3.50	0.088	8.0	87.6	8.02	87.86
14	3.75	0.074	5.2	92.8	5.22	93.08
15	4.00	0.063	3.5	96.3	3.51	96.59
16	4.25	0.053	2.7	99.0	2.71	99.30
Pan	-	-	0.7	99.7	0.70	100

References

[1] Agbo, J.U. and Goni, I.B (1995): *A review of the Geology and Sedimentology of the Bama Ridge in parts of North east Nigeria.Faculty Research Journal of Science*, University of Maiduguri, Vol.2 PP. 11-30.

[2] A.L.T.S. (1976): Topographical map of the Ngadda and the Yedzaram catchments. A publication of the Federal ministry of water resources, Nigeria.

[3] Bawden, M.G. (1972): Physiography, geology, geomorphology and hydrology. In Aitchison (Ed) (1972).*The land resource of N.E Nigeria* Vol.1.London.DOS. PP 43-83.

[4] Bristow, C., Drake, N and Armitage, S. (2008): Paleo Lake Mega Chad shoreline chronology.R.G.S/IBG report, School of Earth Sciences,Birbeck College,University of London. PP. 36.

[5] Dickinson, R. W. (1985): Interpreting Provenance Relations from Detrital Modes of Sandstones. In: G. G. Zuffa (Ed.), Provenance of Arenites. Reidel Publishing Company. PP.333-361.

[6] Dott, R. H. (1964): *Wacke, greywacke and matrix – what approach to immature sandstone classification*? *Journal of Sed. Petrology* Vol. 34 PP.625-632.

[7] Durand, A. (1982): Oscillations of the Lake Chad over the past 50,000 years.New data and hypothesis. *Paleoclimatology,* Vol.39. PP 37-53.

[8] Grove, A.T. (1959): A note on the former extent of Lake Chad. *Geographical Journal*.Vol.125 PP. 465-467.

[9] Grove, A.T. and Warren, A. (1968): *Quartenary Landforms and Climate on the south side of the sahara. Geogr. Journal* .Vol.134. PP. 194 -208.

[10] Iwuagwu, C.J. (1991): *Bama Ridge*: *A beach ridge with a difference*.Paper presented at an N .M.G.S annual international conference, Jos. PP.24.

[11] Kerr, P. F. (1970): Optical Mineralogy. Mcgraw Hill Inc. Mackenzie, W.S. and Guilford, C. (1980): Atlas of rock forming minerals in thin Sections. Longman group Ltd., London. PP. 98.

[12] Maigari, A.S. (2010): Lithostratigraphy, Facies, Depositional environments and clay mineralogy of the middle Pindiga Formation,Upper Benue Trough,Northeast Nigeria.Unpublished P.h.D. thesis,Geology programme. A.T.B.U Bauchi.PP.174.

[13] McBride, E.F. (1963): *Classification of common sandstones*. *Journal of Sedimentary Petrology,* Vol.33 PP. 664-669.

[14] Obi, G. C. (1996): *The origin of the Bama – Maiduguri Ridge complex, Northeastern Nigeria, deduced from pebble form indices*. *Journal of Mining and Geology* Vol.32, No.1, PP.59-64.

[15] Ostaficzuk, S. (1985): *The impact of geology on the vanishing waters of the rivers of Maiduguri.*Paper presented at an international conference on arid zone hydrology and water resources, Center for Arid zone studies, University of Maiduguri.

[16] Seneviratae, H. M. M. B. (1983): An introduction to landforms in Borno State. Geogr. Society, Borno College of Educaton, Maiduguri. Vol.2, PP.58-71.

[17] Servant-Vildary, S. (1977): Etude des diatomces et paleo-Limnologie du Basin Tchadienne au cenozoique Superieur Trav. Et Doc ORSTROM No 84.PP 345.

[18] Tucker, M. E. (1982): Field description of sedimentary rocks. Open University enterprises, Milton Keynes England.149 p.

[19] Tucker, M. E. (1991): Sedimentay Petrology. An Introduction to the Origin of Sedimentary Rocks. Blackwell Scientific Publications, Oxford. PP 262.

[20] Tucker, M.E (2003): Sedimentary Rocks in the field.John wiley and sons, London.PP 234.