Late Maastrichtian to Paleocene sediments of part of Southwestern Iullemmenden Basin, Rabah Sheet 11, Sokoto State, Northwestern, Nigeria.

Sulaiman, Sulaiman Abba[1]*, Mohammed Rilwan[2]

[1] Department of Geology, Ahmadu Bello University, Zaria
[2] Nigerian Institute for Oceanography and Marine Research, Lagos

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Abstract- The stratigraphy and sedimentary structures of the area around Gidan Marafa and environs of Late Maastrichtian to Paleocene in SW Iullemmeden Basin Nigeria. Detailed field work was carried out on a scale of 1:25,000 and two groups were encountered. However, three Formations was studied as follows starting from younger to older; (2) Rima Group; only Wurno Formation was found at the top of this group and are made up of friable, yellow-golden brown fine to medium grained sandstones which intercalates with carboniferous mudstones. This Formation is separated above with Dukanmaje Formation by bone bed with distinct boundary, (1) Sokoto Group; two Formations were analysed. At the base, Dange Formation was studied; it was formed during early Paleocene age and are made up of bluish to dark grey shale and thin beds of fibrous gypsum, fine sandstones and intercalating limestone while at the top, Kalambaina Formation was studied. It is predominantly made up of thick, white limestone bed and at some place it is sandwiched between overlying and underlying shale bed. Structures observed are parallel lamination and mud cracks. Moreover, fossils observed are echinoids, ostracods and bivalves. However, based on the sedimentological analysed results, change in energy regime and fossils present, the environment suggest to be of shallow marine.

Index Terms- Stratigraphy, Sedimentary structures, Gidan Marafa, Late Maastrichtian, Paleocene, Iullemmeden Basin, Wurno Formation Dange Formation, Kalambaina Formation, limestone, shale, gypsum, bioturbation, echinoids, bivalves, depositional cycle, Marine environment, coastal plain sedimentation

I. Introduction

The Iullemmenden Basin is a major Sub-Sahara Inland Basin in West Africa extending about 1000 km north to south and 800 km east to west. It covers western part of Niger, some portion of Algeria, Mali, Benin and Nigeria. It is named after the Iullemmenden, a federation of Tuareg people who live in the central region of Niger. The term Iullemmenden Basin was first proposed by Raider (1957) to describe the sedimentary basin which extends from Mali to western boundary of the Republic of Niger and Northwestern Nigeria into eastern Niger. The Iullemmenden Basin is a Cratonic Basin created by tectonic epiorogenic movement within carbonic rocks (Betrand-Safarti, 1977). Faure (1966), suggested that the emergence of plate tectonic theory and seafloor spreading to explain the origin of Iullemmeden Basin which was affected by series of marine transgressions during the Paleozoic, Mesozoic and Tertiary age respectively. These transgressions progressively affected a great portion of the in a southward direction. This implies that the tertiary marine transgression was the most extensive and covered a considerable portion of the basin. Maastrichtian and Paleocene marine beds outcrop extensively in the Sokoto region of Northwestern Nigeria, Central West Africa and continue northeastward in the neighbouring Niger Republic. The deposits consist of siltstones, shales and organogenic marls were laid down in and around the Saharan Epeiric Sea that flooded the central Sahara during Latest Cretaceous and Early Tertiary times. An embayment of the Saharan sea extended into Sokoto in northwestern Nigeria (Kogbe and Lemoigne 1976; Petters, 1978). The geological map of the Sokoto Basin of northwestern Nigeria (Fig. 1).

II. GEOLOGIC SETTING AND SEDIMENT DEPOSITION

The Iullemmenden Basin seems to have started to subside in Permo-Triassic era and to have experienced gradual down warping during the Upper Cretaceous – Lower Tertiary eras, while steadily filling with sediments. Two prominent fault trends run NNE-SSW through the centre of the basin while, WSW-ENE faults trends are found in the northeast of the basin near the Air Mountains. The sediments from Cambrian to Pleistocene eras are 1,500 to 2,000 meters deep, with alternating layers formed when then basin was undersea and above sea level.

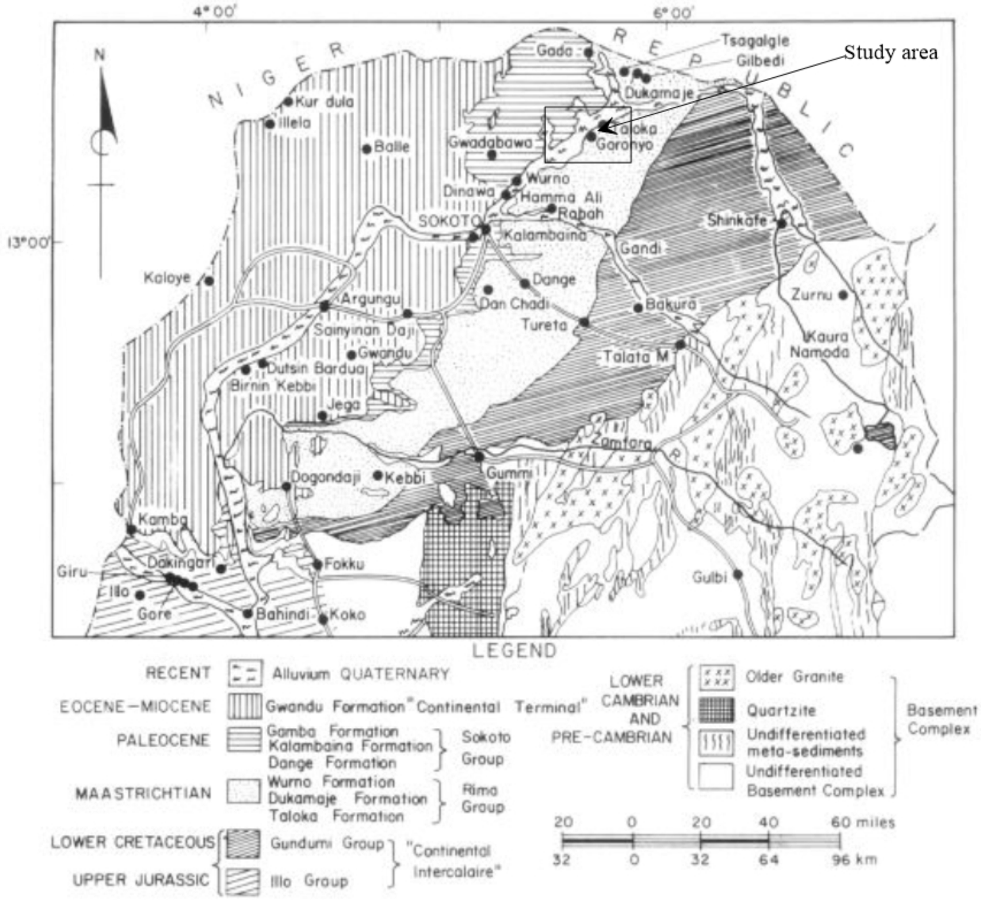


Figure 1: Geological sketch map of the southeastern sector of the Iullemmeden Basin (Sokoto Basin) (After Kogbe, 1981).

The Basin extends over 700,000 km^2 and is bounded to the north by Adrar des iforas the Hoggar and Air range/mountain to the west by Gourma, the liptako and crystalline rocks of the northern boundary of Benin Republic and the Nigeria basement rocks to the south and southeast. The basement is directly overlain by Cambrian beds to the north in the Tesseli and the Hoggar Mountain. As one traverse the basin from the north towards the southwest the formations become younger in age and rest directly on Precambrian basement. This phenomenon is overlap where progressively younger beds rest older series. According to Kogbe, (1979) the Iullemmenden Basin was affected by a series of marine transgressions during the Paleaozoic Mesozoic and Tertiary. The Cenomanian is marine throughout most of the Iullemmenden Basin. It is characterized by the presence of neolobites a well-known Upper Cenomanian Ammonite. The Cenomanian overlies the Tegama Group of sediments uncomfortably and consist of about 100 m of shale sandstone and black fossiliferous limestone. The beds are folded and represent the earliest documented evidence of the first marine transgression in Iullemmenden basin during the Cretaceous. At that time, the Iullemmenden basin was marked by a series of sedimentary cycles resulting from the uplifting of the north eastern margin of the Basin (Greigret, 1966) recognized three transgressions in the Iullemmeden basin during the cretaceous transgression characterized by the abundance of the laower turonian ammonite and the one characterized by the abundance of upper Maastrichtian *ammonite Libycoceras*. Each of the transgression overlap the proceeding one in the upliftment of Air Mountain closed the North-Eastern passage of the sea east of the Hoggar.

Geologic Deposition Sequence of Northwestern Sedimentary Basin

Table 1: Summary of geological sequence in the northwestern Nigeria sedimentary Basin (Kogbe, 1979).

AGE	FORMATION	GROUP	ENVIRONMENT
Quaternary	Sandy drift, laterites	-	Continental
Eocene to Miocene	Gwandu Formation	Continental Terminals	Continental
Paleocene	Gamba Formation Kalambaina Formation Dange Formation	Sokoto Group	Marine

Maastrichtian	Wurno Formation Dukanmaje Formation Taloka Formation	Rima Group	Brackish water with brief intercalation
Lowermost Cretaceous or Older	Illo Formation Gundumi Formation	Continental Intercalaire	Continental
PRECAMBRIAN BASEMENT COMPLEX			

III. METHODOLOGY

This study was undertaken in four stages;

i. Desk study, which involved a detailed review of published and unpublished literature,
ii. Fieldwork and sample collection,
iii. Laboratory analysis,
iv. Processing of data and Compilation

Desk Study

This involved detailed reviewed into the previous work carried out in and around the study area, specifically on Wurno, Kalambaina and Dange Formation respectively by past workers. Relevant materials including topographic base map, journals, textbooks, maps, published and unpublished works were consulted.

Fieldwork

The study area form parts of Rabah Sheets 11. It cover a total area of 13.27 km^2.). It falls within latitude 13^o 27′ 18′ N – 13^o 00′ N and longitude 5^o 30′ E – 5^o 34′ 25′. The fieldwork was conducted during the dry season on 1: 25,000 scale topographic base maps, in order to establish sections and determine sedimentary structures. The geological map was completed using an iterative process of field mapping with the help of surfer 12.0 and Global Mapper 13 softwares. Additionally a systematic logging technique was adopted and this included measuring thicknesses of beds with the help of a measuring tape, location of different lithofacies boundaries across/or along sections with the aid of Global Positioning System (GPS) technology and photography using a digital camera. Samples were collected for hand specimen description and laboratory analysis. Stratigraphic sections were measured in several locations in the study area. The texture, sedimentary structures and bedding contacts were studied and mapping of the area are carried out. Also, samples were collected in the field for petrographic and granulometric analysis respectively.

Laboratory sample preparation and analysis

Analyses of the samples collected were carried out using the following methods;

i. Granulometric analysis.

Granulometric Analysis

Granulometric Analyses (sieve analysis) was carried out on the sandstone samples collected in the field in the sedimentology laboratory, Department of Geology Ahmadu Bello University, Zaria. The primary aim of the sieve analysis was to determine particles size distribution and other grain size parameters such as, inclusive graphic skewness, graphic mean, inclusive graphic standard deviation, and graphic kurtosis. Several samples were selected from different locations for sieve analysis. Samples were carefully disaggregated with the help of pestle and mortar. The weight of the bottom pan, selected empty sieves (2.00 mm, 1.00 mm, 0.5 mm, 0.25 mm, 0.125 mm and 0.063 mm) and 100 g of each disaggregated samples were obtained using a weighing balance. The sieves and the bottom pan were fastened to a mechanical shaker, and the 100 g of the sample poured on the upper sieve. The machine was switched on and allowed to shake for ten (10) minutes. Sediment in each of the sieves and the bottom pan were weighed and recorded. During the course of the sieve analysis care was taken in the separation of the sieves after shaking to avoid spillover of the retained sediments. When disaggregating the samples care was also taken to avoid crushing and grinding in order not to distort the original shape of the grains. The cumulative frequency curves resulting from the analyses are shown in Table 2. The results obtained from the sieve analysis are presented in a tabular form (see Table 3). However, the cumulative frequency curves, critical percentiles (Φ5, Φ16, Φ25, Φ50, Φ75, Φ84 and Φ95) obtained was used for the calculation of grain size parameters such as; graphic mean, sorting (graphic standard deviation), graphic skewness and graphic kurtosis; the results of the parameters for each of the samples are tabulated and shown in Table 2. The formulae for calculating these parameters after Folk and Ward (1957).

IV. FORMULAE TABLE FOR GRAIN SIZE PARAMETERS

Graphic Mean (M)

Mean = $\underline{\Phi16 + \Phi50 + \Phi84/3}$

This is the measure of the average grain size diameter of the sediments. The table below shows the values and corresponding interpretations of the graphic mean according to Folk and Ward (1957).

ϕ scale	Interpretation
- 1.0 to 0.0	Very coarse sand
0.0 to 1.0	Coarse sand
1.0 to 2.0	Medium sand
2.0 to 3.0	Fine sand
3.0 to 4.0	Very fine sand
4.0 to 5.0	Coarse silt.

Graphic Standard Deviation (Sorting) (δ)

$$\text{Standard Deviation } (\sigma) = \frac{\Phi84 - \Phi16}{4} + \frac{\Phi95 - \Phi5}{6.6}$$

This is a measure of degree spread of grain sizes about the mean and corresponds with the standard deviation. The values for sorting and their corresponding interpretations according to Folk and Ward (1957) are given below;

ϕ scale	**Interpretation**
< 0.35	Very well sorted (VWS)
0.35 to 0.50	Well sorted (WS)
0.50 to 0.71	Moderately well sorted (MWS)
0.71 to 1.00	Moderately sorted (MS)
1.00 to 2.00	Poorly sorted (PS)
2.00 to 4.00	Very poorly sorted (VPS)
>4.00	Extremely poorly sorted (EPS)

Graphic Skewness (ski)

$$\text{Skewness (Ski)} = \frac{\Phi84 + \Phi16 - 2\Phi50}{2(\Phi84 - \Phi16)} + \frac{\Phi95 + \Phi5 - 2\Phi50}{2(\Phi95 - \Phi5)}$$

This is a measure of bias in the grain size distribution either towards the coarser or finer grained end of the size range. Positively skewed samples have an excess of fine grains, negatively skewed samples have an excess of coarse grains. The values for skewness and their corresponding interpretations according to Folk and Ward (1957) are given below;

ϕ scale	**Interpretation**
> 0.30	Strongly fine-skewed
0.30 to 0.10	Fine-skewed
0.10 to - 0.10	Near symmetrical
-0.10 to -0.30	Coarse-skewed
> -0.30	Strongly coarse-skewed

Graphic Kurtosis (Kr)

$$\text{Kurtosis (Kr)} = \frac{\Phi95 - \Phi5}{2.44(\Phi75 - \Phi25)}$$

This is a measure of flatness of the grain size distribution as it would appear on a simple frequency curve. Flat distributions are Platykurtic and peak distributions are leptokurtic. The values for kurtosis and their corresponding interpretations according to Folk and Ward (1957) are shown below:

ϕ scale	**Interpretation**
<0.67	Very platykurtic
0.6 to 0.9	Platykurtic
0.9 to 1.11	Mesokurtic
1.11 to 1.50	Leptokurtic
1.50 to 3.00	Very leptokurtic
> 3.00	Extremely leptokurtic

V. RESULTS

The formations studied within Late Maastrichtian to Palaeocene falls under two groups which are as follows; (i) Rima Group; only one formation is available, which is Wurno Formation while, (ii) Sokoto Group; two Formation were studied which are Dange and Kalambaina Formation respectively. Stratigraphic sections were logged and sedimentary structures were observed. The following are the results and interpretation based on age, form older to younger.

VI. WURNO FORMATION

This consist of the oldest sediments in the study area, over 2.2 meters thick was logged (Fig. 2),
Description of section from bottom to top;

They are composed of 0.3 m thick of mudstone pinching eastward (shale), 0.2 m thick of dirty brown of paper shale, 0.4 m thick of intercalating of sandstone with mudstone, 1.2 m thick of fine grained sandstone and 0.1 m thick of ironstone laterite exposed at top. (Pl. 1). It is deeply weathered and gives rise to lowland with flat topography and thick soil cover and underlies most of the study area. Parallel lamination, mudcracks and bioturbation burrows are the dominant structures,

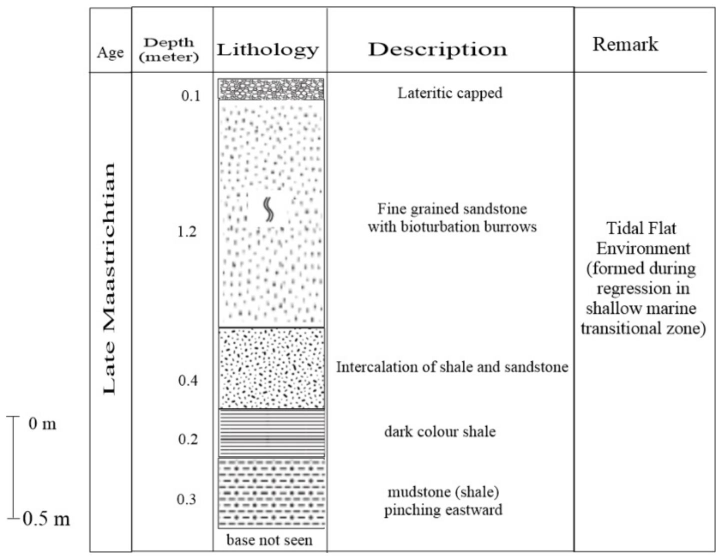


Figure 2: Lithostratigraphic log of Wurno Formation, Rima Group.

Plate I: Wurno Formation, Rima Group, photograph of uneven parallel, fine grained sandstone showing bioturbation burrows.

VII. DANGE FORMATION

This is part of the section of Dange Formation consists of the oldest Palaeocene sediments (Fig. 3). This formation consists of indurated shale as well as finely laminated bluish-grey shale in different places (Pl. II, III).

Description of section from bottom to top;

0.2 m thick of unconsolidated grey limestone bed, 1.2 m thick of bluish-grey mudstone, 0.2 m thick of intercalating mudstone with sandstone, 0.2 m thick of medium to fine grained sandstone, 0.2 m thick of sandstone, 0.6 m thick of dark brown mudstone, 0.1 m thick of yellowish brown sandstone and 0.1 m thick of laterite soil.

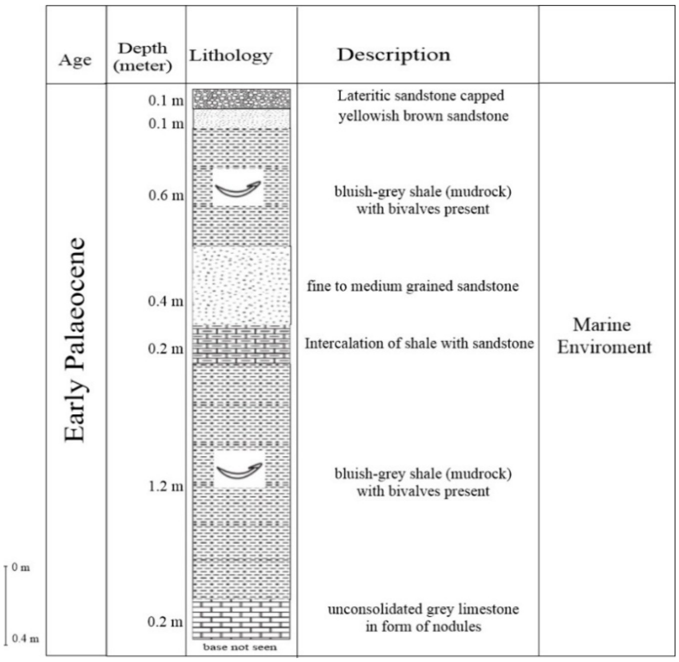


Figure 3: Lithostratigraphic log of Dange Formation, Sokoto Group.

Plate II; Dange Formation, Sokoto Group, photograph showing bluish-grey coloured mudrock (shale) intercalating in between dark coloured mudrock.

The shale include bands of fibrous gypsum with a large number of irregular shaped phosphate nodules. The limestone intercalations are located mostly towards the base of the formation where they occur in few bands which are usually unfossiliferous. However, the fossils are filled with calcareous materials

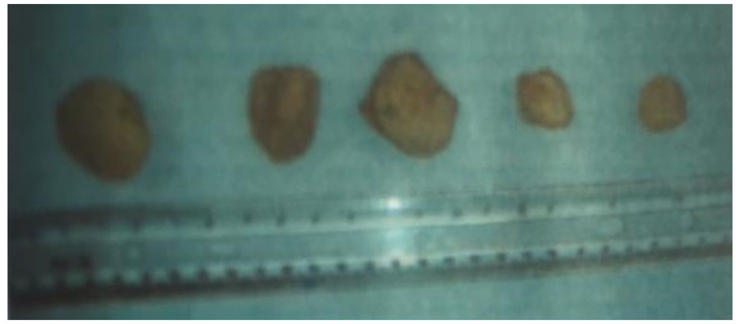


Plate III: Dange Formation, Sokoto Group, photograph of bivalves (*Lucina paraonis*).

VIII. KALAMBAINA FORMATION

This formation is found at different locations but the thickest bed among it was logged, the limestone bed is sandwiched between an overlying and underlying shale bed with fossils present (Fig. 4; Pl. IV, V). This forms the middle part of Palaeocene sediments

Description of section from bottom to top;

0.7 m thick of parallel bedding bluish shale, 0.2 m thick of intercalation of shale and limestone, 0.3 m thick of intercalation of limestone with sandstone, 1.2 m thick of white limestone, 0.1 m thick of intercalation of limestone with shale, 0.3 m thick of grey shale and 0.1 m thick of lateritic material capping the top.

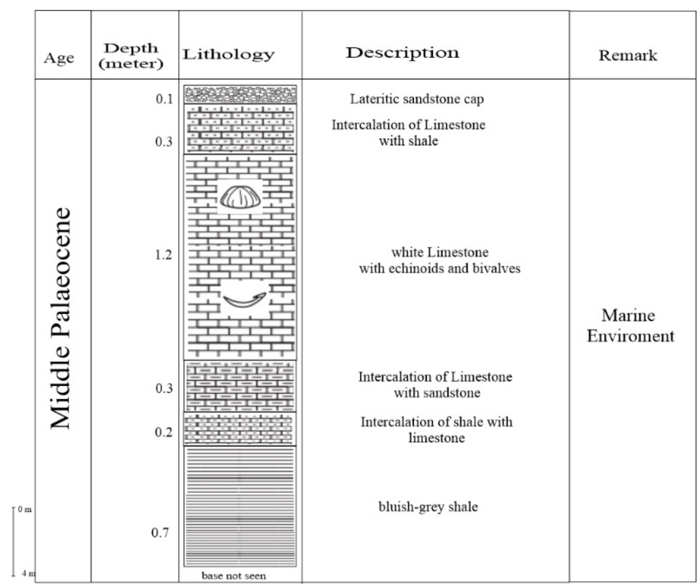


Figure 4: Lithostratigraphic log of Kalambaina Formation, Sokoto Group.

Plate IV: Kalambaina Formation Sokoto Group, Limestone sandstone intercalating with shale

The fossils found are observed along river channels, they are echinoids, bivalves and brachiopods.

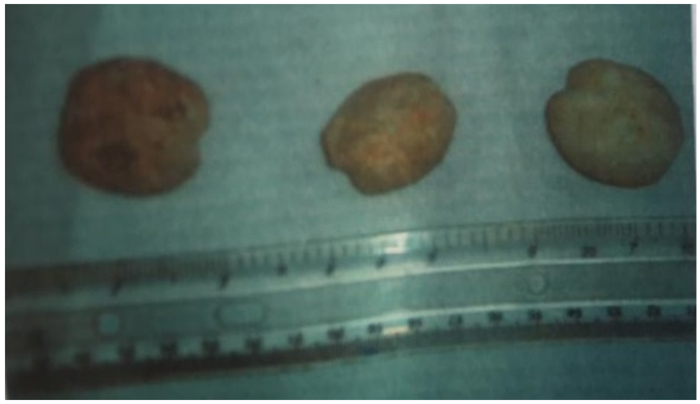


Plate V: Kalambaina Formation, Sokoto Group, photograph of echinoids (*Linthia sudanesis*).

IX. GRANULOMETRIC ANALYSIS

A total of five (5) samples were analysed and the raw data's are tabulated below

Table 2: Cumulative frequency weight distribution of Kalambaina Formation, Sokoto Group.

Sieve Size (mm)	Phi Scale (φ)	Weight of Sieve (g)	Weight of sieve + Sample retained (g)	Weight of Sample (g)	Weight % of Sample Retained	Cumulative Weight %
1.18 mm	- 0.25	347	358.2	11.2	11.2	11.2
600 µm	+ 0.75	349	371.7	22.7	22.7	33.7
300 µm	1.75	367	387.4	20.4	20.4	54.4
150 µm	2.75	325	340.7	15.7	15.7	70
75 µm	3.75	313	336	23.0	23.0	93.2
Pan	> 3.75	301	308.1	7.1	7.1	100
Total				99.9	99.9	

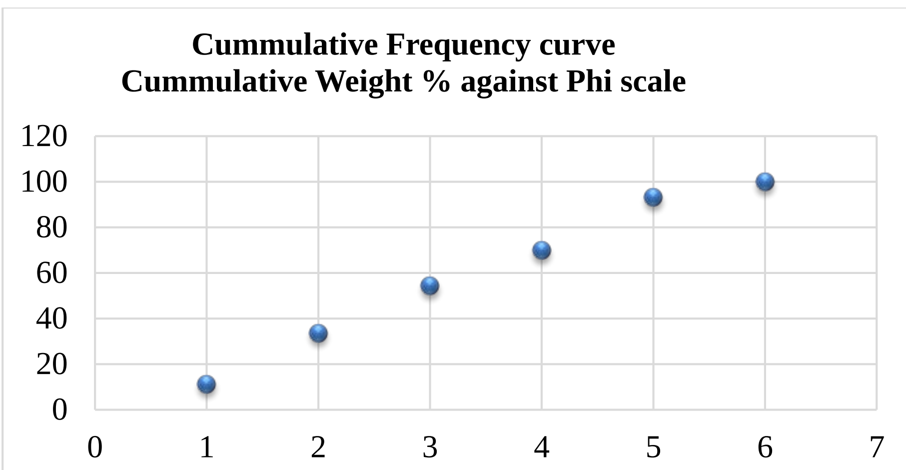


Table 3: Cumulative frequency weight distribution Kalambaina Formation, Sokoto Group.

Sieve Size (mm)	Phi Scale (φ)	Weight of Sieve (g)	Weight of sieve + Sample retained (g)	Weight of Sample (g)	Weight % of Sample Retained	Cumulative Weight %
1.18 mm	- 0.25	347	357.2	9.2	9.2	9.2
600 µm	+ 0.75	349	378	29.0	29.0	38.2
300 µm	1.75	367	388.8	21.8	21.8	60
150 µm	2.75	325	339.5	14.5	14.5	74.5
75 µm	3.75	313	323.2	10.2	10.2	84.7
Pan	> 3.75	301	316.3	15.3	15.3	100
Total				100	100	

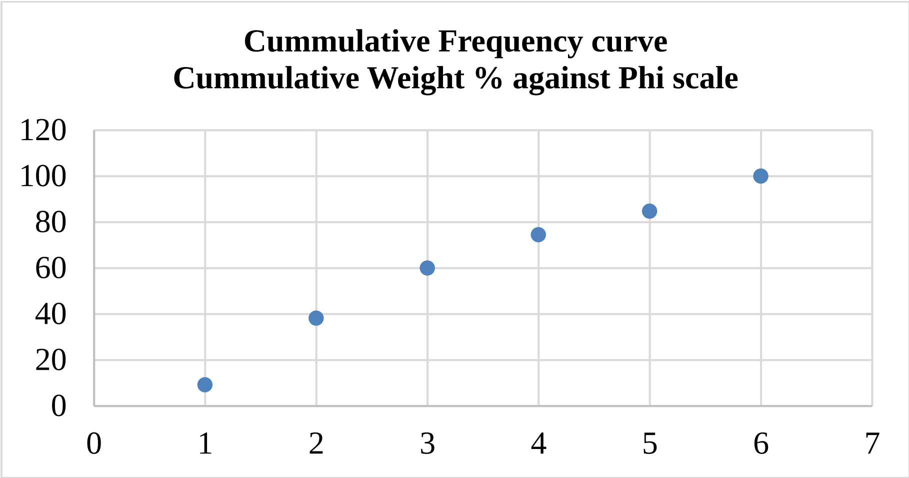


Table 4: Cumulative frequency weight distribution, Kalambaina Formation, Sokoto Group.

Sieve Size (mm)	Phi Scale (φ)	Weight of Sieve (g)	Weight of sieve + Sample retained (g)	Weight of Sample (g)	Weight % of Sample Retained	Cumulative Weight %
1.18 mm	- 0.25	347	352.7	5.7	5.7	5.7
600 µm	+ 0.75	349	373	24	24	29.7
300 µm	1.75	367	389.4	22.4	22.4	52.1
150 µm	2.75	325	340.4	15.4	15.4	67.5
75 µm	3.75	313	327.7	14.7	14.7	82.2
Pan	> 3.75	301	318.8	17.8	17.8	100
Total				100	100	

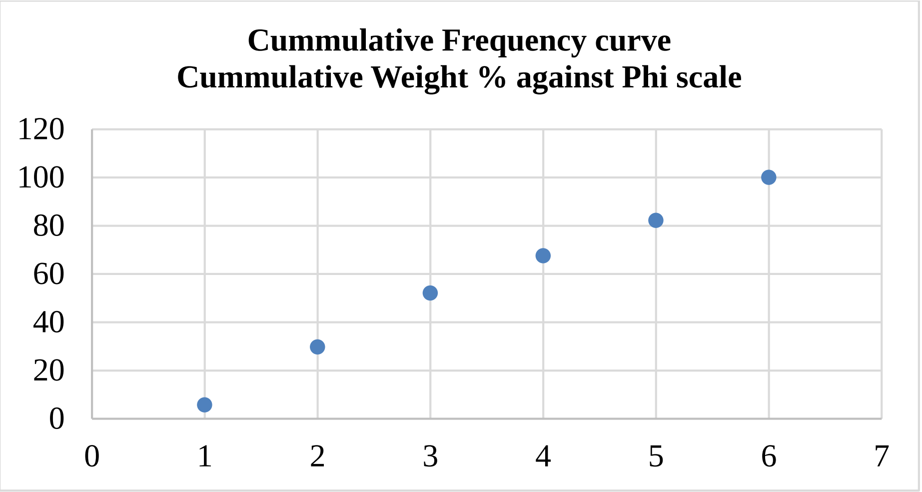


Table 5: Cumulative frequency weight distribution, Kalambaina Formation, Sokoto Group.

Sieve Size (mm)	Phi Scale (φ)	Weight of Sieve (g)	Weight of sieve + Sample retained (g)	Weight of Sample (g)	Weight % of Sample Retained	Cumulative Weight %
1.18 mm	- 0.25	347	354.7	7.7	7.7	7.7
600 µm	+ 0.75	349	369.8	20.8	20.8	28.5
300 µm	1.75	367	386.5	19.5	19.5	48
150 µm	2.75	325	338.6	13.6	13.6	61.6
75 µm	3.75	313	333.2	20.2	20.2	81.8
Pan	> 3.75	301	319.2	18.2	18.2	100
Total				100	100	

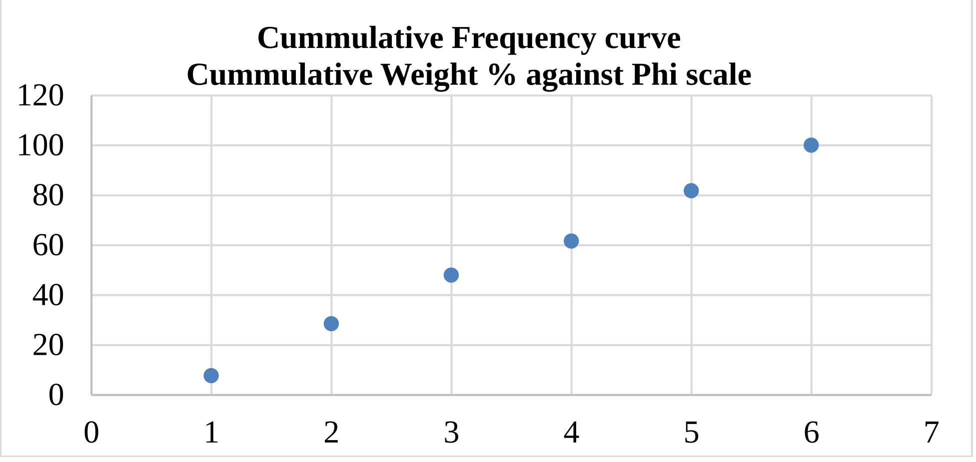
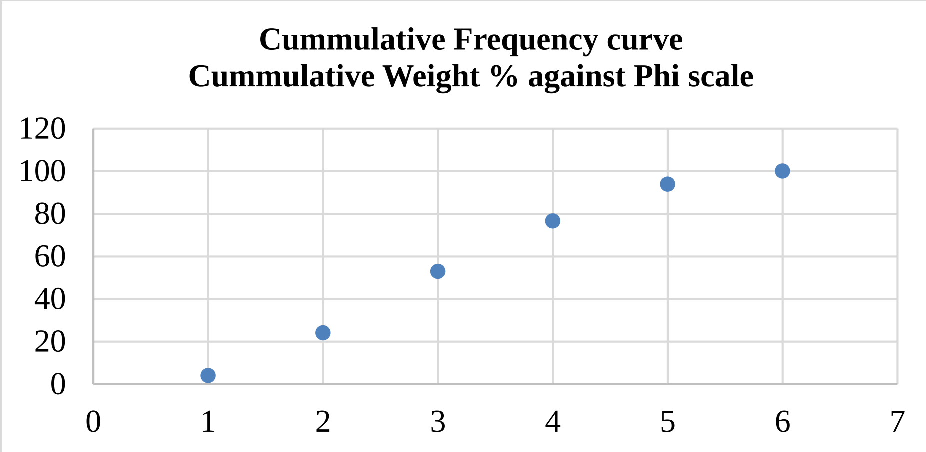


Table 6: Cumulative frequency weight distribution, Kalambaina Formation, Sokoto Group.

Sieve Size (mm)	Phi Scale (φ)	Weight of Sieve (g)	Weight of sieve + Sample retained (g)	Weight of Sample (g)	Weight % of Sample Retained	Cumulative Weight %
1.18 mm	- 0.25	347	351	4	4	4
600 µm	+ 0.75	349	369.1	20.1	20.1	24.1
300 µm	1.75	367	395.8	28.8	28.8	52.9
150 µm	2.75	325	348.7	23.7	23.7	76.6
75 µm	3.75	313	330.3	17.3	17.3	93.9
Pan	> 3.75	301	307.2	6.2	6.2	100
Total				100	100	



X. INTERPRETATION OF RESULTS

Table 7: Summary results obtained from cumulative frequency curve

Sample No.	Φ 5	Φ 16	Φ 25	Φ 50	Φ 75	Φ 84	Φ 95
1	0.1	1.0	1.6	3.0	4.3	4.8	5.4
2	0.1	0.9	1.3	2.9	4.2	4.8	5.7
3	0.2	1.3	1.8	3.2	4.5	5.15	5.7
4	0.3	1.3	1.9	3.2	4.8	5.0	5.8
5	0.4	1.4	1.8	2.7	4.1	4.8	5.8

Table 8: Result of grain size analysed

S.No	Graphic mean (mz)	Sorting	Graphic skewness (ski)	Graphic kurtosis
1	Fine Grained 2.63	Poorly sorted 1.75	Near symmetrical -0.073	Platykurtic 0.81
2	Fine Grained 2.6	Poorly sorted 1.82	Near symmetrical -0.013	Platykurtic 0.79
3	Fine Grained 2.85	Poorly sorted 1.78	Near symmetrical -0.046	Platykurtic 0.80
4	Fine Grained 2.83	Poorly sorted 1.76	Near symmetrical -0.036	Platykurtic 0.78
5	Fine Grained 2.63	Poorly sorted 1.67	Fine skewed +0.192	Platykurtic 0.82

Interpretation of Wurno Formation

This formation is made up of uneven parallel lamination fine grained sandstone that are poorly sorted, near symmetrical skewed and platykurtic with bioturbation burrows which is most vertical and intercalation of sandstone with mudrock. The fine grained indicates low energy regime environment. However, fluctuation of energy regime indicates transitional environment gave rise to the poor sorting morphology. The bioturbation causes destruction or deformation of primary sedimentary structures produced by inorganic agencies (Richter, 1963). The bioturbation structures can be divided into two broad divisions (Schafer, 1956, 1972)

i. Deformative bioturbation structures without any definite form. These appear as formless mottled structures or irregular flecks of different grain size, colour etcetera.
ii. Figurative bioturbation structures which possess definite recognizable forms, such as burrows

The Wurno Formation marks the end of the Late Maastrichtian depositional cycle and a renewed phase of coastal plain sedimentation. Abba (2011), suggested that indicators of tidal are also lack of trace fossils which is found. Based on the sedimentary structures and lamination, the Wurno Formation is of tidal flat depositional environment due to the fact that tidal flat sediment body are elongated parallel to the shore line (Kogbe, 1979). Moreover, Wurno Formation positioned pre and post marine transgression which make it have distinct contact as regressive phase. That is, the Wurno Formation grades into the overlying transgressive Sokoto Group in north-western Nigeria which is equivalent to the Paleocene Adra Doutchi Formation in Niger (Greigert and Pougnet, 1967). Kogbe (1979), described that near the high water line water shed sediments are muddy or clayed while, near the low water line, the sediments are sandy and the wave activity is strongest and active for the longest time as compared to higher parts of the intertidal zone. The ferruginsed laterites are results of sub-aerial exposure and weathering while, lack of body fossils is possibly due to hypersalinity. The cementing mineral are goethite and haematite. The sedimentary structures exhibited by the Taloka and Wurno Formations tend to confirm a tidal flat depositional environment. The most convincing evidence for the tidal-flat environment is the presence of abundant bioturbation structures, the flaser bedding and the wavy bedding (Reineck and Singh, 1973) however, within this study area both flaser and wavy bedding were not seen but occurred in adjacent/opposite places of the same formation (starata). The results above confirm with previous authors that the environment is tidal flat.

Interpretation of Dange and Kalambaina Formation

The formations found in Sokoto Group (Dange and Kalambaina Formations) are composed of bluish shale, fine grained sandstone, thin lens of gypsum, intercalation of shale and sandstone. The Dange Formation are made up of blue –dark brown shale, fine grained sandstone, lenses of gypsum with macro fossil of bivalves found (*Linthia Sudanesis*), the gypsum is formed during precipitation and the presence of coproliths, gypsum, as well as the remains of molluscs (lamellibranchs) in the conglomeratic bed, suggests that the base of the Dange Formation must have been affected by erosion. The siliceous and arenaceous underlying Wurno Formation also suffered considerable erosion and hence the top of the formation is absent. This erosional horizon now constitutes the Cretaceous-Tertiary boundary in this part of the Iullemmeden Basin. The intensiveness of the erosion is indicated by the absence of lower Paleocene beds in the basin (Kogbe, 1981) while Kalambaina Formation are made up of limestone, shale and intercalation of shale with limestone, bivalves, brachiopods and echinoids (*Lucina paraonis*) are observed. However, at the top of both formation they are capped by ferruginised laterites and their contact is not established. In Dange Formation the variation of colour of shale from bluish-grey to brown are as a result of changes in environment from oxic to anoxic environment. The shale are enriched with high contents of micro fossils. The Limestone results from deposits resulted by precipitated calcareous materials (marl) in marine environment which occurred during the transgression in Maastrichtian that contains high amount of micro and micro fossils. As was noted in the by several authors such as ((Sujkowski 1958; Hallam 1964; Duff *et al*. 1967)), the process of formation of limestone/marl alternations as well as their ultimate cause is still unresolved. Part of the controversy has stemmed from the recognition that the lithologic contrast between limestone and marl originated from post depositional dissolution and reprecipitation of carbonate, termed *diagenetic unmixing*, These fossils forms the basis for dating in Palaeocene. Kogbe (1979), described that during the Maastrichtian the Tethys Sea extended to the southern of the interior of western Africa, this resulted in the deposition of evaporate-bearing shales. In conclusion, Dange Formation was definitely deposited during the Palaeocene transgression (Kogbe *et al*; 1972). Furon (1934) suggested that there was a major transgression during the Late Cretaceous, when the Mediterranean Sea was linked with southern Nigeria through a zone extending between the Hoggar and the Tibesti. He remarked that the same link was re-established at the beginning of the Eocene. This latter transgression corresponds to the great Paleocene transgression recorded in Libya by Haynes (1962) (see Figure 19). Other workers (Reyre, 1966; Reyment, 1965; Adegoke, 1969; Kogbe, 1976; Blondeau, 1976; etc.) similarly believe that there was a merger of the Tethys and Guinea seas via the Niger Valley during the Maastrichtian, as well as the Paleocene. Opinions differ, however, on the actual relationship between these two transgressions. Adeleye (1975) suggested a Maastrichtian merger rather than a Paleocene one, and some workers believe that there was a continuous transgression from Maastrichtian to Paleocene with probably only a slight interruption (see Kogbe, 1976, 1979 and 1981). The microfaunal assemblage of Dange and Kalambaina Formation respectively in the Palaeocene clay-shales and limestone is indicative of tropical shallow water marine or probably estuarine condition (Reyment, 1965). This also confirmed to previous author that both Dange and Kalambaina Formations are marine in origin.

XI. SUMMARY AND CONCLUSION

The stratigraphy and structure of Late Maastrichtian to Paleocene sediments of part of Southwestern Iullemmenden Basin in Rabah Sheet 11 comprises of two groups, they are Rima Group and Sokoto Group. Rima group contain the last formation which is Wurno Formation (Late Maastrichtian), and Sokoto Group conatains two formation which are Dange Formation (Early Palaeocene) and Kalambaina Formation (Middle Palaeocene). The following and summary was drawn:

1. The Late Maastrichtian sediments is found to be Wurno Formation and are made up of uneven parallel lamination fine grained sandstone that are poorly sorted, near symmetrical skewed and platykurtic with bioturbation burrows which is most vertical and intercalation of sandstone with mudrock,
2. The formation marks the end of the Late Maastrichtian depositional cycle and a renewed phase of coastal plain sedimentation,
3. The Wurno Formation is of Tidal flat environment,
4. The Early Paleaocene sediments is found to be Dange Formation which are made up of blue –dark brown shale, fine grained sandstone, lenses of gypsum with macro fossil of bivalves found (*Linthia Sudanesis*), the presence of gypsum which is formed during precipitation suggests marine environment,
5. The Middle Paleaocene sediment ai found to be Kalambaina Formation and are made up of limestone, shale and intercalation of shale with limestone, bivalves, brachiopods and echinoids (*Lucina paraonis*) are observed
6. The bluish to grey colouration of the shale are as a result of high contents of micro fossils indicating anoxic environment.
7. The Limestone deposits are as results of precipitated calcareous materials (marl) in marine environment which

was due to transgression in Maastrichtian that contains high amount of micro and micro fossils,

8. The microfaunal assemblage of Dange and Kalambaina Formations in the Palaeocene clay-shales and limestone are indicative of tropical shallow water marine or probably estuarine condition and

The Dange and Kalambaina Formations are of Marine environment.

REFERENCES

[1] Abba S. (2011). Geology of Gidan Marafa and Environs, Rabah Sheet 11 Sokoto State, Northwestern Nigeria. Unpublished B.Sc. Project, Department of Geology, Ahmadu Bello University, Zaria

[2] Adegoke, O. (1969). The Eocene stratigraphy of southern Nigeria. *Bulletin Bureau de Recherches Geologique et Minieres. Memoire* No. 69, 23-28.

[3] Adeleye, D. R. (1975). Nigerian late Cretaceous stratigraphy and Paleography. *Bulletin of the American Association of Petroleum Geologists,* 59, (12) 2303-2313 (5 figures).

[4] Betrand-Safarti, J., Moussine-Pauchikne, A and Fabre, J. (1977). Geodynamique des aires sedimentaraires cratoniques. Quelques exemple sahariens. *Bulletin de Centre de Recherches et Exploration d'Elf-Aquitaine* 1, (i0 217-231.

[5] Blondeau, A. (1976). Paleogene geology of Africa. *Proceeding of the 7th African Micropalentological Colloqium,* Ile-Ife, Nigeria (in press).

[6] Duff, P. McL. D., Hallam,A., and Walton, E. K., 1967, Cyclic Sedimentation, Developments in Sedimentology, v. 10: New York, Elsevier, 280 p.

[7] Folk, R. L. and Ward, W. C. (1957). A study of the significance of grain size parameters, Journal of Sedimentary Petrology, 27 pp.

[8] Faure, H. (1966). Reconnaissance geologique des formations sedimentaires post-paleozoiques du Niger Oriental. Memoire Bureau de Recherches GPologiqnes et Mini&es France 47, 626 pp.

[9] Furon, R. (1934). Le Cretace et Ie Tertiaire du Sahara soudanais (Soudan, Niger, Tchad). Memoire Bureau de Recherches Giologiques et MiniPres, France 29 et Publication Direction des Mines et Gbologie, Rkpublique de Niger IL'o. 1; Archives du iLlus& Nationale d'Histoire Naturelle Paris, SPrie 6 13, l-96, 1935.

[10] Greigrert, J. (1966). Formations Cretace et Tertiares du basin des Iullemmenden (Afrique Occidentale). *Direction des Mines et de la Geologie, Republique du Niger; Publication No 2*, Editions du Bureau de Recherche Geologiques et Minieres. 234 pp.

[11] Greigret, J, and Pougnet, R. (1965). Carte geologique de la Republique du Niger au 1:2,000.000 et notice explicative.

[12] Hallam, A., (1964), Origin of the limestone-shale rhythms in the Blue Lias of England: a composite theory: Jour. Geol., v. 72, p. 157-169.

[13] Haynes, J. (1962). *Operulina* and associated Foramifera from the Paleocene of the NE-Fezzan Libya. *Contribution to Cushman Foundation for Foraminiferal Research* **XIII,** (3) 90-97.

[14] Kogbe, C. A. (1976). Paleogeographic history of Nigeria from Albian times. In Geology of Nigeria (Edited by C. A. Kogbe). Lagos, Nigeria: Elizabethan Publishing.

[15] Koghe, C. A. (1979). Geology of the southeastern (Sokoto) Sector of the Iullemmeden basin. Bulletin Department of Geology, Ahmadu Belle University, Zaria, Nigeria. 2, (1) 420 pp.

[16] Kogbe C. A. (1981). Cretaceous and Tertiary of the Iullemmeden Basin in Nigeria (West Africa) Department of Geology, Ahmadu Belle University, Zaria, Nigeria, *Cretaceous Research* 2, 129-186.

[17] Kogbe, C. A. and Lemoigne, Y. (1972). Bois en structures conservees de Mesozoi'que et Cenozoi'que de I' Afrique Occidentale (Nigeria et Niger). Revista Espan'ola de Micropaleontologid, ser. 7 3,505-521.

[18] Koghe. C. A. and.I,emoigne, Y. (1976). In Press. Fossil wood from the Gundumi and Illo Formations ("Con- tinental Intercalaire") of northwestern Nigeria. Proceedings 13th African Micropaleontoiogical Colloquium, Ile-Ife, Nigeria.

[19] Petters, S. W. (1978). H'laastrichtian-Paleocene Foraminifera from NW Nigeria and their paleo- geography. ilcta Palaeontologica Polonica 23, 131-152.

[20] Radier, H. 1(957). Contribution a l'etude gtologique du Soudan Oriental (A.O.F.). Thise FacultP Sciences UnizersitP Strasbourg, 3 tomes.

[21] Reineck, H. E. and Singh, I. B. (1973). Depositional Sedimentary Bncironments. Berlin, Heidelberg, New York: Springer Verlag.

[22] Reyment, R. A. (1965). Aspects of the Geology of Nigeria. Ibadan: Ibadan University Press.

[23] Reyre, D. (1966). Particularites geologiques des Bassins Cotiers de 1'Ouest Africain (essai de recapitu- lation). Bassins SPdimentaires du I,itoral Africain Partie Atlantique Association de Services Gholo,giques ilfricains, Paris.

[24] Richer, R., (1963). Marken und Spuren im Hansruckschiefer Schichtung und Grundleben. *Senckenbergiana* 18 pp. 215-244.

[25] Schafer, W. (1956). Wirkungen der Benthos-Organismen auf den jungen Schicchtverband Senckenbergiana. *Lethaea* 37 pp. 183-263.

[26] Schafer, W. (1972). Ecology and Paleoecology of marine environments. 538 pp. Edinburgh: Oliver and Boyd.

[27] SuJKowski Z. L., (195). Diagenesis: Am. Assoc. Petrol. Geol. Bull., v. 42, p. 2692-2717.

AUTHORS

First Author – Sulaiman, Sulaiman Abba, Department of Geology, Ahmadu Bello University, Zaria, Email: ssabba12@gmail.com
Second Author – Mohammed Rilwan, Nigerian Institute for Oceanography and Marine Research, Lagos