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Petrography and Paleoenvironmental Interpretation of Taloka and Dukamaje Formations, Southern Gadon Mata, Goronyo, Sokoto Basin-Nigeria

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Abstract

Petrographic study of the various rock units from Gadon Mata area of Goronyo in Sokoto Basin was carried out. Sedimentary structures were used for Paleoenvironmental Interpretation of Taloka and Dukamaje Formations from Sokoto Basin-Nigeria. The two formations which forms part of Rabah Sheet 11NE lies in the southeastern sector of the Iullemmeden Basin. The study area is bounded by latitudes 13^{0}18'38"N to 13^{0}21'58"N and longitudes 5^{0}47'47"E to 5^{0}50'35"E covering 30Km^{2}. The mapping exercise was carried out using a topographic base map on the scale of 1:30,000.

The area is made up of Maastrichtian sediments-Taloka and Dukamaje Formations. Taloka Formation is of deltaic/brackish water environment and is made up of white, grey, brown siltstones, friable sandstones, claystones and biogenic structures. It is of tidal flat depositional environment as confirmed by sedimentary structures like abundant bioturbation, rhythmic bedding and the wavy beddings. The Dukamaje Formation is of marginal marine environment comprising of shales, limestones and mudstones with vertebrate fragments. The abundance of mudcrack can be useful in the interpretation of paleoclimate as they are common in warmer climates. Similarly, while the calcite crystals exhibiting spherulitic texture observed in the thin section implies deposition in shallow agitated marine water of the Dukamaje Formation.

Keywords: Petrographic, Sedimentary structures, Paleoenvironmental, Taloka, Dukamaje, Formation, Iullemmeden.

1. Introduction

The Iullemmeden Basin is entirely a cratonic basin created by tectonic epirogenic movements or stretching and rifting of tectonically stabilized crust during the Palaeozoic (Bertrand-Safarti, 1977). These movements become evident from the beginning of Palaeozoic and continued until the Upper Cretaceous when the opening of the Goa Trench was achieved (Faure, H., 1996). The basin located in central West Africa is a sedimentary basin shared over about 95% of its surface area located in the semi arid environments of the three contiguous countries – Nigeria, Niger and Mali (Fig. 1). It covers an area of 620,000 km^{2} and consists of Sedimentary deposits. The Iullemmeden Basin is one of three important sub-Saharan inland basins consisting of a broad syncline with gently dipping flanks. The overlying sedimentary sequences become progressively younger from the northeast to the southwest, indicating the directions of successive Cretaceous marine transgressions (Kogbe, 1991). The Iullemmeden basin in north western Nigeria is known locally as the Sokoto basin where about 63,000km^{2} of it occurs, which covers the States of Kebbi, Sokoto, Zamfara and parts of Katsina and lies between longitudes 3^{o}40’E and 8^{o}E and latitudes 10^{o}30’N and 14^{o}N. Studies based on the outcrops as well as some borehole material (Kogbe 1972, 1976b Kogbe et al., 1976; Petters, 1979) have led to the erection of its Cretaceous and Tertiary Stratigraphy. Although the Sokoto Basin of Nigeria appears extensive in area extent, it only represents about one-tenth of the entire Iullemmeden Basin of West Africa (Greigert 1961). Overlying the Precambrian basement unconformably, the Illo and Gundumi Formations lies overlain unconformably by the Maastrichtian Rima Group, separated by fossiliferous shally Dukamaje Formation. The Paleocene Dange and Gamba Formation (mainly shales) are separated by calcareous Kalambaina Formation. The overlying Gwandu Formation (Continental Terminal) is of Tertiary age. These sediments dip gently and thicken gradually towards the north-west, with a maximum thickness of over 1,000 meters near the frontier of the Nigeria-Niger Republic (Kogbe, 1976). Thus the detailed geology and Stratigraphy of the Sokoto Basin (Figure 1) are well documented in the works of Kogbe (1972, 1974, 1979); Adeleye (1975); Okosun (1989, 1995); Haynes and Nwabuafo-ene (1998) and Obiosio et al. (1998).

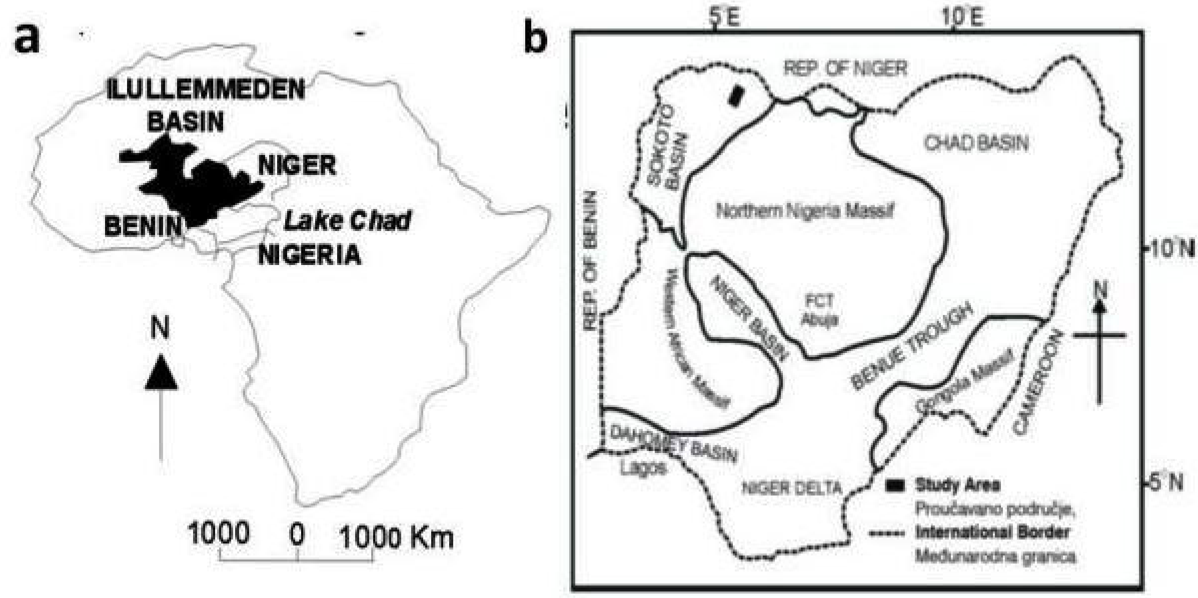

Figure 1: Maps of Africa (a) and Nigeria (b) showing the location of Iullemmeden Basin and Sokoto Basin respectively

2. Field Description and Stratigraphy

The geology of the study area is composed mainly of sedimentary deposits. Two distinct formations were observed; the Taloka and Dukamaje Formations. Laterite and alluvium were also observed. Descriptions of all geologic observations undertaken in the field are discussed below including lithostratigraphic studies and sedimentary structures.

The distribution of the various formations is as shown in Figure 2 while some of the sections from Taloka and Dukamaje formations are presented in figures 3 and 4.

2.1 Taloka Formation

The section of Taloka Formation is on a hill that forms part of a continuous exposed ridge at various locations in the study area. These beds disintegrate rapidly on exposure and the base of the ridges mostly covered by a layer of overburden as shown at locations (L_{48}, L_{42}, and L_{52}). About 90% of the area of study is entirely of Taloka Formation as seen in Figure 2.

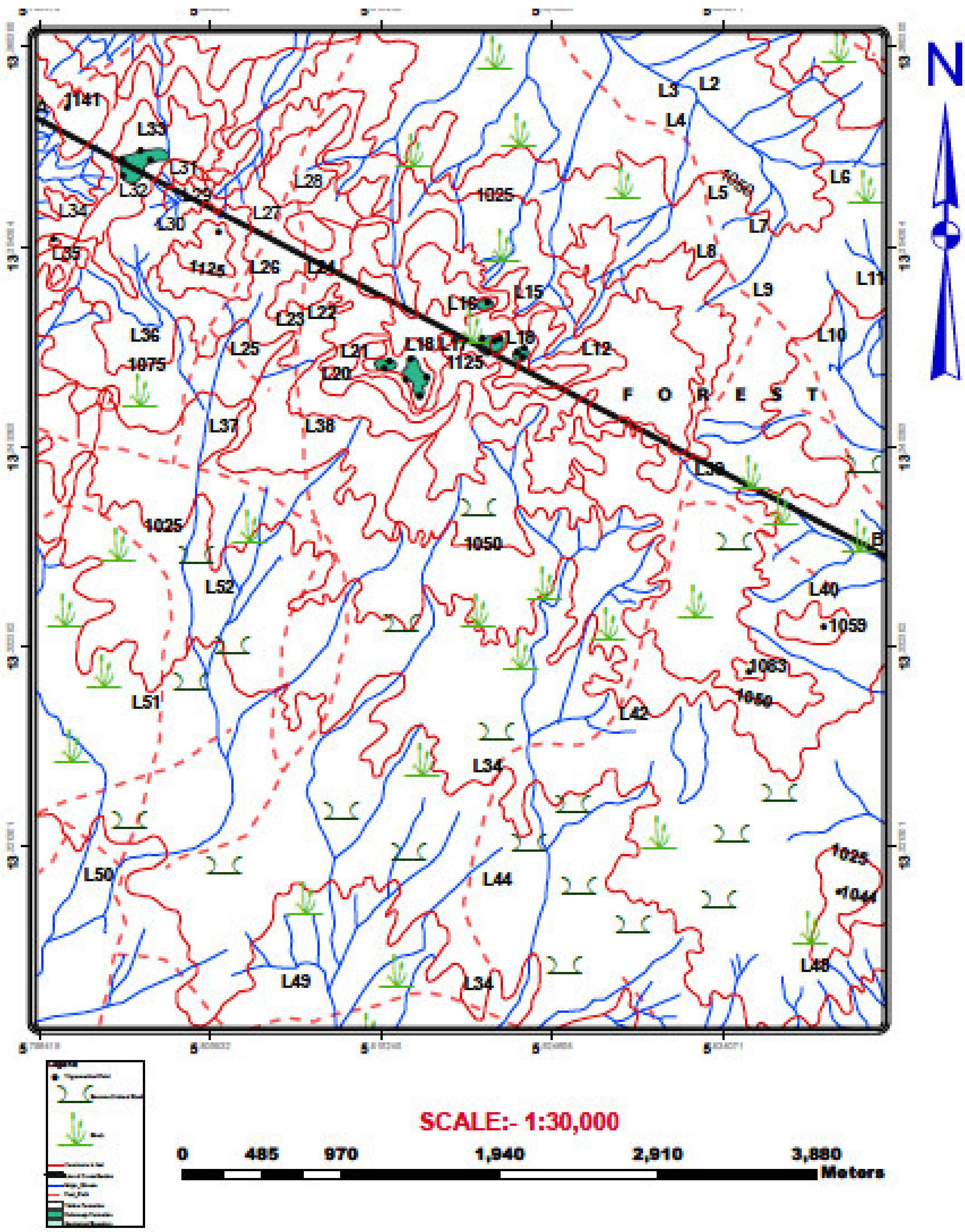

Figure 2: Map of Southern Gadon Mata, Rabah sheet 11NE, Sokoto State- Nigeria showing locations of Taloka and Dukamaje formations.

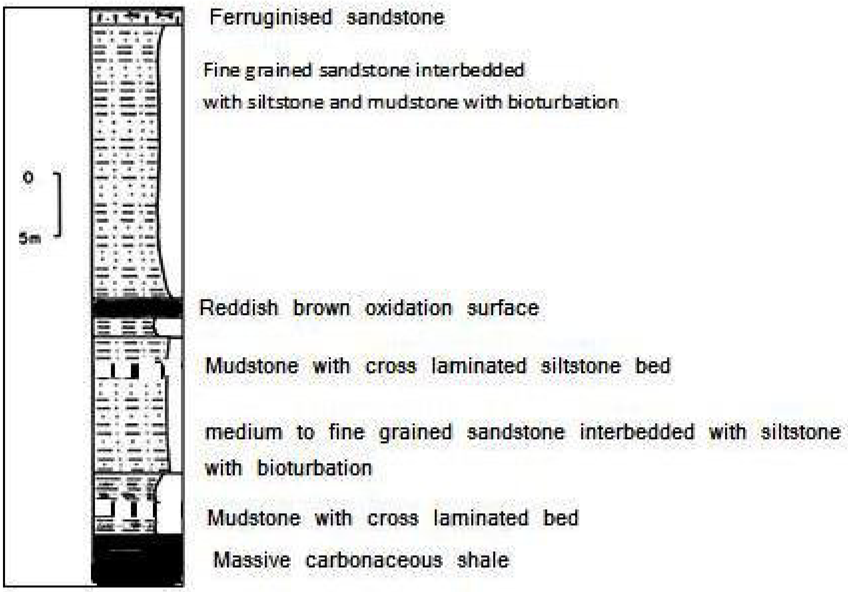

Figure 3: Stratigraphic section of the Taloka Formation

Figure 3c: Alternating thin beds of siltstone with plant remains

2.1.1. Lithologic Description of Outcrop Sections in Taloka Formation

- **Locality-L_{30}, L_{31}, L_{41}, L_{52}, L_{47}, L_{49}**

The section described is at southern Gadon Mata, Goronyo Local Government and has the following sequence (Figure 3). Table 1 and Figure 3 section was observed at locations (L_{30}, L_{31}, L_{41}, L_{47}) in the study area, the base of the fully exposed sections consist of massive carbonaceous shale, reddish grey to purple silty clay with abundant bioturbation. Also, individual beds vary in thickness from a few millimeters to few centimeters. Presence of oxidation surface was noticed separating the reddish grey to purple silty clay from red siltstone. Also, presence of ferruginised sandstone with well bedded silty clay with intercalation was observed at L_{30}, Taloka Formation (Plate 1).

- **Locality L_{42}, L_{48}**

The Taloka Formation is being exposed as a result of gully erosion as seen in figure 3c. The base of formation consists of rapidly alternating thin beds of silty shales with plant remains and fine to medium grained sandstones with some intercalated thin flaggy ironstones.

Table 1: Stratigraphic section of the Taloka Formation

THICKNESS (m)	**LITHOLOGIC DESCRIPTION**
0-3	Ferruginised sandstone (top sequence)
3-18	well bedded fine grained sandstone interbedded with siltstone and mudstone with bioturbation
18-18.5	Reddish brown oxidation surface
18.5- 23.5	Fine grained sandstone interbedded with mudstone with abundant bioturbation
23.5-24	Reddish brown oxidation surface
24- 31	Fine grained sandstone interbedded with siltstone
31-34	Mudstone with cross laminated siltstone beds
34-40	Massive carbonaceous shale (bottom, not seen)

Thus the lithofacies recognized in Taloka Formation can broadly be described in two groups; macroscopically and microscopically as follows;

i) Sandstone

Hand specimen: It appears light brown to grayish with alternating of yellow to brownish claystone. It ranges from medium to fine grained with average diameter of 1/16mm to 2mm. It exhibits reverse grading. It does not contain fossils because the energetic environments where sand beds form do not favour their preservation.

Thin Section: The grains appear equigranular. The interstitial cement seen is quartz (SiO_2). Minerals present include quartz, muscovite. Accessory mineral is zircon. Also, grains are well sorted as observed in Plate 4.

a) Quartz: The quartz occurs as colorless anhedral crystal with no alteration. It has wavy extinction with no cleavage. About 58% of the sandstone is quartz.
b) Feldspar: Orthoclase feldspar was seen which occurs as dark green under plane polarized light with high interference color of pink to bluish under crossed polarized light. It makes up of about 40% of the rock sample.
c) Zircon: Zircon is dark under plane and crossed polarized light (Isotropic) and it makes up of about 2% rock sample (Plate 4).

ii) Siltstone

It appears grayish with white patches. It is gritty and occurs as thin lamination. The field test for siltstone is that individual grain sizes are invisible but you can feel them by rubbing on the hand. It is fine grained as observed in figure 3, 3c, Plate 1 and 2.

iii) Mudstone

It appears grayish brown in color. It is gritty and formed as a result of consolidation of clayey particles (Plate 2).

Plate1: Bedded silty clay with intercalation of yellowish siltstone with abundant bioturbation at Taloka Formation

Plate 2: Mudstone with cross laminated grayish with white patches siltstone beds at Taloka Formation

iv) Oxidation surfaces

It appears reddish brown which is intercalated between well bedded silty clay and siltstone. A band of oxidation surface, 0.30m thick is seen at location (L_{30}) and figure 3.

v) Shale

It has fine grained texture with grey to brownish color. It is formed largely by the hardening of clay size and silt size particles occurring as massive carbonaceous shale of 7m as seen at locations (L_{30}, L_{49}) of figure 3, table 1.

vi) Ferruginised Sandstone

Hand specimen: The Ferruginised sandstone sample is coarse grained. Ooids are clearly visible, appearing reddish brown.

Thin section: The ferruginous oolites are spherical in shape. The concentric shells consist of nucleus at the centre having quartz materials, fragments of pre-existing oolites. The iron content type seen is goethite. Also, the oolites are embedded in a matrix of silty clay impregnated by iron oxide (Plate 4).

vii) Taloka Lignite Occurrence and its Palaeoenvironmental Significance

Lignite beds were observed in Gilbedi, upper beds of Taloka Formation ranging in thickness up to 1m extending laterally to considerable dimension. Lignite presence is of special environmental significance as it confirms the paralic nature of the depositional environments during the Maastrichtian in the Iullemmeden basin. During the upper Maastrichtian, the sea encroached the Iullemmeden basin and the Taloka Formation represents the coastal plain sands and clays of the encroaching Maastrichtian Sea.

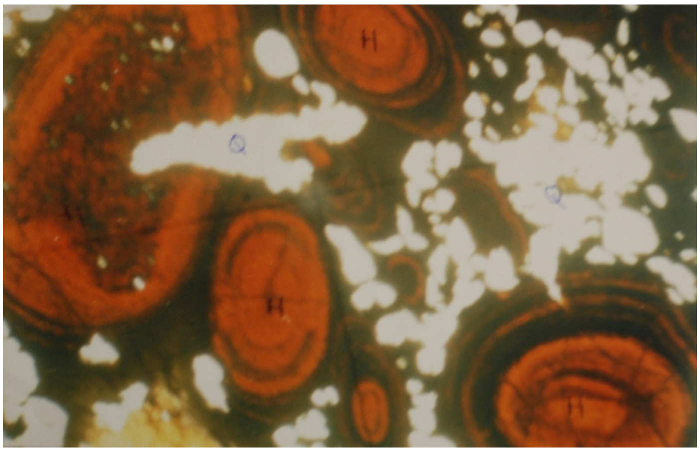

Plate 3: Photomicrograph of oolitic ironstone (concentric) under plane polarized light at location L_{23}, Taloka Formation. Minerals present are mostly Haematite (H) and quartz (Q). Magnification X 30

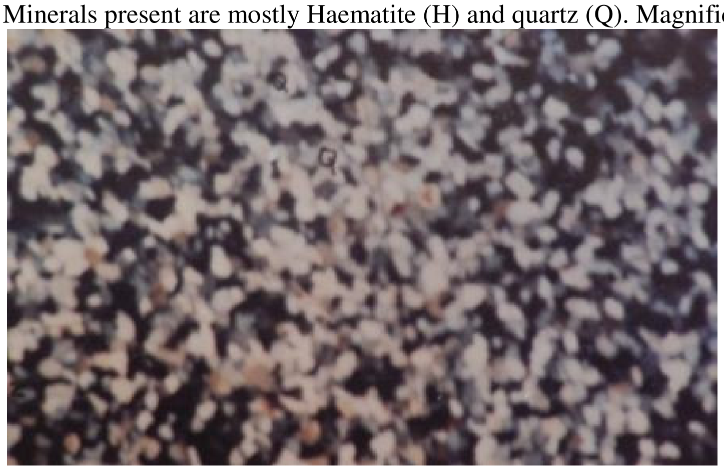

Plate 4: Photomicrograph of sandstone (equigranular) under crossed polarized light location L42. Minerals are mostly quartz (Q), Feldspar (F) and zircon (accessory mineral).

viii) Superficial deposit

It was observed at the southern portion of the study area at locations (L_{43}, L_5) along river channels. It consists of top layer of brown to yellow silt clays, a middle horizon of grey or white silty clays. It usually forms as a result of erosion and weathering of the Taloka Formation.

2.2. Dukamaje Formation

The Dukamaje Formation (Figure 4) was observed at locations (L_{14}, L_{18}, and L_{33}). It consists predominantly of shales, limestones, and mudstone. The shales observed at location (L_{32}) contains some fragments of vertebrae as seen in plate 7. Limestones, bone bed, gypsum observed described as follows;

- **Locality-L_{13}, L_{14}, L_{16}, L_{18}, L_{33}, L_{34}**

The Dukamaje Formation was observed in the study area and has the following sequence. It consists of shale with plant remains at the bottom followed by grey gypsiferous bone bed. Above the fine grained unconsolidated sandstone lies dark grey shale (Figure 4).

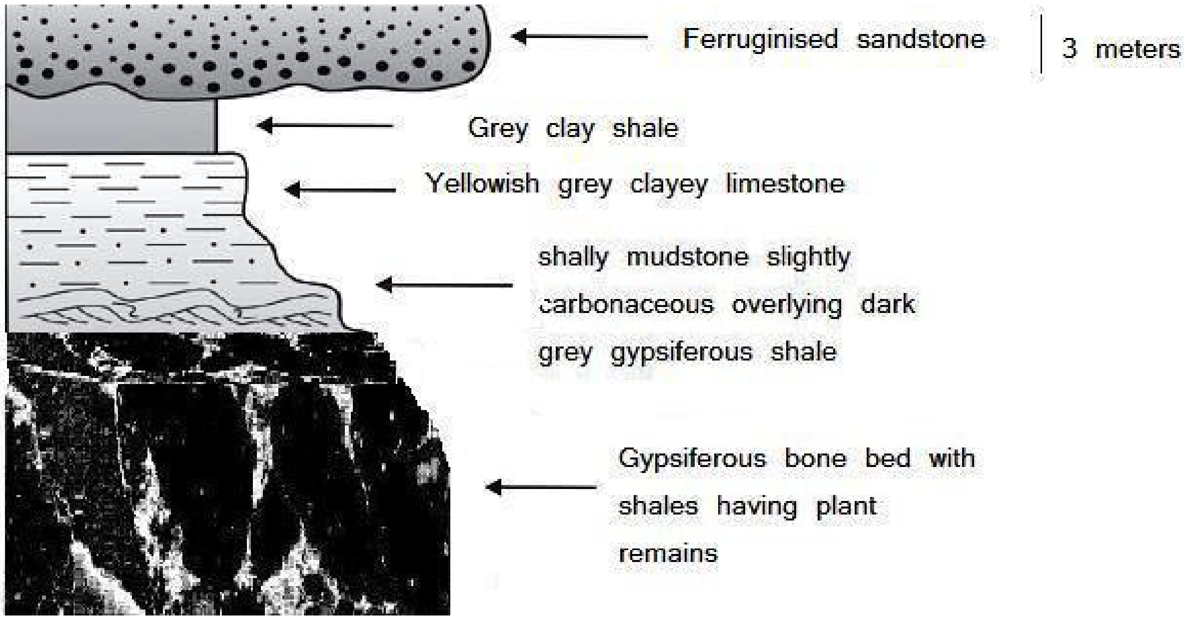

Figure 4: Section through Upper Cretaceous Dukamaje Formation

i) Limestone

Hand specimen: The rock is medium to coarse grained. It is pale yellow to grayish in color as observed in plate 5 below.

Thin section: The rock contains medium to coarse grained crystals of calcite and dolomite which are highly fractured (Plate 6). Most of the calcite grains exhibit spherulitic textures appearing colorless under plane polarized light, pale green to purple under crossed polarized light. It is made up of about 55% of the rock sample. Dolomite appears as greenish grey, angular to sub angular crystals. It is made up of about 45% of the rock sample.

Depositional environment

The calcite crystals exhibiting spherulitic texture observed in the thin section; implies deposition in shallow agitated marine water. The predominance of sub angular to angular calcite grains in the rock suggests a moderate distance of transportation.

i) Vertebrae bone

Vertebrate bone collected from the area of study is identified as fossilized reptilian limb bone (Plate 7). The preservation of the bones is due to the protection provided by the shales.

ii) Gypsum

Occurrence of gypsum as discontinuous state was observed at location L_{33}, figure 4. This indicates that the gypsum is of diagenetic origin.

iii) Shales

They are consolidated mudstones, fine grained texture which is grayish in color as observed in figure 4 below.

Plate 5: An impure limestone at location L_{33}; $13^{0}20'970''$ N, $5^{0}97'35''$ E, Dukamaje Formation

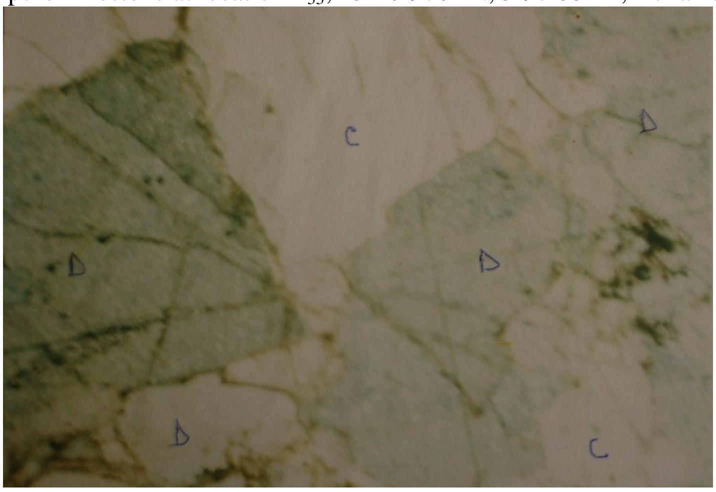

Plate 6: Photomicrograph of limestone (radiating habit) under crossed polarized light at location L_{14}. Minerals are mostly calcite (C) and dolomite (D). Magnification X 30

Plate 7: A fossilized reptilian bone protected by the shales at location L_{33}
$13^{0}20'$ $970''$ N, $5^{0}47'35''$E, Dukamaje Formation about 11cm wide

Plate 8: Ferruginised sandstone at location L_{13} at Dukamaje Formation affected by bioturbation burrows

Plate 9: Mudcrack at location L_{34} covering about 50 meters of the Dukamaje Formation

3. Sedimentary Structures and Paleoenvironmental Interpretation

Sedimentary Structures: Sedimentary structures were observed in well exposed outcrops of Taloka and Dukamaje formations. They have been found to provide information about their sedimentary history.

- **Bedding**: This is a term signifying the existence of layering in the sedimentary rocks. They are common in the various locations of the mapped area.
- **Reverse Grading**: This is a gradational decline in grain size downwards. In other words coarse grains appear at the top, and then medium grained and finally fine grained below (coarsening upwards). They are most common in the sandstone.
- **Rhythmic Bedding:** This is a definite cyclic type of sedimentation. It consists of alternations of repeated clay-siltstones and siltstone. In several outcrops the cyclic sedimentation is most pronounced by the ferruginisation of the siltstone layers as observed in Figure 3c above.
- **Wavy bedding**: This type of bedding is very common in the outcrop of Taloka Formation at locations (L_{21}, L_{30}, and L_{25}). The wavy bedding is due to alternation of clay and siltstone layers, which are linked to form continuous layer. The mud layer almost completely fills the ripple trough and makes a thin cover over the ripple crest. The ripple bedded sand layers of wavy bedding are vertically discontinuous and isolated.
- **Bioturbation structures:** This is a burrowing structure formed as a result of burrowing activities of biological organisms (Plate 1, 2, 8).
- **Mudcrack:** These are some sort of vertical shrinkage cracks formed as a result of contraction of cohesive muddy sediments which are usually preserved by infilling of different sediments. They are common structures found at locations (L_{14}, L_{16}, L_{18}, and L_{34}). The erosion of mud cracks produces clay balls. The abundance of mud crack can be useful in the interpretation of paleoclimate as they are common in warmer climates (Plate 9).
- **Clay galls**: Are found above the carbonaceous layers layer of the Taloka Formation as observed at location (L_{42}, L_{52}, and L_{5}).

4. Conclusions

It can be concluded that two distinct formations were studied from the Gadon Mata area of the Sokoto Basin. These are the Taloka and Dukamaje formations. It was observed from the above that the sedimentary structures are indicative of a specific environment. The abundance of bioturbation burrows, wavy bedding, and rhythmic bedding of Taloka Formation indicates tidal flat deposition environment. Similarly, presence of mud crack at Dukamaje Formation shows evidence of marginal marine environment.

In terms of petroleum significance, the abundance of carbonaceous dark shales within the Taloka and Dukamaje Formations could possibly constitute potential source rocks and the sandstone facies in the Taloka Formation will constitute a good reservoir rocks in the subsurface.

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