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PETROGRAPHIC STUDIES OF LIMESTONE IN DUKAMAJE FORMATION AT GILBEDI, GADA, SOKOTO BASIN, NIGERIA

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ABSTRACT

The study was conducted in and around Gilbedi village and its environs in the Iullemmeden Basin, Sheet 4 SW, Gada local government area, Sokoto, North-West Nigeria. The research area is located in the Sokoto Basin, which is part of the Iullemmeden Basin. The study area is bounded by latitudes 13^{0}46'05"N to 13^{0}43'22"N and longitudes 5^{0}45'00"E to 5^{0}40'45"E covering 25 Km^2. The mapping exercise was carried out using a topographic base map on a scale of 1:25,000. The observed Dukamaje Formation is derived from a marginal marine depositional setting and is primarily composed of shales, limestones, and mudstone with gypsum intercalation. Shales are consolidated mudstones with a fine-grained texture which is greyish. Limestone is medium to coarse-grained. It is a pale yellow to greyish in color. Petrographic observation showed the grains to be equigranular, and having interstitial quartz cement. The quartz occurs as colorless anhedral crystal with no alteration but with wavy extinction and without cleavage. Other minerals present include muscovite. Based on Folk's classification for limestone, the limestone in the study area is called "extramicrite" because the allochems are extraclasts. The limestone also lime mud supported which is less than 10% of grains Based on Dunham's classification schemes for limestone, the limestone of the studied Dukamaje Formation is a "mudstone".

Keywords: Allochem, Dukamaje Formation, Micrite, Limestone

INTRODUCTION

The Iullemmeden Basin is one of three important sub-Saharan inland basins consisting of a broad syncline with gently dipping flanks (Obaje, 2004). The Iullemmeden Basin is a cratonic basin created by tectonic epeirogenic movements or stretching and rifting of tectonically stabilized crust during the Palaeozoic (Bertrand-Safarti, 1977; Zaborski and Morris, 1999; Edegbai et al., 2019). These movements continued until the Upper Cretaceous when the opening of the Goa Trench was achieved (Faure, 1996). The Basin is contemporaneous with the West and Central African Rift Systems (Fairhead and Binks, 1991; Binks & Fairhead, 1992) Over about 95% of its surface area is located in the semi-arid environments of the five contiguous countries Nigeria, Niger and Mali, Algeria and Benin Republic, covering about 620,000 km^2, land and containing sedimentary infill of Late Jurassic-Pliocene age (Fig. 1; Kogbe 1981; Yelwa et al., 2015; Yelwa et al., 2019; Lawal et al., 2022). The sedimentary sequences in the Basin become progressively younger from the northeast to the southwest, indicating the directions of successive Cretaceous marine transgressions (Kogbe, 1989; Yelwa et al., 2015; Yelwa et al., 2019).

This research aims to describe sedimentary deposits and structures based on field observations and petrographically depict the study area's depositional setting.

Geologic Setting

In general, the expansive Iullemmeden Basin stretches from Algeria in the north to Niger in the east and from Nigeria and the Republic of Benin in the south to Mali in the west (Kogbe, 1981; Zaborski & Morris, 1999). The Iullemmeden basin in North-western Nigeria is known locally as the Sokoto Basin. The Sokoto Basin is about 63,000km^2 in size, covering parts of Kebbi, Sokoto, Zamfara and Katsina areas and located between longitudes 3^{o}40'E and 8^{o}E and latitudes 10^{o}30'N and 14^{o}N (Yelwa et al., 2015; Yelwa et al., 2019). 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). Studies based on the outcrops and borehole data erected Cretaceous and Tertiary Stratigraphic models (Kogbe 1972, 1976b; Kogbe et al., 1976; Petters, 1976; Lawal et al., 2022).

The stratigraphy of the Basin begins with are the Illo and Gundumi Formations, which overlies the Precambrian basement rocks of northern Nigeria unconformably and they are in turn overlain unconformably by the Maastrichtian Rima Group, (Taloka Formation, fossiliferous shales of Dukamaje Formation and siltstone of the Wurno Formation) (Kogbe, 1989; Yelwa et al., 2015; Yelwa et al., 2019). Younger deposits, the Sokoto Group (the Dange, the Kalambaina and the Gamba Formations) is dominated mainly by shales, calcareous sediments and phosphatic shales) all of Paleocene age. The stratigraphy is capped by the Gwandu Formation ("Continental Terminal") of Tertiary age (Fig. 2). The sediments dip gently and thicken gradually towards the north-west, with a maximum thickness of over 1,000 meters near the Nigeria-Niger Republic frontier (Kogbe, 1976). Thus, the geology, stratigraphy, sedimentology, and petroleum potential of the Sokoto Basin (Fig. 2) are substantiated in the works of Kogbe (1972, 1974, 1979); Adeleye (1975); Okosun (1995a, 1995b); Haynes and Nwabuafo-ene (1998); Obiosio et al, (1998); Obaje et al., 2013, 2020a, 2020b; Edegbai et al., 2019; and Lawal et al., 2022; but more detailed work is expected in ongoing research.

Figure 1: Location map of the of Iullemmeden Basin and Sokoto Basin (a) map of Africa; (b) map of Nigeria showing the study area (modified after Yelwa et al., 2015).

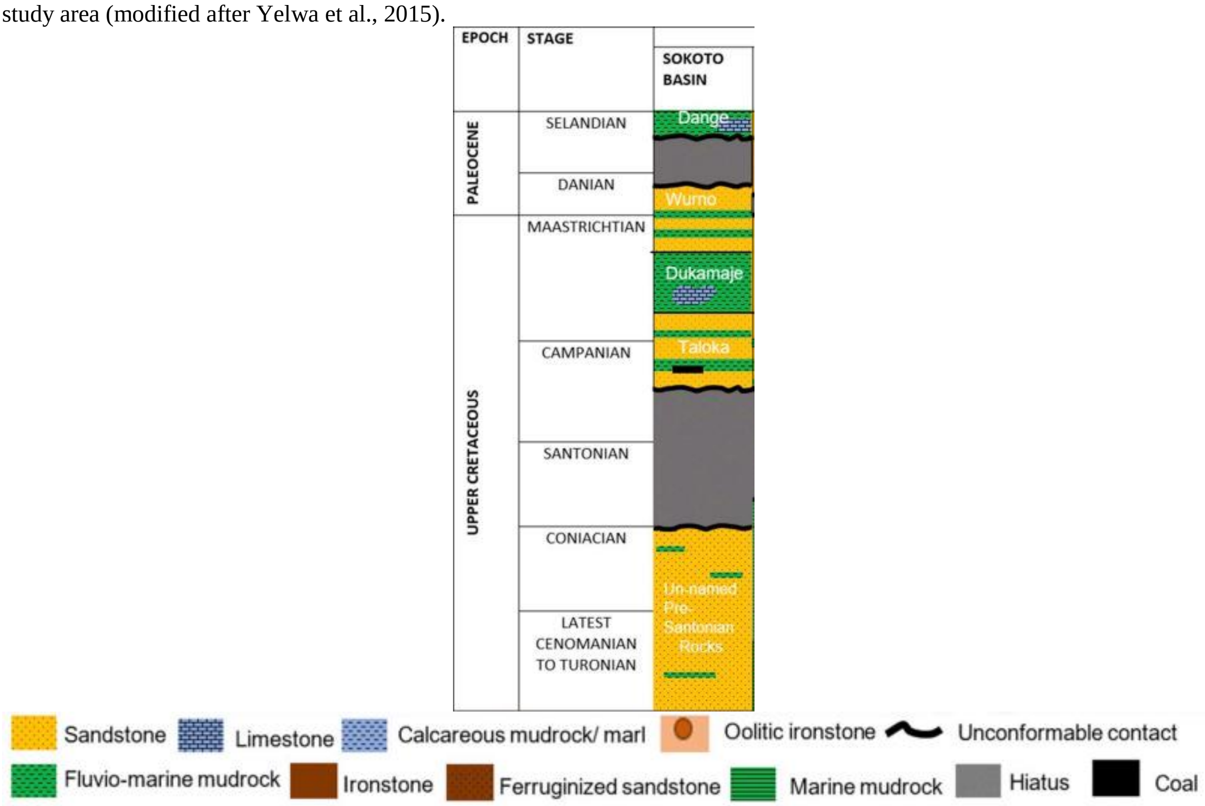


Figure 2. Cenomanian- Paleocene stratigraphic scheme of Sokoto Basin illustrating stratigraphic groups with important geological formations (copied from Yelwa et al., 2019)

MATERIALS AND METHOD

First, outcrop units in the area were studied. Descriptions of all geologic observations on the outcrop were undertaken in the field. Samples were collected from studied outcrops for further analysis. Accordingly, petrographic analysis was applied to the limestone samples. This petrographic analysis includes preparing slides for further analysis using a thin section machine. The rock slab was marked and cut with a large diamond saw exposing the rock fabric. The cut sample/ chip was mounted on a glass slide. Epoxy was used to impregnate one side of the chip on the other. In addition, the glass was frosted, and the chip with the slide was cleaned. The chip was glued to the slide with epoxy; then, the slide was trimmed with a razor blade to remove excess balsam, then acetone, and properly labelled. Thereafter, the sample was passed through a grinding process on the thin section machine. The slab was ground with 400 grit, followed by 1000 grit or finer. The thin section slides so produced are examined under cross-polarized and plane polarised light to determine the petrographic properties of the limestone samples.

RESULT AND DISCUSSION

Field Occurrence and Stratigraphy

The geology of the study area comprised mainly sedimentary deposits. Descriptions of all geologic observations including lithostratographic studies and sedimentary structures in the field are discussed below. The distribution of the various Formations is as shown in Figure 3 while some of the sections of Dukamaje Formation are presented in figures 4 and 5.

Generally, the deposits observed comprised a thin-bedded siltstone with ferruginised mud drapes which belongs to the Taloka Formation interpreted as either tidal flat (Kogbe, 1972) or tide-influenced channel environment (Lawal et al., 2022). These unit is overlain by the Dukamaje Formation, details discussed in the next section.

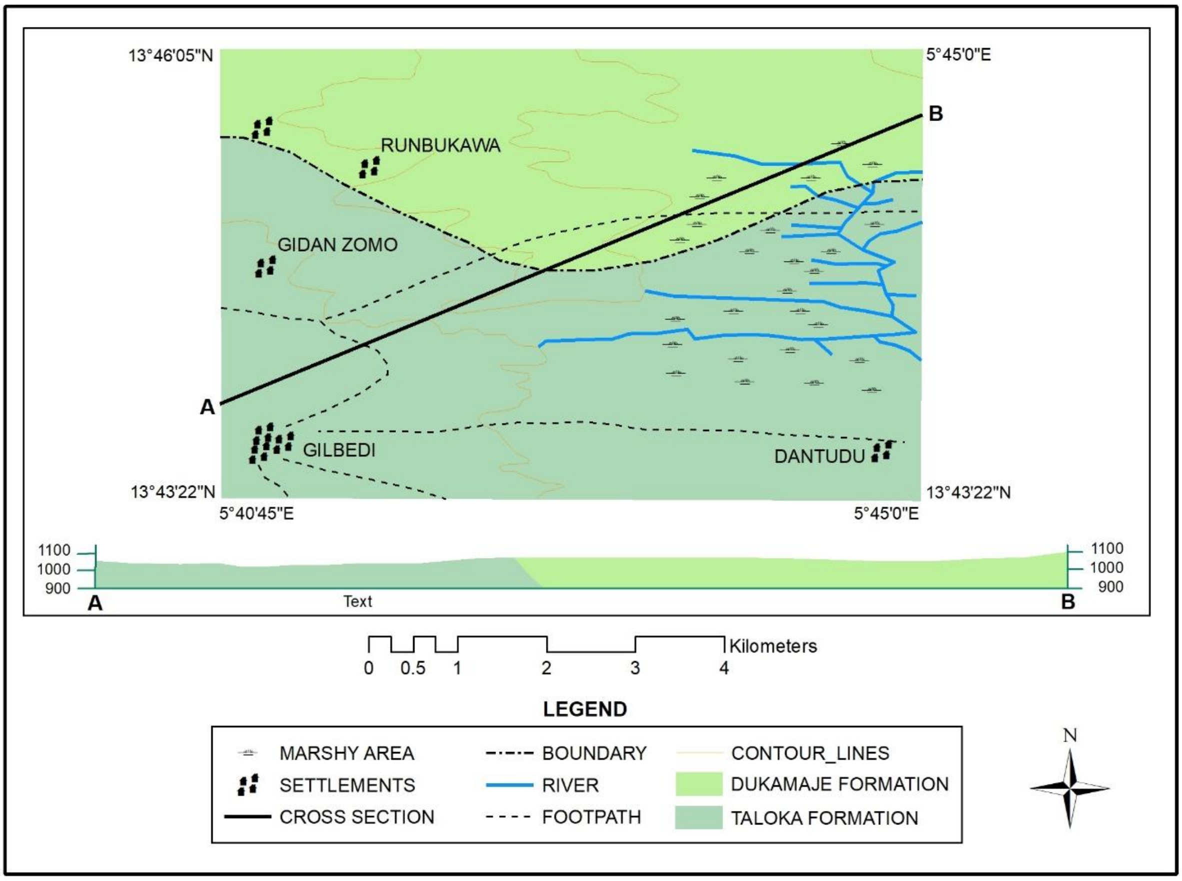


Figure 3: The Geological Map of Gilbedi and its Environs, Part of Sheet 4 Sokoto SW.

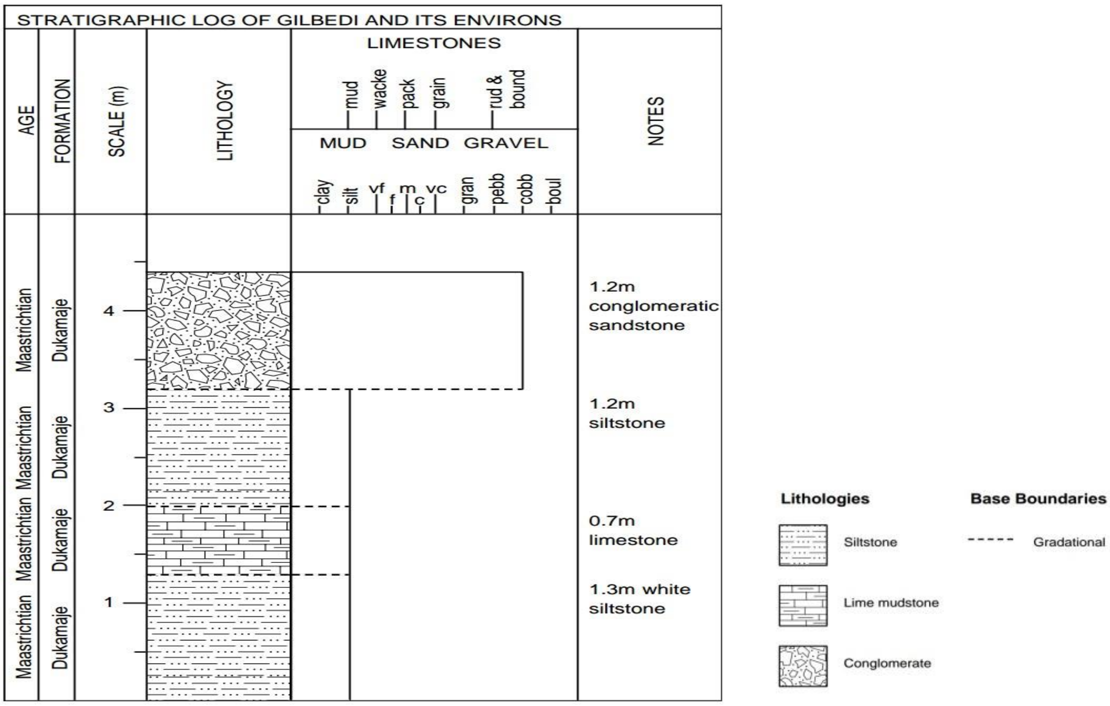


Figure 4: Stratigraphic section of the Dukamaje Formation exposed in Gilbedi

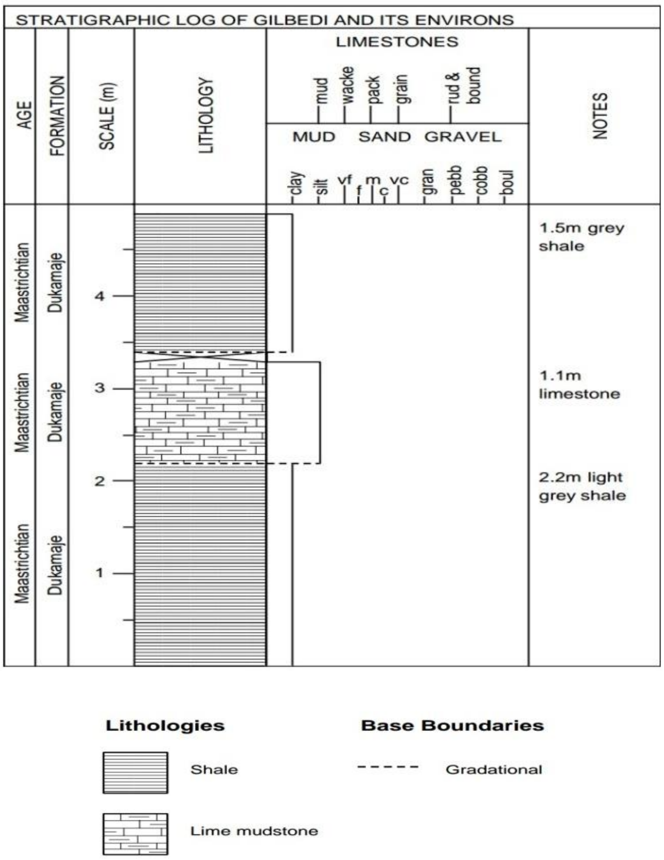


Figure 5: Stratigraphic section of the Dukamaje Formation

Lithologic characteristics of outcrop sections in the Dukamaje Formation

***Gilbedi Locality** (N13˚42' 56.6", E5˚44' 27.3")*

The section described here is located at Northern part of Gilbedi village and has the following sequence (Figure 4) above. The section exposed at N13˚42' 56.6" and E5˚44' 27.3" has a base consists of whitish siltstone of 1.3 m thick at its base, followed by a fractured limestone of 0.7 m thick. 1.2 m thick fractured siltstone overlies the limestone, and at the top of the section, a unit of conglomeritic sandstone of 1.2 m thick sits.

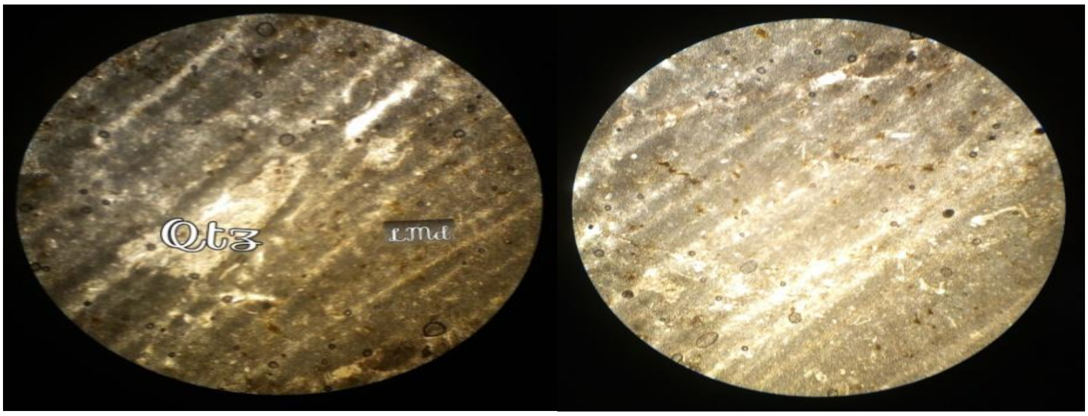
***Locality Dukamaje (**N13˚43' 28.6", E5˚45' 04.4")*

This section has beds that disintegrate rapidly on exposure, and the base of the ridge is covered by a layer of overburden. From bottom to the top, 2.2 m thick of fractured, light gray shale is overlain by 1.1 m thick limestone unit which is in turn overlain by 10.0 cm thick phosphate and at the topmost part of the section is 1.5 m thick fractured shale, which is in turn overlain by 0.5 m thick ferruginized ironstone. Plate 1 below shows the exposure of the locality. Dukamaje Formation is recognized under shallow marine environment (Kogbe, 1981; Adetunji & Kogbe, 1986; Zaborski & Morris 1999). The Dukamaje Formation is a marginal marine environment with gypsiferous shales, carbonaceous shales, shelly carbonate shales, limestones, mudstones, paleontological fossils and broken reptilian pieces (Kogbe, 1981; Zaborski and Morris, 1999; Yelwa et al., 2015, 2019).

Plate 1: An exposure of gypsiferous shale and limestone of the Dukamaje Formation at locality N13˚ 43' 28.6", E5˚ 45' 04.4"

Petrographic analysis of samples from the Dukamaje Formation

The samples of the outcrop sections described earlier were subjected to petrographic examination (Plate 2). The following minerals were observed based on certain properties under plane polarized light and crossed polarized light. Two main minerals, which are clay and quartz respectively The crystal grains in the analysed samples exhibit anhedral shape. The minerals observed are discussed below:



(a) (b)

Plate 2: Limestone under with observed crystal grains in (a) in cross polarized light (XPL, Mag. 0.25mm x10) and (b) in plane polarized light (PPL, Mag.0.25mm x10) at a location, N13˚ 43' 28.6", E5˚ 45' 04.4" in Dukamaje. Lmd = Lime Mud, Qtz = Quartz.

Quartz: Mineral: The quartz mineral is observed under plane polarized and cross polarized. The quartz shows a medium to low relief and is colorless both under the plane polarized and cross polarized.

Lime Mud*:* Here, the grains appear equigranular. The interstitial cement seen is quartz (SiO_2). Minerals present include quartz, muscovite. The quartz occurs as colorless anhedral crystal with no alteration. It has wavy extinction with no cleavage. It makes about 35% of the minerals in the sandstone.

Mineralogy

Determination of the mineralogy of the limestone of Dukamaje Formation was carried out using thin section, viewed under the microscope. Subsequently, the limestone was found to contain about 65% of lime mud and 35% of quartz. This availed the opportunity for a standard limestone classification discussed below.

Composition and limestone classification of the Dukamaje Formation

The Dukamaje Formation consists predominantly of shales, limestones and mudstone with intercalation of disseminated gypsum. These beds are probably deposited in marginal marine to marine environment. The shales are consolidated, grayish mudstones with very fine-grained texture. Limestone is medium to coarse-grained having a pale yellow to gray color. In thin section, the grains appear equigranular. The interstitial cement seen is quartz (SiO_2). Minerals present include quartz and muscovite. The quartz occurs as a colorless anhedral crystal with no alteration. It has wavy extinction with no cleavage.

Folk's Classification Scheme

The presence of quartz in limestone implies that the grains are brought in from outside of the basin as detrital material (extraclasts). Based on Folk's classification for limestone, the limestone in the study area is interpreted as "extramicrite" because of the presence of allochems which are extraclasts. Extramicrite is a limestone in which the allochems are extraclasts and in which grains are held together by a micrite matrix.

Dunham's Classification Scheme

Based on Dunham's classification schemes were applied based on observed features that characterized the samples of limestone beds. The limestone observed in the area of study is named "Mudstone". This is because the original components are not bound together during deposition and it contains lime mud which is mud supported and has less than 10% of other grains dispersed within it.

Geological Structure

Sedimentary structures (bedding, mud crack and reverse grading) were observed in Dukamaje Formation covered in the study area. Sedimentary structures were observed in well exposed outcrops of Dukamaje Formation. The structures can provide more information about the sedimentary history of the deposits. The structures are discussed in more details below.

Sedimentary Structures

(i) Bedding: This is a term signifying the existence of layering in sedimentary rocks. They are common in the various locations of the mapped area (Fig. 4, 5).

(ii) Reverse Grading: This is a gradational decline in grain size downwards. In other words, coarse grains appear at the top, and then medium grains in the middle and finally fine grains occupy the bottom position (upward increase in grain size). Reverse grading is most common in the sandstone beds.

(iii) Bioturbation structures: This is a burrowing structure formed as a result of the burrowing activities of biological organisms (N13˚ 42ˈ 56.6ˈˈ and E5˚ 44ˈ 27.3ˈˈ).

(iv) Mud crack: 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 at N13˚ 43ˈ 28.6ˈˈ, E5˚ 45ˈ 04.4ˈˈ. The erosion of mud cracks produces clay balls. The abundance of mud cracks can also aid in interpreting paleoclimate; mud cracks are common in warm, arid climates (Yelwa et al., 2015; Yelwa et al., 2019).

(v) Fractures: These were observed at N13^0 44' 13.0'' and E005^0 43' 37.8''(Plate 3). They are formed as a result of stress exceeding the rock strength, thereby causing the rock to lose cohesion along its weakest plane. Plate 3 below shows an example of fractures found in shales of Dukamaje Formation.

Plate 3: Fractured Shale Overlain by silty shale (near the top) at Dukamaje area.

CONCLUSION

Dukamaje Formation was studied mainly in the Northern part of the Gilbedi Village. The Dukamaje Formation consists predominantly of gray shales, limestone and mudstone beds that are highly rich in fossils and with intercalations of disseminated gypsum. The shales are consolidated mudstones of very fine-grained texture. Limestone is medium to coarse-grained pale yellow to grayish in color. In thin sections, the grains appear equigranular. The interstitial cement seen is quartz (SiO_2). Minerals present include quartz and muscovite. The quartz mineral found are colorless anhedral crystals with no alterations, wavy extinction with no cleavage. Based on Folk's classification for limestone, the limestone in the study area is called "extramicrite" because the allochems are extraclasts. Dunham's classification schemes for the limestone suggest that it is "Mudstone" because it contains lime mud (which is mud supported and is less than 10% of grains). Finally, the presence of mud cracks in the deposits of the Dukamaje Formation shows evidence of marginal marine environment.

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