

Sedimentological and Palynological Assessment of Bima Group, Bornu Basin, Northeastern Nigeria.

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ABSTRACT

Sedimentological analysis was carried out on 244 samples obtained from Murshe-1 well located in Bornu Basin, Nigeria. Nine different lithofacies units were established including heterolith of sand and shale, sand, shale, gypsiferous shaly sand, shaly gypsiferous sand, gypsiferous sand / sandy gypsum, gypsiferous shale/shaly gypsum, gypsum and claystone.

The Pre-Bima is characterized by sand / shale heterolith restricted to the lower part (2980-3630m); while the presence of gypsum in heterolith of sand and shale is of various proportions. The sand grains vary in size from fine to pebble, angular to rounded and poorly sorted; suggested to be deposited in fluviomarine to marine systems. The Pre - Bima is dated Albian age based on pollen assemblages such as *Steevesipollenites sp.*, *Cretaceiporites sp.*, *Forma PO 304 Lawal*, *Ephedripites multicostatus*, *Afropollis jardinus*, *Gnetaceaepollenites sp.*, *Galeacornea cursea*, *Leptolepidites verrucatus*, and *Patellasporites distaverrucosis*.

The Bima Formation is predominantly dark grey to black shale with interbeds of gypsum deposited in marine setting. It is defined palynologically by co - occurrence of *Elaterosporites klaszi*, *Ephedripites sp1*, *Ephedripites sp3*, and *Hexaportricolpites emelianovi*, dated Cenomanian age and deposited under marine condition. Both the Pre-Bima and Bima Formations are here referred to as Bima Group.

(Keywords: lithofacies, fluviomarine, heterolith, formation, group)

INTRODUCTION

Bornu Basin form part of the larger Chad Basin, which is the largest intra cratonic basin in Africa (Reaburn and Brynmor, 1934; Barber, 1965). The discovery of petroleum in the adjacent Chad Basin prompted serious effort in exploring for hydrocarbon in the Bornu Basin, Nigeria. A number of exploratory wells, over twenty in number, have been drilled in the basin in order to unravel the geological architectural stacking pattern of the formations. Therefore, it is imperative to understand the complex stratigraphic pattern of the basin through further research study on the drilled wells.

Earlier works have been done on the basin especially the Bima Formation. The work of Olugbemi (1997) dwelled on sedimentology in term of distinguishing the formations into Pre - Bima and Bima Formations. The study carried out by Ola -Buraimo and Boboye (2011) though considered the stratigraphy but particularly dated the Bima Formation as Albian–Cenomanian age.

However, this present study aims at reappraising this fact; establish more facts on the different lithofacies contained which are more complex and at variance to Olugbemi (1997) submission. In this paper both the Pre-Bima and Bima Formations are referred to as Bima Group. Thus, the two formations were independently dated and assigned ages based on distinctive palynological assemblages. Palynological study becomes necessary in order to unravel the chronostratigraphy, paleoenvironment and lithofacies identification and differentiation into formations.

GEOLOGIC SETTING

The geology of Bornu Basin has been widely investigated by earlier workers such as Falconer (1911), Raeburn and Brynmor (1924), Carter, et al. (1963), and Barber (1965). The Formation of Bornu Basin was predicated on third failed arm of a triple junction formed during the Albian due to opening of the South Atlantic (Wright, 1968; Burke, et al., 1970). Other authors that supported the plate tectonic theory include Genik (1933), Kings (1950), and Avbovbo, et al. (1980).

The stratigraphy of Bornu Basin have been widely studied, these include the work of Adegoke, et al. (1973), Petters (1978b), Kogbe (1979), Petters (1981), and Avbovbo, et al. (1986). The biostratigraphic studies in this basin are incomparable to other sedimentary basins in Nigeria. Few works done include those of Barber and Jones (1960), Carter, et al. (1963), Reymont (1965), Adegoke, et al. (1978), Petters (1982), Odusina, et al. (1983), Wonzy and Kogbe (1983), Popoff, et al. (1986), Oti (1990), Okosun (1995), Olugbemiro (1997), Ola-Buraimo (2005), Ola-Buraimo (2009), and Ola-Buraimo and Boboye (2011). However, few palynological studies were reported from the basin, including the work of

Adegoke, et al. (1973), Boboye (2007), and Ola-Buraimo and Boboye (2011).

Avbovbo, et al. (1986) suggested six events leading to the evolution of the Bornu Basin. These include the period of Pre-Albian, Albian–Maastrichtian, Maastrichtian-Danian which led to cessation and collapse as sub-crustal swells, associated with folding, faulting, sedimentation, erosion, and volcanism. The fifth event was noted for stress redistribution and initiation of secondary situation; followed by Tertiary–Recent event characterized by continental–lacustrine sedimentation and volcanism.

Bima Formation is the oldest stratigraphic unit deposited under continental environment. The formation is diachronous and Albian-Turonian age (Carter, et al., 1963). Lithologically, it was described to be poorly sorted, sparsely fossiliferous, thickly bedded, cross stratified; sand size varies from feldspathic coarse to conglomerate. Avbovbo et al, 1986 identified marine shale sequence deposited over localized conglomerates and poorly sorted alluvial deposits lying unconformably on the basement. The distinct continental deposit (conglomerate) is termed the Pre-Bima dated Albian age (Oti, 1990).

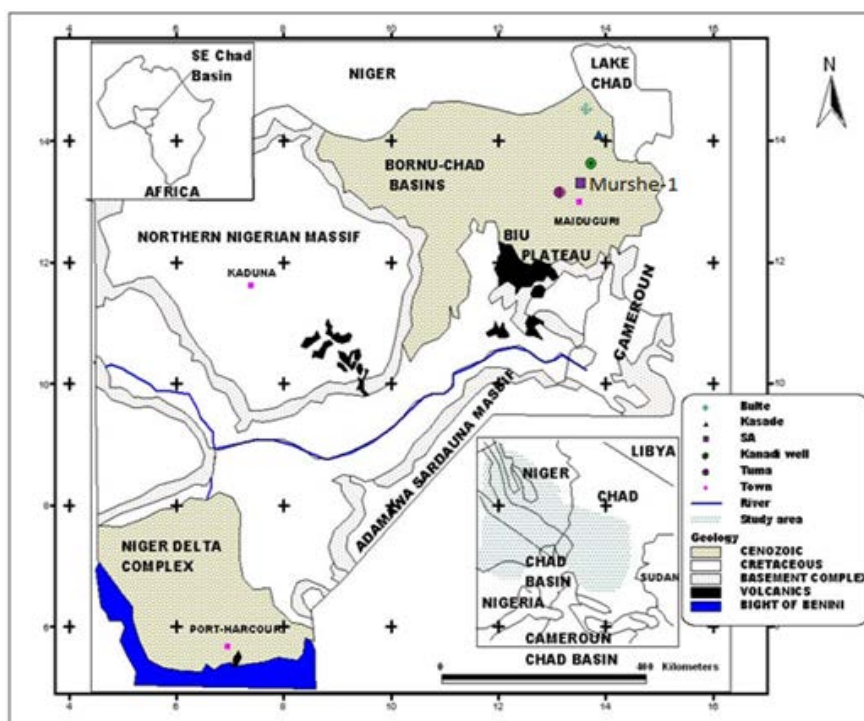


Figure 1: Geological Map of Nigeria showing the Location of Bornu Basin and the Studied Well (modified after Whiteman, 1982 and Genik, 1993).

MATERIALS AND METHODS

Ditch cutting samples of about 244 in number were first arranged serially in order of depth. Lithologic description was carried out by looking at the sediments under the microscope; comparison of the textural parameters with standard monograph plates of Western Atlas. Textural features taken into consideration include, grain size, shape in term of roundness and angularity. Others parameters include sorting, color, lithology, post depositional effect such as ferruginization; fossil contents, presence of accessory minerals and effect of dilute hydrochloric acid on the samples which depicts the presence of carbonate. The selected samples at 27.4m (90ft) interval were thoroughly washed with distilled water through a 5µm polyester sieve to remove drilling mud contaminants and then dried for 24 hours at 50°C for palynological analysis.

Ten (10) grams of each sample was digested with 10% HCL to remove CaCO₃. It was later soaked with 60% hydrofluoric acid (HF) for 24hrs to digest the silica. The content was sieve- washed (5µm) with water and later oxidized in Schulze solution (mixture of nitric acid and potassium chlorate) for 30 minutes, washed with 10% potassium hydroxide, followed by heavy liquid separation with Zn₂Br₄ and centrifuged. The aliquotus were dispersed with polyvinyl alcohol, dried and then mounted in DPX mountant. The biostratigraphic study involved the analysis of pollen, spores, dinoflagellates and algae under the microscope for chronostratigraphic biozonation. Important palynomorph pictures were taken using Nikon Koolpix™ P6000 digital camera.

RESULT AND DISCUSSION

Sedimentology

The litholog of the well section analyzed is presented in Figure 2 below. Nine main lithofacies units are identified; these include heterolith of sand and shale, sand, shale, gypsiferous shaly sand, shaly gypsiferous sand, gypsiferous sand / sandy gypsum, gypsiferous shale / shaly gypsum, gypsum, claystone.

Lithofacies Unit 1: Heterolith Sand and Shale

This lithofacies lies at the basal part of the well, probably overlying the crystalline basement rock. The shaly sand facies unit is fairly thickly bedded of about 210m. The sand/shale ratio varies at different levels but characterized by fine to coarse, angular to rounded, poorly sorted sand grains. The interval shows interbed of gypsum. The lithofacies unit 1 occurs at different intervals within the analyzed stratigraphic section, including: 3420 - 3630m, 3165 - 3240m, and 2980 - 3060m. At the middle part of the well section (2980 - 3060m) where the facies ends shows an uphole increase in shale content. The sand/shale lithofacies is restricted to the lower part (2980 - 3630m) of this interval; suggested to be equivalent to the Pre-Bima Formation described by Odusina, et al. (1983) and Avbovbo, et al. (1986). However, a variation from what was earlier reported is the presence of gypsum in the Pre-Bima Formation which occurs as heterolithic gypsiferous sand and gypsiferous shale.

Unit 2: Sand

The sand facies occur as thin to medium thickly bedded units interbedding with heterolith facies and shale units. The sand units are fine to pebbly, moderately to poorly sorted, indicating continental deposit. The sand facies present at 3615 - 3620m is fine grained and well sorted; while interval 3565 - 3575m is milky colored; size varies from fine to pebble, angular to rounded, and moderately sorted. At 3470 - 3475m, the sand property is similar to that underlying it, but not pebbly in size. Another interval at 2985 - 2990m marks the top of the sand facies and sand heterolith; thereby marking the top of Pre-Bima Formation in this well section.

Unit 3: Shale

The shale lithofacies is present at both the lower and upper parts of the stratigraphic interval analyzed. The general trend is that shale facies tends to increase in content from the base to the top of the well section. However, moderately thick shale sequence is present at the upper part (1930 - 2485m) and the middle part 2830 - 2980m; while the fairly thick shale intervals 2520 - 2620m and 2795 - 2825m are present within the section. The shale facies are generally black, fissile and relatively ferruginized. At different

intervals the shale beds are intercalated with heterolith gypsum deposits. The shale content increases uphole. The upper part represented by dominant shale facies is here described as Bima Formation.

- 3460m, 3305 - 3310, and 3255 - 3260m; all showing similar characteristics as above.

Unit 4: Gypsiferous Shaly Sand

This lithofacies is not common but occurs sparsely in the lithostratigraphic section. At interval 3585 - 3590m, the facies is milky to black fissile gypsiferous shaly sand. The heterolith ratio is s/sh= 55/25%, gp= 20% (55: 25: 20%). Sand property is poorly sorted. Other intervals are 3435

Unit 5: Shaly Gypsiferous Sand

This facies fairly occur in the stratigraphic section. Few intervals at which it occurs are 3555 - 3565m, 3485 - 3490m, 3420 - 3430m, and 3315 - 3385m. The lithofacies is milky to black in color, while the sand is characterized by fine to pebbly sized grains, angular to rounded, moderately to poorly sorted at lower part; rarely ferruginised in nature. The heterolith ratio varies from depth to depth, but the sand content is quite high with an average value of s/sh = 70/10%, gp = 20%.

Thickness (m)	Lithology	Description	Formation	Paleo - Environment
1980m	[Green shale pattern]	Dark grey to black fissile shale calcareous, various degree of ferruginisation at different levels.	Bima	Marine
2485m	[Green shale pattern]			
2620m	[Green shale pattern]	Alternation of shale and gypsiferous shale units; uphole increase in gypsum content		
2795m	[Green shale pattern]	Black fissile shale unit with intercalated thin layer of gypsum	Pre - Bima	Fluviomarine - Marine
2980m	[Green shale pattern]	Top defined by top occurrence of sand in the stratigraphic section. Further characterized by increase in gypsum content intercalated with sand and shale facies		
3060m	[Green shale pattern]	Mainly shaly sand, the basal parts is fine to coarse, poorly sorted with interbed of gypsum		
3165m	[Green shale pattern]			
3290m	[Green shale pattern]			
3470m	[Green shale pattern]			
3630m	[Green shale pattern]			

Figure 2: Lithostratigraphic Section of Bima Formation, Associated Facies and Paleoenvironment of Deposition.

Unit 6: Gypsiferous Sand/Sandy Gypsum

These two lithofacies are present at different levels. The presence of either facies type is dependent on the relative proportion of sand and gypsum. At interval 3535 - 3540m, the sand / gypsum ratio is (s/gp = 90/10%) 90:10%, while at 3530-3535m the s/gp is 45/55%. The heterolith is milky colored, while the sand grains vary from fine to coarse, angular to rounded, moderately sorted, micaceous and rarely with shale fragments. At various intervals the sand / gypsum ratio varies which might be as a result of the influence of incursion of fresh water into restricted marine environment. Thus, the paleoenvironment is suggested to be fluviomarine in nature.

Unit 7: Gypsiferous Shale/Shaly Gypsum

These heterolith facies of gypsiferous shale and shaly gypsum are present at different interval in the well section analyzed. However, like other heterolith facies the presence of the unit 7 facies is dependent on the preponderance of shale or gypsum over one another. The intervals at which shaly gypsum occurs include 3580 - 3585m, and 3090 - 3095m.

Gypsiferous shale intervals are 2825 - 2835m (gyp/sh = 15/85%), a fairly thick shale within interval 2615 - 2770m characterized by black to light grey fissile shaly gypsum, slightly ferruginized with an average gypsum/shale ratio-70:30% (gyp/sh = 70/30); though, with slight variations at the uppermost part of the interval. The intervals are suggested to have been deposited in a marginal marine environment.

Unit 8: Gypsum

This lithofacies occurs only at an interval 2685 - 2690m with gypsum/shale ratio of 95:5% (gyp/sh = 95/5%); characterized by milky colored gypsum with minor shale content. The lithofacies is suggested to have been deposited in a marginal marine environment characterized by shallow water depth, with little or no influx of fresh water.

Unit 9: Claystone

This lithofacies is restricted mainly to the upper part of analyzed stratigraphic interval. It is found at two intervals 2520 - 2525m and 2540 - 2545m;

characterized by light brown color, bulky and ferruginized. The claystone is suggested to be deposited at the distal part of fluviatile environment probably a flood plain sub-environment.

PALYNOLOGY

An interval range of 1900 - 3830m was analyzed for palynological content. Twenty-one samples were prepared and analyzed under the microscope. Palynomorph recovery varies from depth to depth; but generally the palynomorph abundance and diversity is relatively moderate to poor, while preservation is poor probably due to unfavorable ecological condition or post deposition effects. Palynozone deduction was based on the evolution, extinction and quantitative and co-occurrence of the microfloral present.

One palynological zone referred to as *Afropollis jardinus* assemblage zone is established and compared to the works of Jardine and Magloire, (1965), Lawal and Moullade (1986), and Ola-Buraimo and Boboye (2011). The details of the basis of the established zone are given below.

Interval: 1900-3830m

Zone: *Afropollis jardinus* assemblage zone

Age: Albian – Cenomanian

Characteristics: The base of the interval where the analysis commenced at 3825-3830m is marked by the appearance of *Triorites africaensis*, *Steevesipollenites* sp., *Cretacaeiporites mulleri*, and *Ephedripites multicosatus*, at the near base (3615-3620m) is the occurrence of more diagnostic forms such as *Forma PO 304 Lawal*, *Gnetaceapollenites* sp., *Afropollis jardinus* and *Galeacornea causea*.

The interval is further defined by the appearance of new forms such as *Cretacaeiporites polygonalis*, *Liliacidites* sp, *Cretacaeiporites scrabratus*, Dyad pollen, *Inaperturopollenites* sp, *Cyathidites* sp, *Galeacornea clavis*, *Monosulcites* sp, *Patellasporites distaverrucosus* and *Leptolepidites verrucatus* (See plates).

The upper part of the stratigraphic section is characterized by the appearance of a new

marker form - *Elaterosporites klaszi* which marks the Cenomanian sediments; recovered first at interval 2805 - 2810m. Other forms that characterize the upper part are *Ephedripites* sp 1, *Ephedripites* sp 3 of Kotova (1984) and *Hexaportricolpites emelianovi*. The top of the interval is defined by poor recovery of pollen and spores; the only pollen present is *Cretacaeiporites scabratus*.

The assemblage of some of the key forms such as *Afropollis jardinus*, *Forma PO 304 Lawal*, *Steevesipollenites* sp., *Gnetaceaepollenites* sp., *Cretacaeiporites scabratus*, *C. Mulleri*, *C. Polygonalis*, and *Elaterosporites klaszi* are depictive of Albian to Cenomanian age. The assemblages of forms observed at this interval is similar to those observed by Jardine and Magloire (1965) for both Ivory Coast and Senegal sedimentary basins. It is also similar to *Afropollis jardinus* assemblage zone established by Lawal and Moullade (1986) for the Upper Benue Trough, Nigeria, dated Albian to Cenomanian and Ola - Buraimo and Boboye (2011) for Bornu Basin, Nigeria.

The details of the stratigraphic importance of some of the important pollen have been given by Ola-Buraimo and Boboye (2011). However, in this research work, top of the continuous occurrence of *Afropollis jardinus* and *Forma PO 304 Lawal* present at 2900m is taken as the top of Albian deposit. This is correlable lithostratigraphically to the top of sandstone lithofacies placed at 2980m. The lower section of the analyzed interval is equivalent to the Albian deposit and referred to as Pre - Bima Formation. However, the upper part of the entire section where stratigraphically marker forms such as *Elaterosporites klaszi* appeared is dated Cenomanian age based on comparison with the work of Kotova, (1978) on the deep sea project located in Eastern North Atlantic.

Therefore, the mappable sandy facies termed Pre-Bima and assigned Albian age by Oti (1990) is similar to our observation in Murshe- 1 well but the lithofacies is not entirely conglomeratic, rather it has variation of sand, shale, heterolith sandy shale/shaly sand and intercalated gypsum. Thus, the upper part which is predominantly shaly is dated Cenomanian and referred to as Bima Formation. Hence, the combined Pre-Bima and Bima Formations are here referred to as Bima Group and dated Albian to Cenomanian age.

CONCLUSION

The Pre-Bima Formation is mainly characterized by different lithofacies which varies from sand, heterolith of sand and shale, claystone and gypsum heterolith in sand and shale facies. The sequence is dated Albian based on diagnostic fossils such as *Forma PO 304 Lawal*, *Afropollis jardinus*, and *Steevesipollenites binodosus*.

The Bima Formation is mainly marked by higher proportion of shale to sand within the sequence. It is dated Cenomanian based on the co-occurrence of *Cretacaeiporites mulleri*, *C. scabratus*, *C. polygonalis*, *Elaterosporites klaszi*, *Ephedripites barghoorni formgroup*, and *Galeacornea clavis*. Both the Pre - Bima and Bima Formations are here referred to as Bima Group. The Bima Group is dated Albian to Cenomanian in age.

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APPENDIX

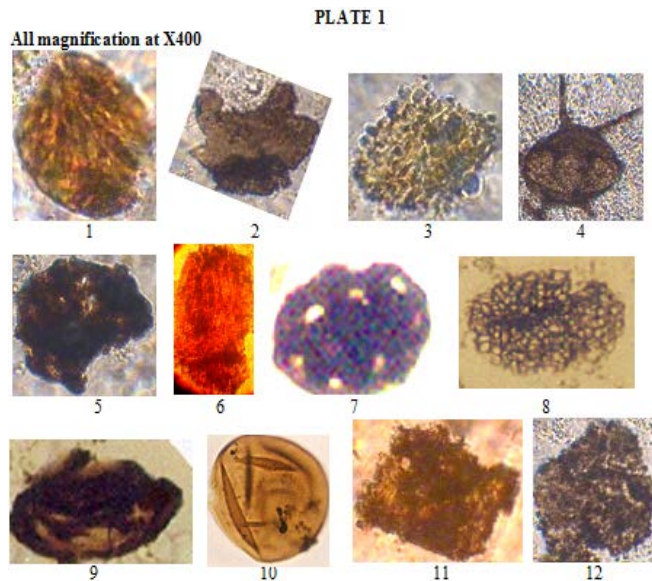


PLATE 1

- 1 *Ephedripites* sp.
 2 *Elaterosporites* sp. (New Form)
 3 *Patellasporites distaverrucatus*
 4 *Elaterosporites* cf. *Klaszi* **Jardine and Magloire, 1965**
 5 *Hexaportricolporites emelianovi*
 6 *Ephedripites barghoorni* form group **Hergreen, 1973**
 7 *Cretacaeiporites mulleri* **Hergreen, 1975**
 8 *Afropollis jardinus* (**Brenner**) **Doyle et al, 1982**
 9 *Galeacornea clavis* **Stover, 1963**
 10 *Inaperturopollenites* sp.
 11 Forma A
 12 *Senegalinium* sp.

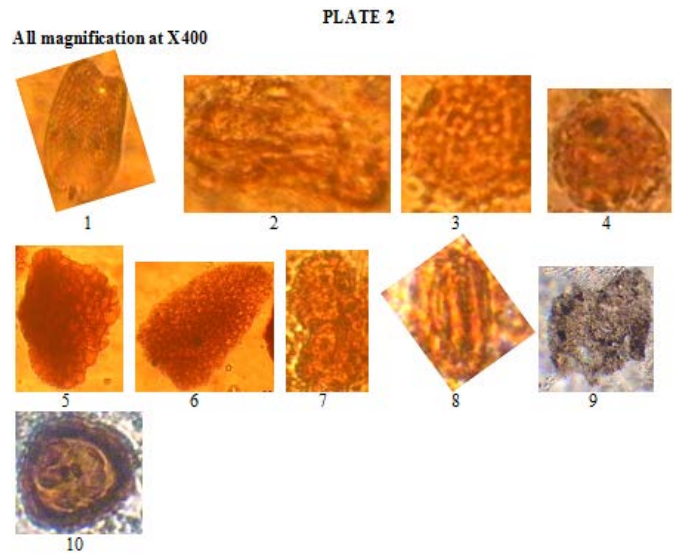


PLATE 2

- 1 *Gnetaceaesporites* sp.
- 2 *Galeacornea causea* (corroded)
- 3 *Afropollis jadinus* (corroded)
- 4 *Podocarpites* sp.
- 5, 6 Forma PO 304 Lawal
- 7 Dyad pollen
- 8 *Tricolpites* sp.
- 9 *Senegalinium* sp.
- 10 *Cingulatesporites* sp. **Jardine & Magloire, (1965)**

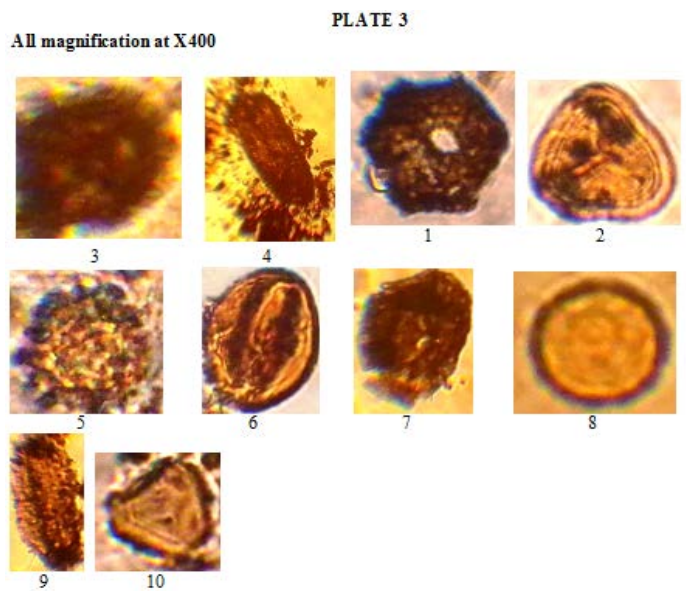


PLATE 3

- 1 *Cretacaeiporites mulleri*

- 2 *Ephedripites multicostatus*
- 3 *Cretacaeiporites polygonalis*
- 4 *Cyathidites sp.*
- 5 *Galeacornea sp.*
- 6 *Tricolpites sp.*
- 7 *Hexaporotricolpites emelianovi*
- 8 *Cretacaeiporites scabratus*
- 9 *Steevesipollenites binodosus*
- 10 *Triorites africaensi*

SUGGESTED CITATION

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