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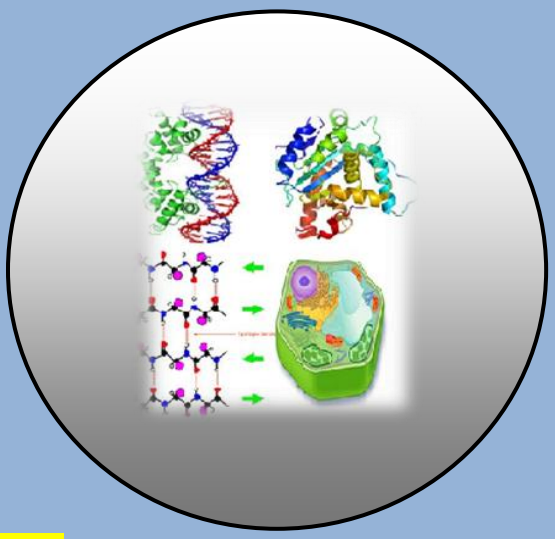

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RESEARCH PAPER

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Palynological age dating of the Topmost Bima through Gongila and Fika Formations in Kemar-1 well, Bornu Basin, Northeastern Nigeria

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ABSTRACT

Ditch cuttings samples retrieved from interval 905-1360m of kemar 1 well located in Bornu Basin were subjected to lithological and palynological analyses. The lithological analysis was carried out in order to determine the lithofacies sequence present while the palynological anslysis was for establishment of palynozone, age dating, and paleoenvironment of deposition. Laboratory analysis for the pollen and spore follows standard procedures which include digestion, sieving, and floatation in heavy liquid. One lithofacies unit of light to dark grey fissile shale, deposited marginal marine environment is present for the entire section Palynological deductions revealed four palynological zones- Cretacaeiporites spp assemblage zome 1 characterized by the maximum development of Cretacaeiporites spp, Galeacornea sp, Gnetaceaepollenites sp; dated Cenomanian in age and equivalent to the uppermost part of Bima Group . The Triorites africaensis/Droseridites Senonicus assemblage zone 2 (1180-1355m) is characterized by co-occurrence of Triorites africaensis and Droseridites senonicus; dated Turonian to Coniacian and it is equivalent to Gongila Formation. The Milfordia spp acme zone 3 is marked by maximum development of Milfordia spp; dated Campanian and equivalent to lower part of Fika Formation. Buttinian andreevi assemblage zone 4 is characterized by co-occurrence of Buttinian andreevi, Cingulatisporites ornatus, Retidiporites magdalenensis, Constructipollenites ineffectus, and Periretisyncolpites sp.; dated Early Maastrichtian and equivalent stratigrapically to upper section of Fika Shale. Fika Shale is diachronous and here dated Campanian – Early Maastrichtian age. Paleoenvironment of deposition is generally marginal marine based on the dominance of peridinacean forms such as Andalusiella laevigata, Andalusiella polymorpha, Senegalinium spp. and Odontochitina costata.

Keywords: Bima Group, Palynozone, Acme zone, Early Maastrichtian, Diachronous, and Peridinacean.

INTRODUCTION

The Bornu Basin is situated in the northeastern part of Nigeria (Fig. 1). Most activities in the pursuit of hydrocarbon exploration in the area have dwindled due to insurgence of terrorist group known as "Boko Haram". Until of recent when there is twist in the occupational area of the terrorist and reoccupation of the vast areas by the Nigerian military which brought sanity and safety of lives and properties to the affected areas. As a result of this the Nigerian government through its agency: Nigerian National Petroleum Corporation (NNPC) has decided to resume exploration for oil and gas in the area. This is necessitated by the drop of oil price in the international market whereby there is need to get oil at cheaper rate in inland basins compared to more expensive oil exploration and exploitation in the deep offshore of Niger Delta, Nigeria. Therefore, it is of great importance to the government to look inward towards increasing her hydrocarbon reserves and to tap the hidden liquid treasure in the Bornu Basin considering the fact that economic hydrocarbon has been found in Sudan and Chad which both share the extended Bornu Basin known as Chad Basin in the Nigeria frontier.

The Gombe Formation in Kemar-1 well, one of the stratigraphic units in the Bornu Basin had been re-established in terms of age through a high resolution biostragraphy in the work of Ayinla et al., (2013). What is important to us in this study is the palynological assessment of the lower section of Kemar-1 well which particularly contains older sediments. The lower section under investigation in this study has its equivalent being determined for hydrocarbon potential through the application of petrographic kerogen analysis in another paper (in Press).

Stratigraphic setting

Bornu Basin contains Cretaceous-Tertiary age sediments (Fig.1). It is thought to have formed as a result of failed third arm of triple junction during the Albian resulting to opening of the South Atlantic (Wright, 1968; Burke et al., 1972). Other researchers such as Genik, (1933); Kings, (1950); and Avbovbo et al., (1980) believe that the basin was formed based on the theory of plate tectonic.

Early workers on the Bornu Basin include Falconer, (1911); Carter et al., (1963); barber, (1965); Odusina et al., (1983); Avbovbo et al., (1986); Oti, (1990); Okosun, (1995); and Olugbemiro, (1997). The Bornu Basin comprises of seven litho-formations; Pre-Bima, Bima Formation, Gongila Formation, Fika Shale, Gombe sandstone, Kerrikerri abd Chad Formations. The oldest stratigraphic units are the Bima Formations. They are diachronous in age and range from Albian to Lower Cenomanian (Ola-Buraimo and Boboye, 2011). The formation uncomformably overlies the basement, poorly sorted, sparsely fossiliferous and medium to coarse grained feldsparthic sandstone deposited in continental environment (Avbovbo et al., 1986). Recent study shows that the two Bima Formations are lithologically distinctively different. The Pre-Bima is mainly characterized by sand, heterolith of sand and shale, claystone and gypsum in sand and shale facies deposited in fluviomarine to marine environment and dated Albian in age based on the co-occurrence of *Forma PO 304 Lawal, Afropollis jardinus* and *Steevesipollenites binodosus* (Ola-Buraimo and Oluwajana, 2012). The overlying Bima Formation is marked mainly by higher proportion of shale to sand, deposited in marine environment and dated Cenomanian based on palynomorph content. The two Bima Formations are collectively referred to as Bima Group (Ola-Buraimo and Oluwajana, 2012).

Among recent studies on the basin include the works of Ola-Buraimo (2005, 2009, 2013); Boboye, (2007); Ola-Buraimo and Boboye, (2011). Detail palynostratigraphic studies of Bornu Basin is well documented in the studies of three well (Boboye, 2012; Adegoke, 2012); on Tuma-1 well (Ola-Buraimo, 2012) and on Murshe-1 well (Ola-Buraimo, 2013). Another notable work is the use of palynology for reconstruction of paleoenvironment and age dating of Gombe Sandstone (Ayinla et al, 2013). A recent study on the use of palynology to determine the organic richness, kerogen type and thermal maturity was carried out by the authors on the section under investigation in this study (in Press).

The Bima Formation is overlain by Gongila Formation, dated Late Cenomanian to Turonian and described to consist of shale, limestone, silty sandstone and sandstone (Okosun, 1995; Olugbemiro, 1997 and Ola-Buraimo, 2013b. The Gongila Formation is most likely to range beyond Turonian because it is found to extend in age up to Senonian (Ola-Buraimo, 2013a). The formation is succeeded by Fika Shale. The Fika Shale is composed of dark grey to black fissile shale. The formation is diachronous in age and has been assigned Turonian-Maastrichtian by Carter et al., (1963) but was recently dated Campanian- Maastrichtian through palynomorph content (Ola-Buraimo 2012, 2013a). A continental to deltaic facies comprising of mudstone, claystone, sandstone and shale overlies the Fika Shale and known as Gombe Formation; dated Paleocene age (Ola-Buraimo, 2012, 2013a). However, this is in contrary to the work of Boboye, (2012) where Paleocene was assigned to Fika Formation in the three wells that were analyzed.

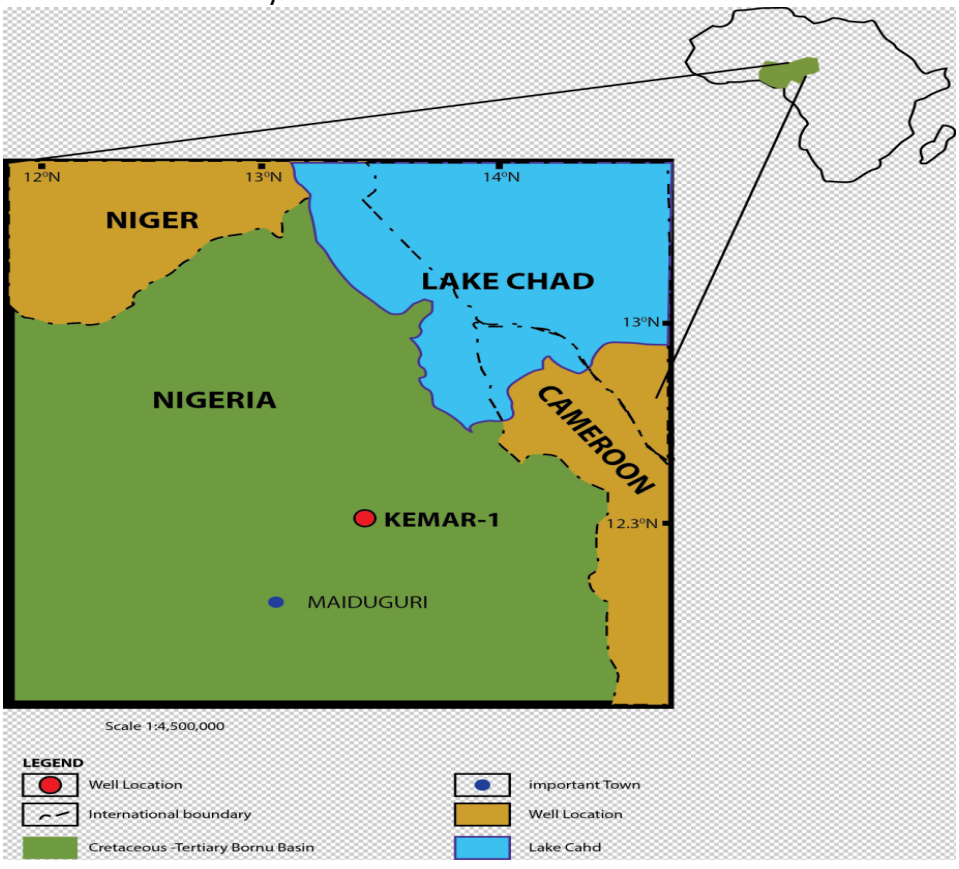


Fig 1. Location map of Kemar-1 (exploration well) in NE Bornu Basin (insert map shows position of Chad Basin in Nigeria and Africa respectively).

Overlying the Gombe Sandstone is the unconformable Kerrikerri Formation characterized by carbonaceous shale with intercalated limestone and mudstone, deposited in marine to continental environment; dated Upper Paleocene to Upper Eocene in age (Ola-Buraimo 2012, 2013a); whereas, Kerrikerri Formation was wxclusively dated Paleocene age by Adegoke et al, (1978). The youngest facies in the Bornu Basin is Chad Formation which consists mainly of ferruginous sandstone, claystone, sandstone and mudstone (Ola-Buraimo, 2012). The Chad Formation has been variously dated. Barber and Jones, (1960); Carter et al., (1963), dated it Pleistocene age; Barber, (1965) dated it Pliocene; while Ola-Buraimo, (2012) dated it to range from Late Miocene-Pliocene based on palynomorph content; though recent sediments in the basin classified as part of Chad Formation is Quaternary in age.

MATERIALS AND METHODS

Samples collected from the well exposed road cut were sampled from the base upward, numbering 1-13 in that order. The samples are mainly dark gray to black fissile shale and claystone. They were weighed to about 20gm, soaked overnight in Hydrofluoric acid (HF), and stirred intermittently for effective digestion. This was followed by sieving process with 5µm mesh in order to remove clay particles present, enhance collection of the debris and to achieve clean slide making. The retrieved debris of the samples was mildly oxidized, followed by heavy mineral liquid separation of the macerals using Zinc bromide ($ZnBr_2$) at 2.1g/cc. The collected residue was mounted on glass slides with DPX mountant. The preparation method was in accordance with international standard method.

Frequency count of pollen, spores, dinoflagellates, fungal spores, microforaminiferal wall linings and other stratigraphically significant forms present were determined for each sample, and interpreted by comparison with established works. However, diagnostic species photographs were taken with Nikon Koolpix P6000 digital camera.

RESULT AND DISCUSSION

Litho-Description

Lithofacies description of fifty three samples was carried out with the view of delineating them into various facies units. The detail procedure for the litho-description was presented in under methodology section. However textural characteristics and other salient features such as fossil content and post depositional effect were considered. The result revealed only one monotonous lithofacies of light to dark grey fissile shale throughout the analyzed interval (905-1360m) (Fig. 2).

Biozonation

The palynomorphs recovered from the analyzed samples are fairly rich in abundance and diversity (Table 1). The miospores are well preserved. Palynological interpretation of the analyzed interval 905-1360m was based on the presence of marker species present in the samples. Four palynological zones were established and compared with the works of Jardine and Magloire, (1965) on Senegal and Ivory Coast sediments; Lawal and Magloire, (1986) on deposits of Benue Trough, Nigeria; Ola-Buraimo, (2012) on Tuma -1 well located in Bornu Basin, Nigeria; Ola-Buraimo and Akaegbobi, (2013) on sedimentary deposits of Anambra Basin, Nigeria. The four palynological zones are *Cretacaeiporites spp* assemblage zone 1, *Triorites africaensis/Droseridites senonicus* assemblage zone 2, *Milfordia spp* acme zone 3, and *Buttinia andreevi* assemblage zone 4 (Table 1). The basis of establishing the zones are given below.

Interval: 1355-1360m
Zone: *Cretacaeiporites spp* Assemblage zone 1
Age: Cenomanian

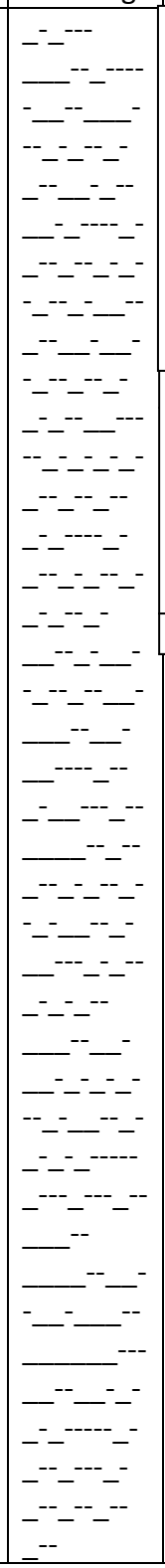
Depth(m)	Litho-log	Formation	Characteristics	Paleoenvironment
905		FIKA	Light to dark grey fissle shale	MARGINAL MARINE
		GONGILA		
		BIMA		
1360				

Figure 2. Litho-log of interval 905-1360m of Kemar-1 well, Bornu Basin, Nigeria.

Characteristic: The *Cretacaeiporites spp* zone 1 is limited to the basal interval (1355-1360m) the interval is marked by the co-occurrence of *Cretacaeiporites infrabaculatus, Galeacornea sp,* and *Gnetaceaepollenites sp.* (Table 1). They are suggestive of Cenomanian age (Jardine and Magloire, 1965; Kotova, 1978). The interval is equivalent to uppermost part of Bima Group (Ola-Buraimo and Oluwajana, 2012).

Interval: 1180-1355m

Zone: *Triorites africaensis/Droseridites* senonicus Assemblage Zone 2

Age: Turonian-Coniacian

Characteristic: The interval is marked at the base by the last uphole appearance of *Gnetaceaepollenites sp* and *Galeacornea sp*. The base is further characterized by basal occurrence of *Cretaceaiporites infrabaculatus, Retimonocolpites sp, Cretaceiporites polygonalis* and *Trifossapollenites rouse*. Other important forms present are *Triorites africaensis, Cretacaeiporites mulleri, Ephedripites multicostatus* and *Droseridites senonicus.* The majority of the forms present are diagnostic of Turonian age. However, there is admixture of Turonian and Coniacian forms towards the top of the interval. Therefore, the interval is suggested to belong to *Triorites africaensis/Droseridites* senonicus assemblage zone. This interval is marked at the top by the last appearance of *Cretacaeiporites mulleri*. The interval is dated Turonian- Coniacian belonging to Gongila Formation (Table 1). Some of the marker forms reported here are similar to the works of Jardine and Magloire, (1965), Kotova, (1978); Lawal and moullade, (1986) and Ola-Buraimo, (2012).

Interval: 1010-1180m

Zone: *Milfordia spp* Acme Zone 3

Age: Campanian

Characteristics: The interval is characterized by maximum development of *Milfordia spp.,* such as *Milfordia jardinei* and *Milfordia sp*. The interval exhibits the same character to those described for Tuma –1 well located in the Bornu Basin, northeastern Nigeria (Ola-Buraimo, 2012) and for Asata/Nkporo Shale in Anambra Basin, Nigeria (Ola-Buraimo and Akaegbobi, 2013). Therefore, the interval is conveniently dated Campanian age and equivalent stratigraphically to lower part of Fika Formation (Table 1).

Interval: 905-1010m

Zone: *Buttinia andreevi* assemblage Zone 4

Age: Early Maastrichtian

Characteristics: The interval is defined at the base by the first appearance of *Buttinia andreevi, Cingulatisporites ornatus*, and last appearance of *Longapertites sp 3*. Other important forms present are *Zlivisporites blanensis, Longapertites sp, laevigatosporites sp, Retidiporites magdalenensis,, Constructipollenites ineffectus, Periretisyncolpites sp, Monocolpites marginatus, Longapertites marginatus, Syncolporites sp, Inaperturopollenites sp, Araucariacites sp,* and *Tricolpites sp*. The assemblages are similar to palynomorphs recovered from Lower Benue Trough dated Maastrichtian (Lawal and Moullade, 1986); similar to miospores studied in Coal Measures in Anambra Basin, Nigeria (Ogala et al, 2009); miospores recovered from Tuma-1 well (Ola-Buraimo, 2012) and those pollen and spores at the upper section of Asata /Nkporo Shale, Anambra Basin, Nigeria (Ola-Buraimo and Akaegbobi, 2013). Therefore, the interval is dated Maastrichtian age and stratigraphically equivalent to Fika Formation.

The formation is diachronous in age and has been assigned Turonian-Maastrichtian by Carter et al., (1963) but was recently dated Campanian- Maastrichtian through palynomorph content (Ola-Buraimo 2012, 2013a). Here, the analyzed interval is in conformity with the results of Ola-Buraimo, (2012, 2013a) on Tuma-1 and Murshe-1 wells on Fika Shale age respectively. The only difference in the stratigraphic age dating of the Fika Shale to earlier reports is the further refinement of the Maastrichtian age into Early Maastrichtian age for the upper section of the Fika Shale.

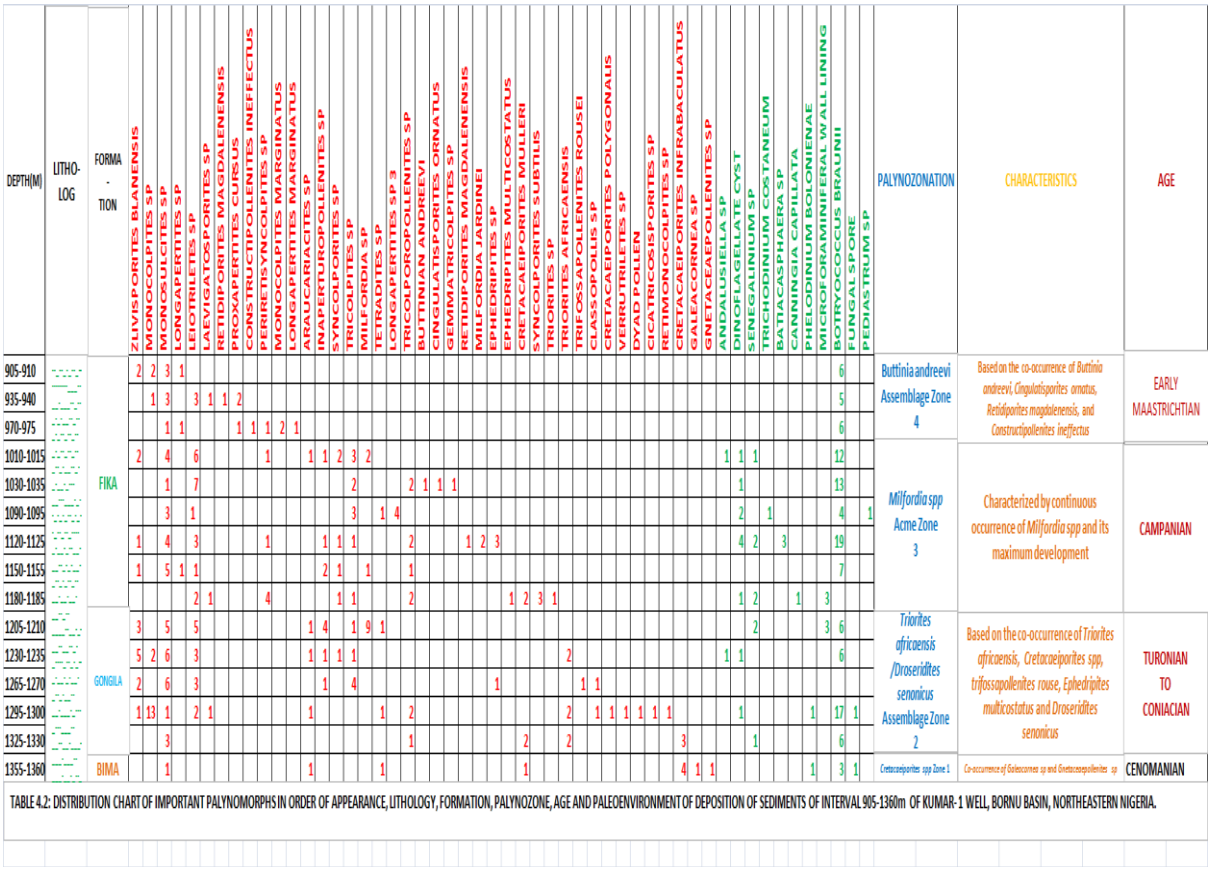


TABLE 4.2: DISTRIBUTION CHART OF IMPORTANT PALYNOMORPHS IN ORDER OF APPEARANCE, LITHOLOGY, FORMATION, PALYNOZONE, AGE AND PALEOENVIRONMENT OF DEPOSITION OF SEDIMENTS OF INTERVAL 905-1360m OF KUMAR-1 WELL, BORNU BASIN, NORTHEASTERN NIGERIA.

Table 1: Distribution chart of interval 905-1360m of Kemar-1 well, Bornu Basin, southeastern Nigeria

Paleoenvironment of Depsition

The paleoenvironment of deposition of the sediments in the entire analyzed interval is characterized by marginal marine The paleoenvironmental deduction made for this research work is based on the combined data of non-pollen palynomorphs such as algae, fungi, microforaminiferal wall linings, gonyaulacacean/peridinacean ratio (G/P) after Harland (1983); and terrestrially derived pollens and spores. Different methods have been used for the interpretation of paleoenvironment from palynological data (Batten, 1973, 1982; Van Berger et al, 1990; and Vadja-Santivanez, 1998). The use of relative abundance of terrestrially derived pollen and marine derived dinoflagellate cysts have also been documented in the works of Lawal, (1982); Schrank, (1984); Edet and Nyong, (1992); Ojo and Akande, (2000); Ogala et al, (2009); Ola-Buraimo and Adeleye, (2010) and Ola-Buraimo and Akaegbobi (2013).

In this research work, the G/P ratio obtained varies from positive value (+ve), negative value (-ve) to zero value when there is no microplankton recovered; but dominated by land derived miospores only. The positive value is here suggested to represent marine environment dominated by gonyaulacacean forms (Ola-Buraimo and Akaegbobi, 2013). The dinoflagellates that characterized this depositional system are peridinoid forms such as *Andalusiella laevigata*, *Andalusiella polymorpha*, *Andalusiella sp*, *Phelodinium bolonienae*, *Senegalinium spp*, and *Odontochitina costata.* They are described to be dinocysts having relatively long processes. They are the only type of dinoflagellates that are present in the samples analyzed.

The peridinoids which are usually greater in abundance than the short spines–gonyaulacacean forms is attributed to relative low or reduced salinity as a result of admixture of fresh water from the fluvial mixing with the saline water of the marine environment present in the estuarine setting. This view had been expressed by Upshaw (1964), Hulbert (1967), Sarjeant, (1970), Jain and Millepied (1973), Oloto (1987), Ogala et al (2009), Ola-Buraimo and Akaegbobi, (2013) and it is similar to present study. Thus, the sediments of Bima, Gongila and Fika Formations are suggested to have been deposited in marginal marine environment.

PLATE 1

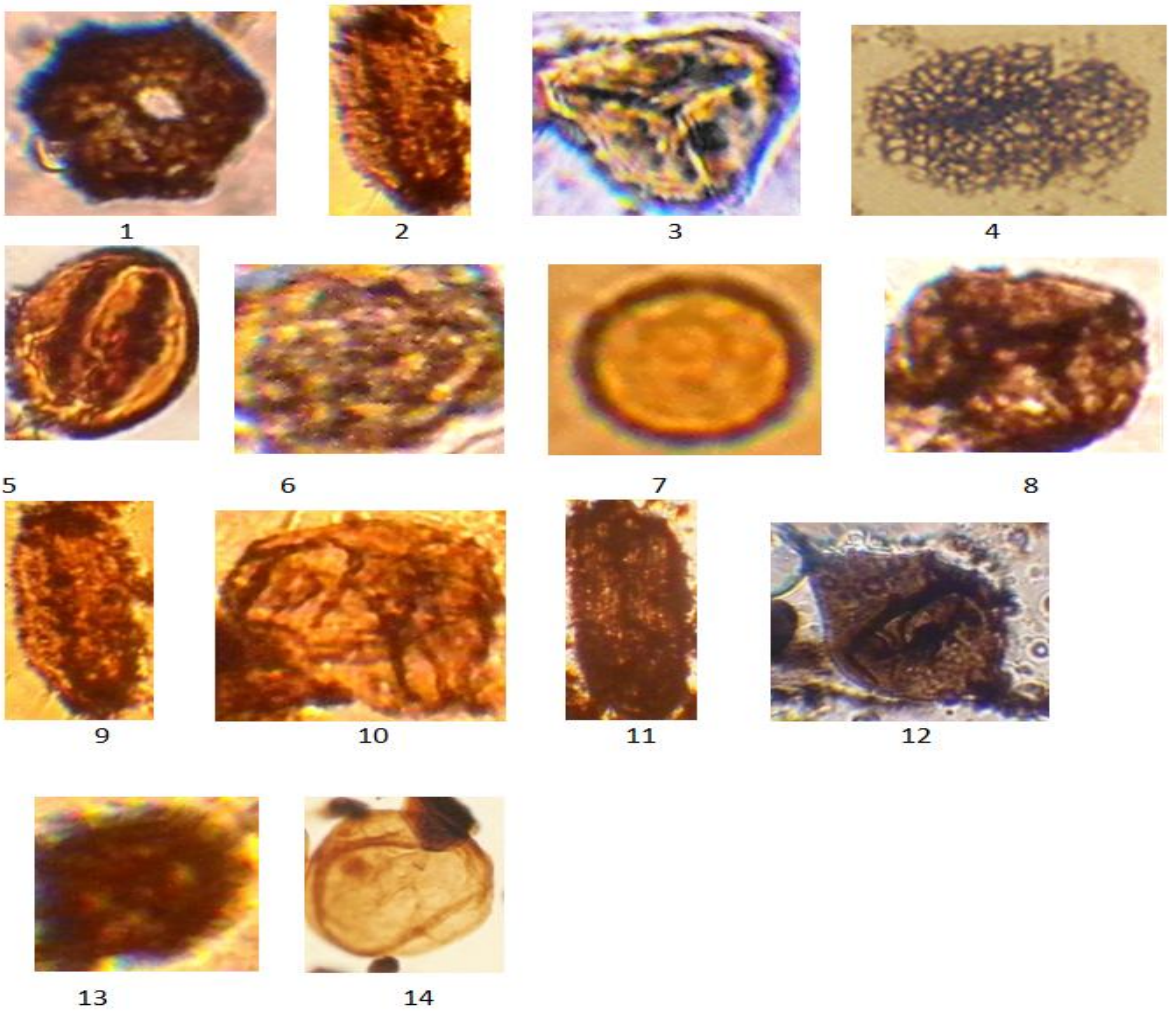


PLATE 1

1	Cretaceiporites polygonalis
2	Steevesipollenites binodosus
3	Cyathidites sp
4	Afropollis jardinus
5	Tricolpites sp
6,7	Cretacaeiporites scrabratus
8	Phelodinium bolonienae
9	Steevesipollenites binodosus sp 6
10	Zlivisporites blanenisis
11	Ephedripites multicostatus
12	Andalusiella polymorpha
13	Cretacaeiporites sp
14	Inaperturopollenites sp

PLATE 2

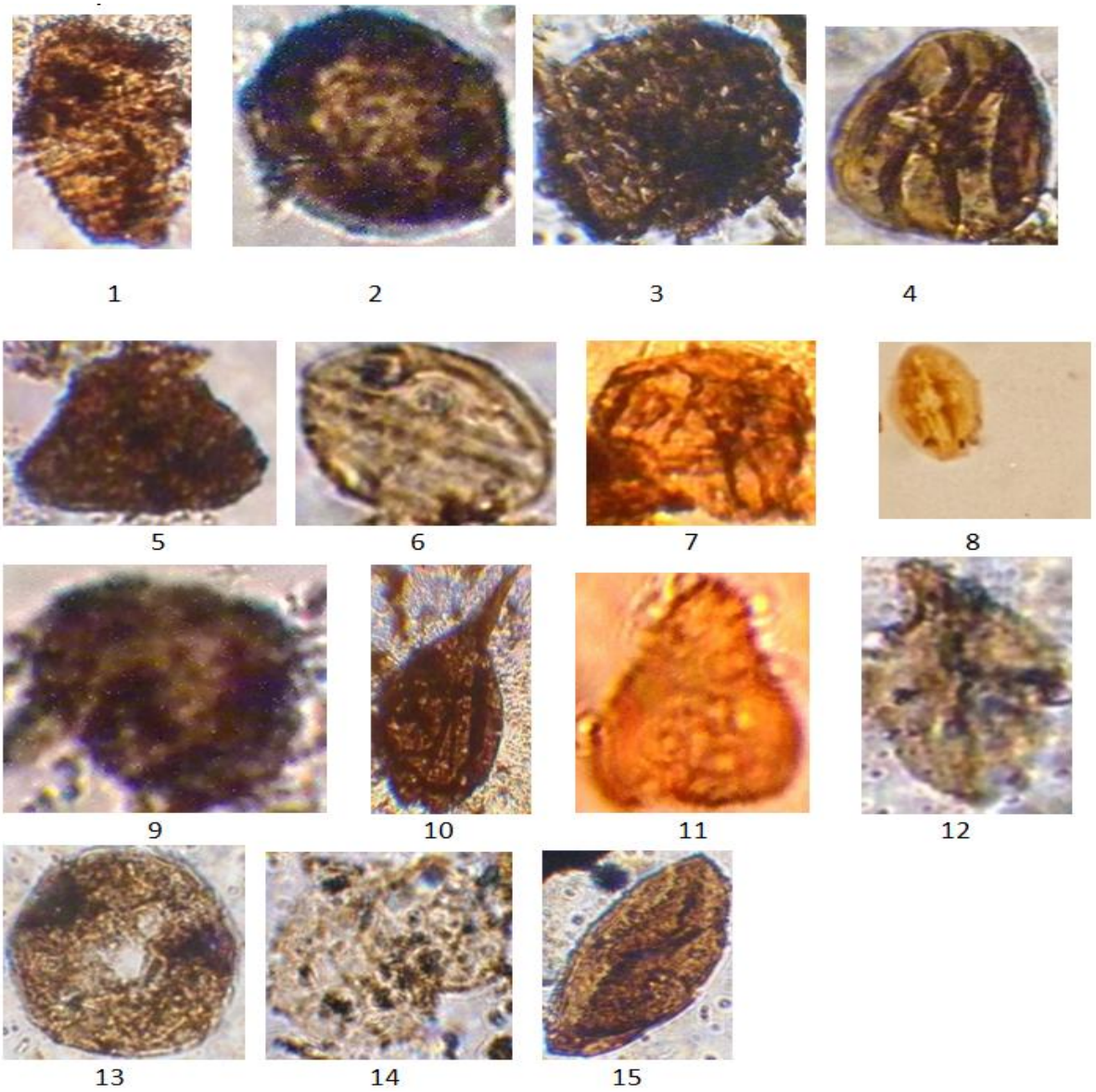


PLATE 2

1	Monosulcites sp
2,3	Milfordia sp
4	Tricolpites sp
5	Triorites africaensis
6	Monocolpites sp
7	Zlivisporites blanensis
8	Tricolporopollenites sp
9	Classopollis brasiliensis
10	Andalusiella polymorpha
11	Triorites africaensis
12	Auriculiidites reticularis
13	milfordia jardinie
14	Senegalinium sp
15	Monosulcites sp

PLATE 3

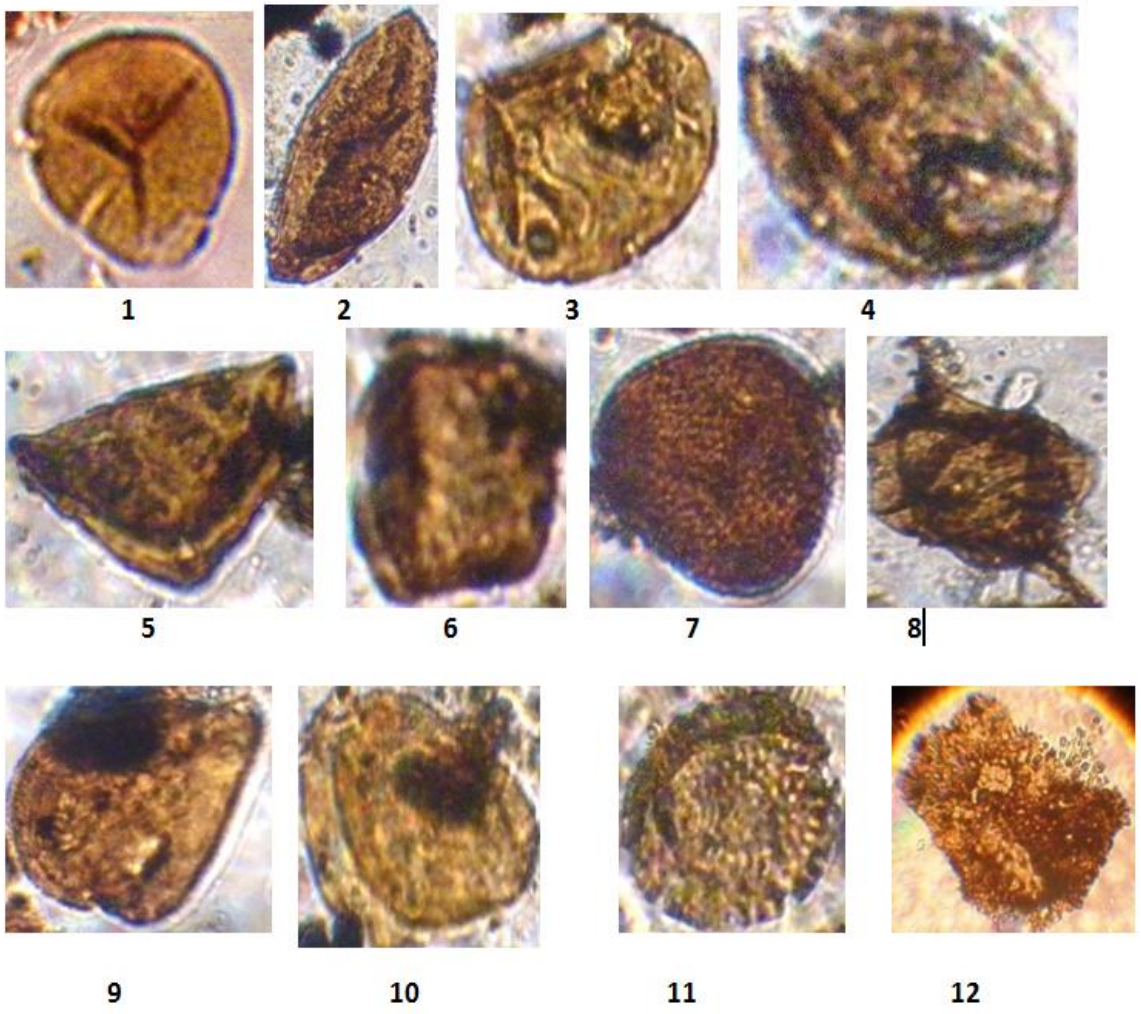


PLATE 3

1 Cyathidites sp
2 Monosulcites sp
3 Laevigatosporites sp
4 Tricolporopollenites sp
5 Auriculiidites reticularis
6 Retidiporites magdalenensis
7 Foveotriletes margaritae
8 Andalusiella oilymorpha
9 retidiporites magadalenensis
10 Longapertites marginatus
11 Proxapertites cursus
12 Phelodinium bolonienae

CONCLUSION

Laboratory analysis of the litho-description and palynological show that there is only one monotonous facies of shale throughout the sequence and three palynozones are established such as *Triorites africaensis;* dated Cenomanian and equivalent to the topmost part of Bima Group; *Triorites africaensis/Droseridites senonicus* assemblage zone 2, dated Turonian to Conician age and equivalent to Gongila Formation; while *Milfordia sp* acme zone 3 is dated Campanian and equivalent to the lower section of the Fika Formation. The established zone 4 is Buttinia andreevi assemblage zone mainly marked by the co-occurrence of *Buttinia andreevi, Cingulatisporites ornatus,* and *Retidiporites magdalenensis*; dated Early Maastrichtian and is equivalent stratigraphically to upper section of Fika Shale. Therefore, the Fika Shale is diachronous and range in age from Campanian to Early Maastrichtian. The paleoenvironment of deposition of the sediments from the topmost Bima to Gongila and Fika Formations were deposited in marginal marine environment

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