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Full Length Research Paper

Biostratigraphy and high resolution paleoenvironmental reconstruction of part of Kemar-1 well, Bornu Basin, Northeastern Nigeria

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Forty seven composited samples from Kemar-1 well in Bornu Basin were analyzed for both lithologic and palynomorph contents. The samples were subjected to lithologic description through the observation of textural parameters and other important features to determine type of lithology and various units present in the sequence. Palynologic sample preparation went through sample digestion, floatation and mounting on glass slides in order to determine palynomorph contents such as pollen, spore, dinoflagellate, foraminifera lining and algae present. The study was intended to evaluate the geologic age and paleoenvironment of deposition by employing various techniques such as ratio of land derived miospores to marine sourced; frequency percent (%) of palynomorph type/group and semi quantitative method by the use of "Palynomorph Marine Index" (PMI) value. The lithostratigraphy shows dominant medium-coarse grained sandstone at the base, overlain by intercalation of brownish sandy clay and clayey sand with various thicknesses. This is overlain by fining upward sequence stacking pattern, prograding and deltaic in nature. The upper part is characterized by repetitive cycle of sandy clay and clayey sand facies. Palynomorph deductions show two zones: *Spinizonocolpites baculatus* zone 1 dated Late Maastrichtian; characterized by occurrence of *Spinizonocolpites baculatus, Retimonocolpites sp, Echitriporites trainguliformis,* and *Zlivisporites blanensis; Proxapertites operculatus* assemblage zone 2, dated Paleocene and characterized by co-occurrence of *Constructipollenites ineffectus*, *Ctenolophonidites costatus, Longapertites sp* and *Monocolpites marginatus.* A K/T boundary is placed at the base of zone 2 at the onset of paucity in palynomorph recovery. The paleoenvironment of deposition is mainly continental at interval 420-600m, while the upper part 50-420m is characterized by alternation of fluviatile and shallow marine settings. This study will help in understanding the chronostratigraphy of the well and in correlation across fault in adjacent wells.

Keywords: Palynomorph group, Palynomorph Marine Index (PMI), Fluviatile, Marine setting

INTRODUCTION

Bornu Basin is a sub basin of the larger Chad Basin which is a regionally extensive intracratonic basin in North-central Africa (Fig 1). It extends from North-eastern Nigeria, Northern Cameroon, Southeastern Niger Republic and Southwestern Chad Republic (Okosun, 1992). Recent upsurge in understanding the geology and petroleum potential of the Basin resulted from a dual reasons; the need by the government to develop the inland basins in the country in order to increase hydrocarbon reserves and the discovery of economic hydrocarbon in Sudan and Chad which are part of the Chad Basin (Obaje et al., 2006).

Works of Carter et al., 1963; Dike, 1993; Zaborski et

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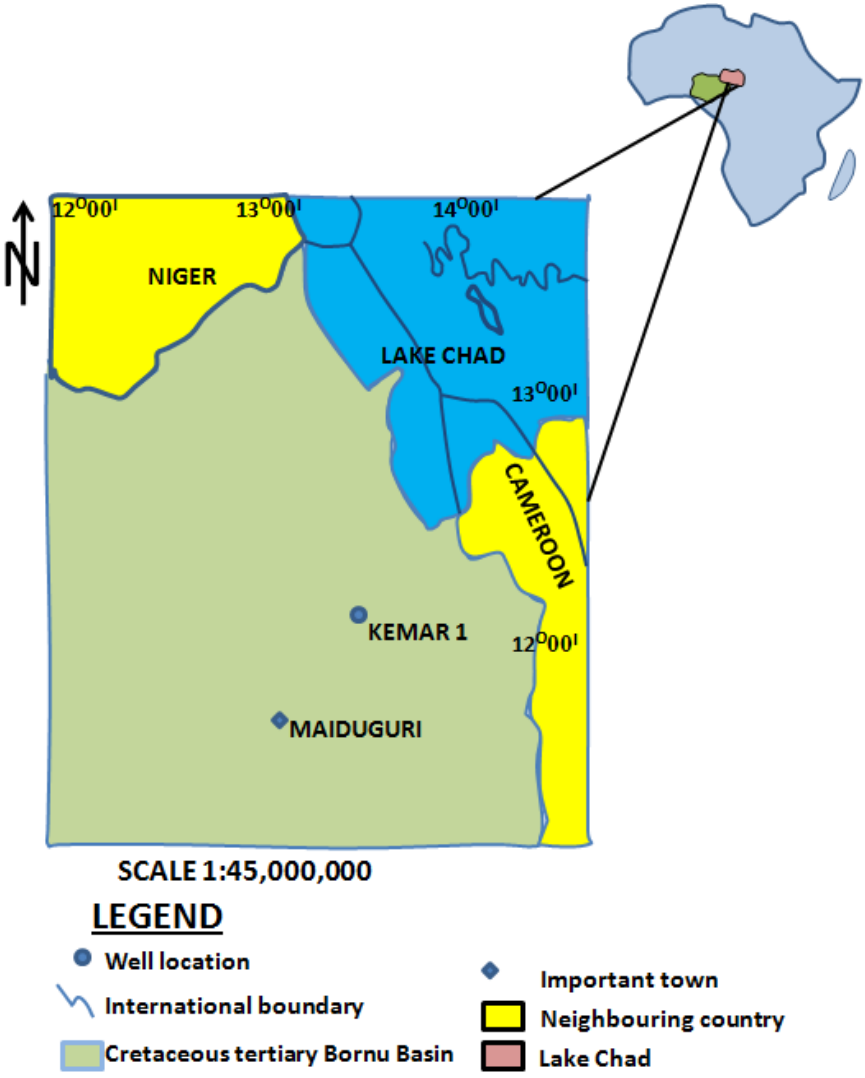


Figure 1. Location map of Kemar-1 (exploration well) in SW Chad Basin (insert map shows position of Chad Basin in Nigeria and Africa respectively).

Al., 1997; Mode, 1997; Zaborski, 1998 and (Ola-Buraimo, 2009) have enunciated the geology and sedimentology of Gombe Sandstone and Kerri Kerri Formation. Recent geological publications on the Bornu Basin are; differentiation of Chad Formation into members and reconstruction of the environment of deposition (Ola-Buraimo, 2005); Palynological investigation of Bima Formations dated Albian–Lower Cenomanian (Ola-Buraimo and Boboye, 2011); detailed lithofacies and palynological study of Bima Group and age definition of the formations (Ola-Buraimo and Oluwajana, 2012); Biostratigraphy and paleoenvironment of Fika Formation dated Turonian to Coniacian – Santonian on the basis of miospores and 3 foraminifera forms and lithostratigraphy and palynostratigraphy of Tuma-1 well with establishment of seven zones ranging in age from Cenomanian-Late Miocene/Pliocene (Adegoke, 2012; Ola-Buraimo, 2012); Albian-Eocene palynological biostratigraphy study of three wells in Bornu Basin (Boboye, 2012). However this present study is aimed at ascertaining the age, palynozones and high resolution paleoenvironment of Gombe Sandstone from Kemar 1 well.

Stratigraphic setting

Bornu Basin was initiated by the Cretaceous-Tertiary rifting which formed from the third failed arm of a triple junction formed during the Albian due to opening of the South Atlantic (Wright, 1968; Burke et al, 1972). Other authors that supported the plate tectonic theory include Genik, (1933); Kings, (1950); and Avbovbo et al., (1980).

Although outcrops are scarce in the area, the detailed stratigraphic units of this basin are known (Carter et al.,

Table 1. Stratigraphical succession in the Bornu Basin, north-eastern Nigeria (modified after barber and Jones, Carter et al., 1963; Avbovbo et al., 1986).

AGE	FORMATION	LITHOLOGY	THICKNESS (m)*	THICKNESS (m) Olugbemiro (1997)	THICKNESS FROM SEISMIC DATA (m) Avbovbo et al., (1986)	AVERAGE THICKNESS (m) Carter et al., (1963)	DEPOSITIONAL ENVIRONMENT
Pliocene, Pleistocene	Chad Formation	Clay, Sand	985	717-1695	800	400	Lacustrine
Palacocene (?)	Kerri-Kerri Formation	Coarse Sandstones, Claystones Sandstones	Not Investigated	Not Investigated		130	Continental
Manstrichtian	Gombe Sandstone	Shale, Sandstone, Siltstone	Not Investigated	Not Investigated	0-1000	315	Deltaic, Estuarine
Turonian-Santonian	Fika Shale	Blue-black Shales	845	840-1453	0-900	430	Marine
Turonian	Gongila Formation	Shales, Limestone, Sandstone	1,295	162-420	0-800	420	Marine-Estuarine
Albian (?) -Cenomanian	Bima Formation	Sandstones, Shale, Limestone	1,525	716-850	2000	3050	Continental
Albian	"Pre-Bima"	Sandstones, Shale		995 (?)	Variable		Paralic-Marine (?)
Pre-Cambrian	Crystalline basement						

1963; Odusina et al., 1983; Avbovbo et al., 1986; Okosun, 1995; Olugbemiro, 1997). In Bornu Basin, six stratigraphic units are recognized this include; Bima sandstone, Gongila Formation, Fika shale, Gombe sandstone, Kerrikerri and Chad Formations (Tab 1). The oldest stratigraphic unit is the Bima Formation. It is diachronous and range from Albian- Lower Cenomanian (Ola-Buraimo and Boboye, 2011). The formation unconformably overlies the basement and it is described to be poorly sorted, sparsely fossiliferous and medium to coarse grained feldspathic sandstone deposited in continental environment (Avbovbo et al., 1986). The Bima Formation is overlain by Gongila Formation. It has been dated as Cenomanian–Turonian and described to consist of shale, limestone, silty sandstone and sandstone (Okosun, 1995; Olugbemiro, 1997). The Gongila Formation is succeeded by open marine sediments known as Fika Shale. It consists of bluish - black, ammonite-rich shale which is locally gypssiferious and contain one or two thin impersistent limestone beds. The Formation is diachronous and has been assigned a Turonian- Maastrichitan age by Carter et al. (1963). An Estuarine/Deltaic sequence comprising of sandstone, siltstone, shales, clays, thin coal beds and ironstone intercalations that overlain the Fika shale is known as Gombe sandstone. The formation has been assigned an Upper Maastrichtian - Palaeocence age. Overlying the Gombe Sandstone is the Kerri-Kerri Formation which is similar in both structure and lithology to the Bima Formation. A Paleocene age had been assigned to this formation (Adegoke et al., 1978). This is succeeded by Chad Formation, the Formation had been assigned Pleistocene age (Barber and Jones, 1960; Carter et al., 1963) and probably Pliocene (Barber, 1965).

METHODOLOGY

Ditch cuttings of forty two (42) samples from depth 50-600m obtained from Kemar-1 well were arranged serially in order of depth. The samples were washed in order to remove drilling mud present. Lithologic description of samples was undertaken by observation of the samples under the microscope and by considering textural parameters which were compared with standard monograph plates of Western Atlas. Textural features considered include grain size and shape in term of roundness and angularity. Other parameters include

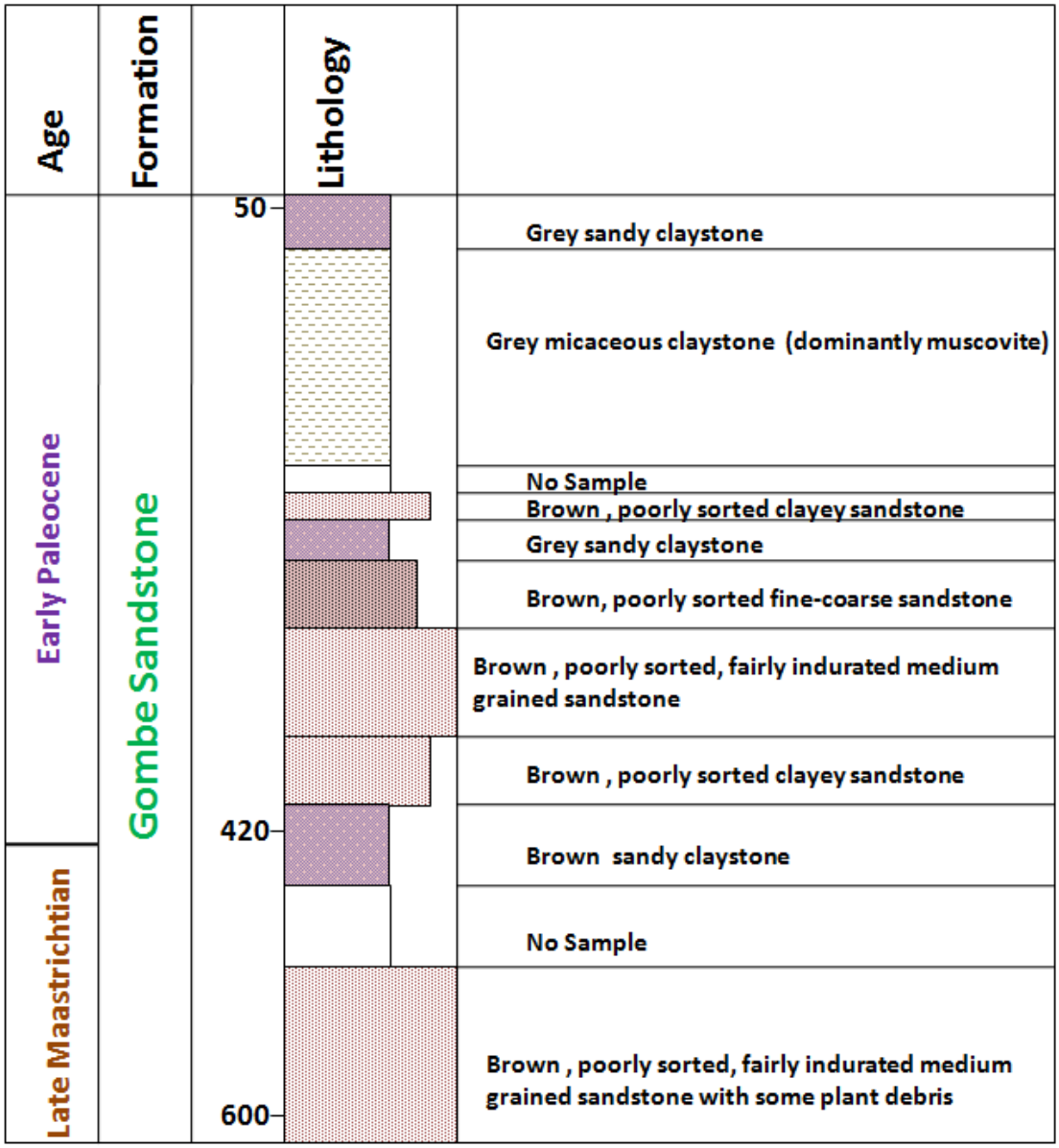


Figure 2. Lithological section and description of interval 50-600m in the Kemar – 1 Well Palynology

sorting, colour, lithology, post depositional effect such as ferruginization; fossil contents and presence of accessory minerals. Dilute hydrochloric acid was used to test for the presence of carbonate in the samples. Samples for palynological purpose were selected at 10m interval, thoroughly washed with distilled water through a 5µm polyester sieve in order to remove drilling mud contaminants and then dried for 24hrs at 50^0C.

Ten (10) grams of each sample was digested with 10% Hydrochloric acid (HCl) acid to remove carbonates. The samples were later soaked in 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 chloride) for 30minutes; washed with 10% Potassium hydroxide, followed by heavy liquid separation with Zinc bromide (Zn_2Br_4) through centrifuging. The aliquots were dispersed with polyvinyl alcohol, dried and then mounted on glass slides with Depex (DPX) mountant. The biostratigraphic study involved the analysis of pollen, spores, dinoflagellates and algae counts under the microscope for chronostratigraphic biozonation. Palynological Marine Index was also calculated in addition to other means of deducing paleoenvironment of deposition. Data obtained was plotted on stratabug software for adequate interpretation. Important palynomorphs were photographed using Nikon Koolpix P6000 digital camera.

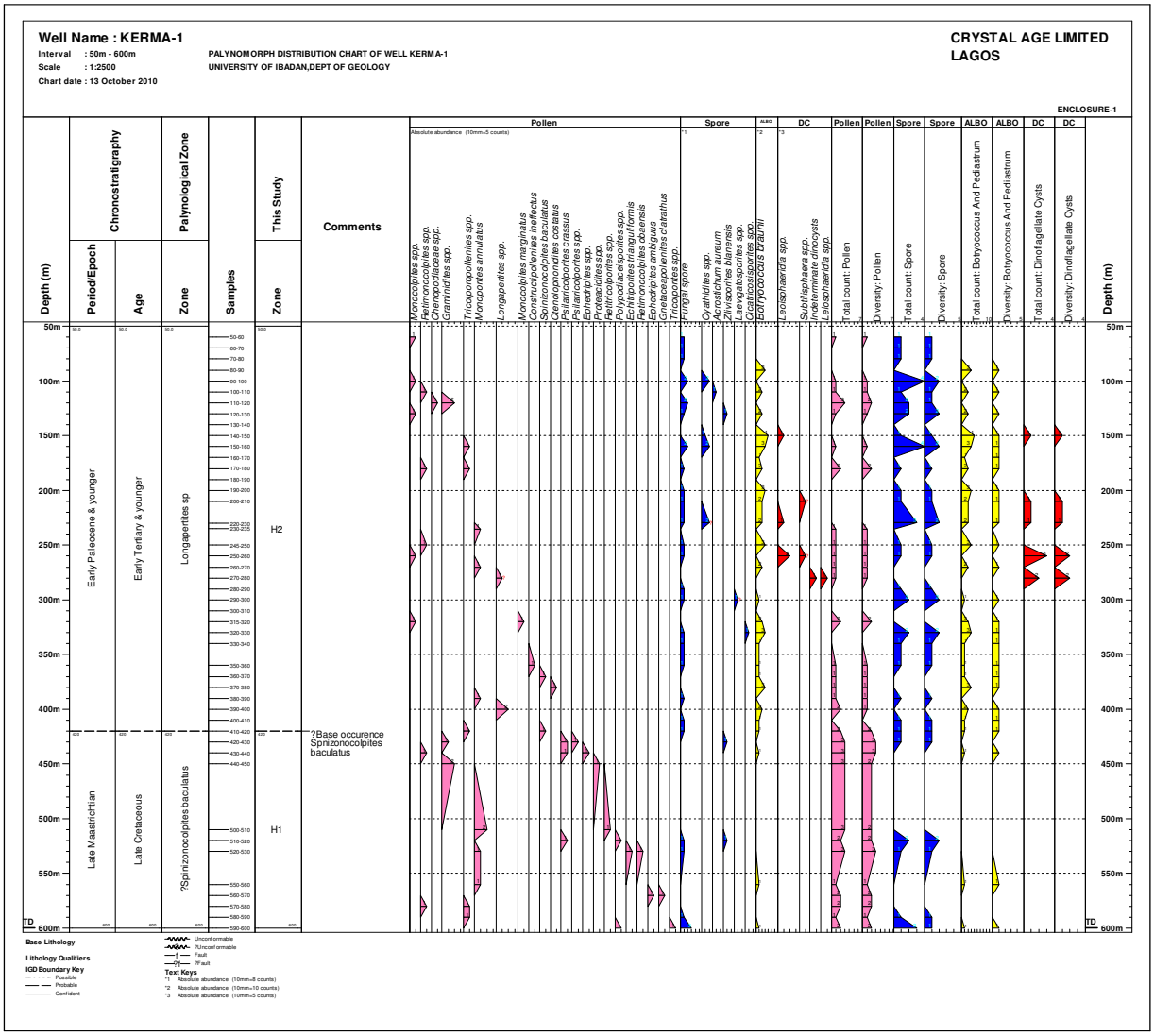


Figure 3. Distribution Chart of Kemar-1 well (50-600m)

RESULT AND DISCUSSION

Lithostratigraphy

The lithologic description carried out on the well yielded information on different lithofacies present in it. The lithologic sequence varies from the bottom at about 600m to 420m with predominant sandstone facies. The sandstone facies varies in size from fine to coarse with an average medium sand grain size. It is further characterized by fair induration and associated with plant debris. This is overlain by intercalation of brownish sandy clay and clayey sand with various thicknesses which may suggest fluctuation in energy of transportation. Overlying sequence at about the middle of the analyzed stratigraphy interval is medium grained sandstone, fairly indurated but poorly sorted in nature. An upward grain size projection shows an apparent fining upward sequence from medium grained sandstone in relationship to the overlying strata characterized by fine grained sandstone in association with minor coarse clasts. This facies is overlain by clay with minor sand grains.

The stratigraphy stacking pattern suggests a progradational sequence typical of a deltaic setting (Fig 2). A repetitive cycle of sandy clay and clayey sand overlies the deltaic deposit. However, a fairly thick claystone is present within the sequence close to the top of the interval, while the topmost bed is characterized by sandy clay facies (Figure 2). The entire stratigraphic sequence is suggested to be Gombe Formation and it is similar in features to observations made by earlier workers (Avbovbo et al, 1986; Ola-Buraimo, 2012; Ola-Buraimo, 2013).

Detailed palynological analysis carried out on the forty two (42) samples of Kemar-1 well (50-600m) recorded poor to fair recovery of palynomorphs in term of

abundance and diversity. The zonation exercise carried out was compared to earlier works done on Cretaceous sediments in Pan Tropical Areas (Germeraad et al, 1968); sedimentary deposits in southern Nigeria (Evamy et al, 1978); Senegal and Ivory Coast deposits (Jardine and Magloire, 1965); in Benue Trough, Nigeria (Lawal and Moullade, 1986); in Anambra Basin, Nigeria (Edet and Nyong, 1994; Ogala et al., 2009; Ola-Buraimo, 2012); in Bornu Basin (Ola-Buraimo 2012, 2013; Boboye 2012).

Details of the palynological zones recognized are discussed below and shown graphically in the palynology distribution chart of Fig 3. However, the erection of biozones is dependent of the evolution, extinction and quantitative occurrence of marker forms present in the sediments (Ola-Buraimo, 2012).

Biozonation

Interval

420-600m

Zone

Spinizonocolpites baculatus zone 1

Age

Late Maastrictian

Characteristics

The interval is marked by the occurrence of Maastrichtian forms and older forms which might be present either as a result of depression of the bioevent or as a result of caving during drilling. However, characteristic forms present are *Spinizonocolpites baculatus*, *Retimonocolpites sp., Echitriporites trianguliformis, Graminidites sp Zlivisporites blanensis,* and *Polypodiaceisporites sp*. This assemblage is similar to those reported on Late Maastrichtian sediments of Senegal and Ivory Coast described by (Jardine and Magloire, 1965); Benue Trough, Nigeria (Lawal and Moullade, 1986); Anambra Basin (Edet and Nyong, 1994; Ogala et al, 2009; Ola-Buraimo, 2012, 2013) and for Bornu Basin (Ola-Buraimo, 2012, 2013; Boboye, 2012). The palynomorph assemblage is also comparable to part of forms reported on Afowo Formation in Dahomey Embayment, southwestern Nigeria (Ikhane et al, 2012; Ola-Buraimo et al, 2012). Other miospores present are *Tricolporopollenites sp, Psilatricoporites sp., Retimonocolpites obaensis, Tricolpites sp.,* and older forms such as *Ephedripites ambiguous* and *Gnetaceapollenites latrathus; botryococcus braunii.* The interval is conveniently dated Late Maastrichtian and correlatable stratigraphically to Gombe Formation.

Paleoenvironment

Paleoenvironment of deposition deduction can be carried out through different means based on the obtained palynomorph data. A comparison of land derived forms to marine sourced microplankton was carried out. Data available shows that freshwater environment pollen such as *Psilatricolporites sp. Laevigatosporites sp.,* and algae of *Botryococcus braunii* are present. Also in negligible frequency is the appearance of *Leiosphaeridia sp.* which suggests a neritic environment.

Further data analysis shows that combined pollen and spore frequency percentage is 92% while dinoflagellate gives 8%. This is shown graphically in the frequency distribution chart (Fig 4) and distribution pattern of palynomorph types and palynostratigraphic sequence respectively (Fig 5).

A semi quantitative interpretation technique was also employed to further determine the paleoenvironment of deposition of interval 420-600m of this well. This is referred to as Palynological Marine Index (PMI). The method is dependent on the amount of terrestrially and aquatic derived palynomorphs separately. Heles et al., (1998, 1999) defined PMI as:

$PMI = Rm / Rt + 1) \times 100$

Where Rm = number of aquatic palynomorphs (Dinoflagellates + Acritarch + Prasinophytes + Foraminifera linings)

Rt = number of terrestrial palynomorphs (Pollen + Spores + Fungal remains)

The data shows that interval 420-600m is dominated with terrestrial environment (fluviatile setting) than the overlying interval. Thus, a predominant fluviatile deposit is suggested for the interval.

Interval

50-420m

Zone

Proxapertites cursus assemblage zone 2

Age

Paleocene

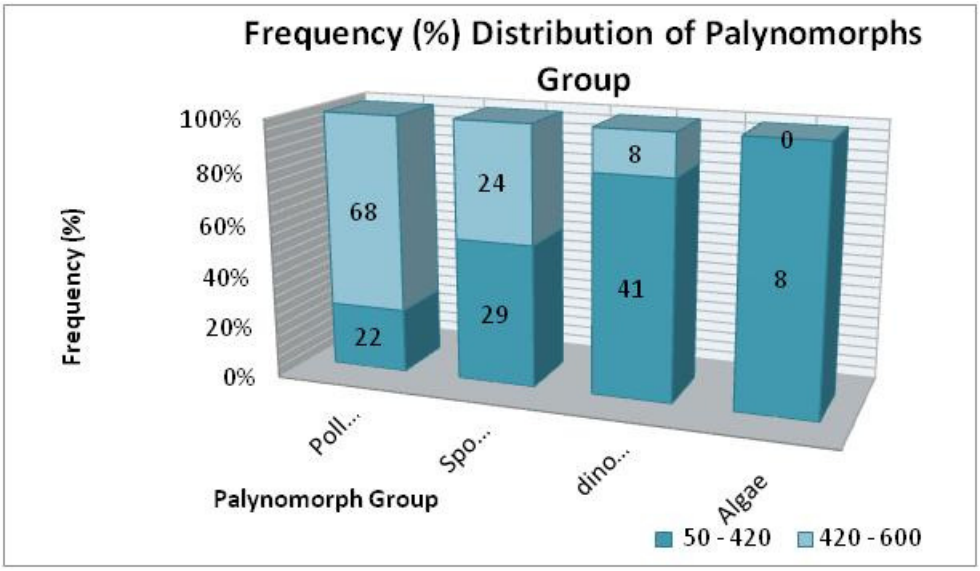


Figure 4. Frequency distribution plot of palynomorphs in Kemar-1 well

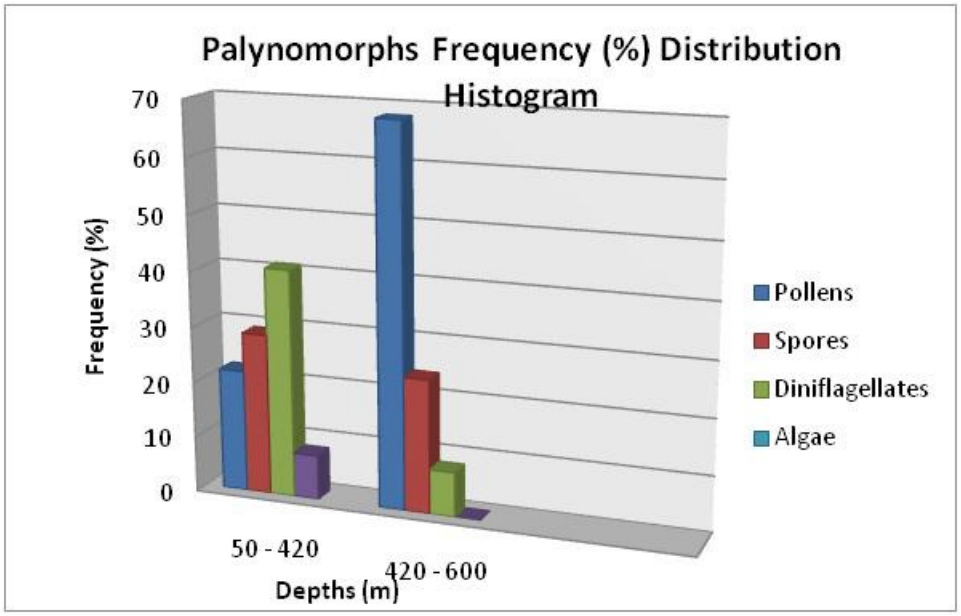


Figure 5. Histogram of frequency (%) palynomorphs distribution (Kemar-1).

Characteristics

The base of the zone coincides with the top of the older underlying zone characterized by the occurrence of *Spinizonocolpites baculatus.* The top of the zone is not present in the analyzed interval but it is tentatively placed at 50m where the analysis commenced. The interval in marked by the appearances of important miospores such as *Monocolpites sp., Retimonocolpites sp., Chenopodiaceae sp, Tricolporopollenites sp., Longapertites sp,* and reduced frequency of *Monocolpites marginatus.* Other forms present are *Constructipollenites ineffectus, Spinizonocolpites baculatus, Ctenolophonidites costatus, Psilatricolpites sp, Ephedripites sp,, Cyathidites sp, Acrostichum sp, Zlivisporites b;anensis* and *Laevigatosporites sp*. A substantial amount of the assemblage found in this well have been reported for Paleocene sediments of Pantropical area (Germeraad et al, 1968); for the Paleocene sediments in southern Nigeria (Evamy et al., 1978); in Aanambra Basin, Nigeria (Ola-Buraimo, 2012). The interval is dated Paleocene and correlatable to

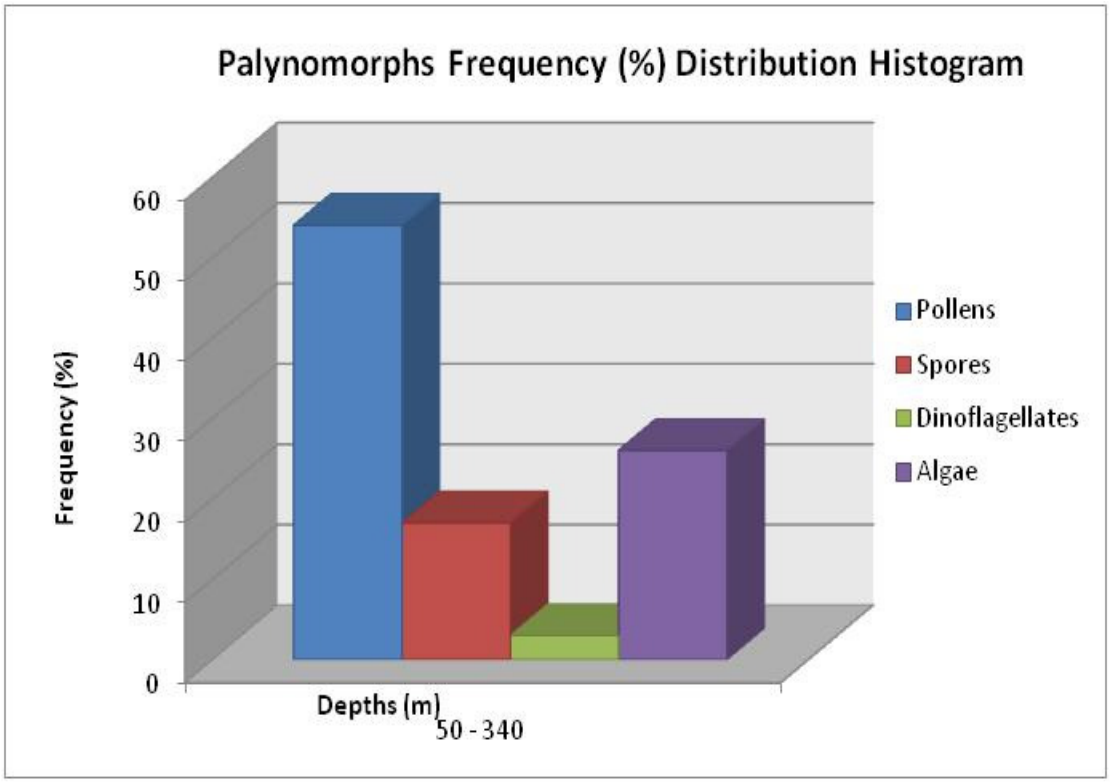


Figure 6. Histogram of frequency (%) palynomorphs distribution for interval 50-420m in Kemar-1 well.

Paleocene sediments in adjacent well located in the basin belonging to Gombe Formation (Ola-Buraimo, 2012; 2013).

One of the main characteristic features of Paleocene sediments is that some of the major forms present in the older Maastrichtian facies are often seen in the interval however, the Cretaceous-Tertiary (K/T) boundary is usually marked by paucity in the frequency of palynomorph recovered as noticed in the in this well section (Lawal and Moullade, 1986; Ola-Buraimo, 2012; 2013). This observation further put the age of the interval to be Paleocene and stratigraphically equivalent to Gombe Formation. In this well Gombe Formation can be described to be diachronous ranging from Maastrichtian to Paleocene in age.

Paleoenvironment

The paleoenvironment of deposition of the interval 50-420m was determined by considering the preferable environment of deposition of environmentally indicative forms such as *Polypodiaceaesporites sp, psilatricolpites sp, Laevigatosporites sp* and *Botyrococcus braunii* which are indicative of freshwater environment (Fredericksen, 1985, Ruta et al, 2007); *Acrostichum sp* is suggestive of brackish (mangrove) environment, while *Leiosphaeridae sp* is indicative of neritic environment. Therefore, the interval can be suggested to vary from continental through brackish to inner neritic setting.

Frequency percentage distribution of the palynomorphs shows that the interval (50-420m) has 51% of land derived grains, 41% of dinoflagellates and 8% of algae present. This could suggest an alternation of fluviatile and marine regimes for the interval. A similar graphic pattern constructed for the interval shows that land derived pollen and spores accounted for 71%, dinoflagellates-3%, and algae-19%. Interplay of sea level changes in association with fluctuating climatic conditions are suggested for paleoenvironmental pattern observed.

Further paleoenvironmental deduction based on distribution patterns of palynomorph types using frequency % distribution shows similar shift in coastline position from landward to seaward at different periods (Fig 6).

Quantitative interpretation technique applied using Palynomorph Marine Index (PMI) values show that intervals with PMI value range between 200-300 are 140-150m, 190-210m, 250-260m, 270-280m, and 290-300 are equivalent to marine deposits; while PMI value <200 such as interval 50-130m, 140-190m, 230-250m, 270-290m, and 300-420m are equivalent to fluviatile deposits (Fig 7). Other stratigraphic intervals are either not provided with samples or are barren of palynomorphs recovery. A, general overview of the plot of PMI values against analyzed stratigraphic interval 50-600m shows

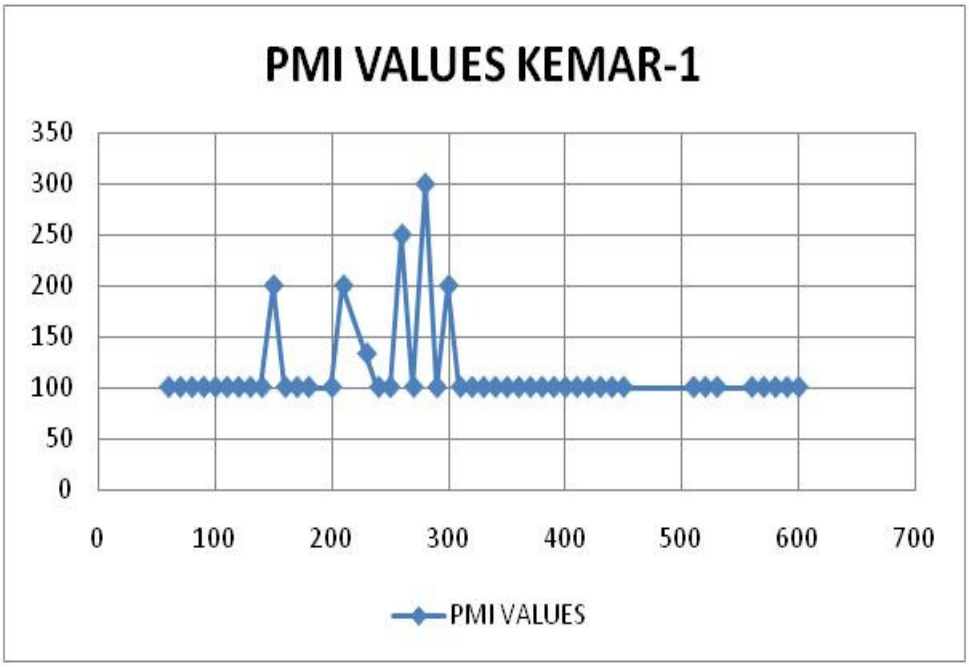


Figure 7. Palynomorph Marine Index (PMI) chart of kemar-1 well.

that between interval 300-600m is characterized by PMI value of about 100, indicative of fluvial deposit; while between interval 150-1300m shows an alternation of value range between 100-300 suggesting an alternation of continental and marine deposits. The uppermost part with a depth range be of 50-150 is defined by PMI value of 100, suggestive of continental deposit due to dominance of land derived palynomorphs. Therefore, paleoenvironment that fluctuate between continental and shallow marine environments is suggested for the upper part of the Gombe Formation.

CONCLUSION

Lithofacies relationship in the well sequence varies from base where the analysis ends to the top at 50m. At the bottom of the studied interval at 600m upward to about 500m is the deposition of medium to coarse grained sandstone, overlain by intercalation of brownish sandy clay and clayey sand with various thicknesses. This is stratigraphically overlain by a fining-up sequence stacking pattern, prograding and deltaic in nature. The upper part of the interval is characterized by repetitive cycle of sandy clay and clayey sand depicting continental deposit.

Palynology Inference shows two main palynological zones: *Spinizonocolpites baculatus* zone 1, dated Late Maastrichtian and characterized by co-occurrence of *Spinizonocolpites baculatus, Retimonocolpites sp, Echitriporites trianguliformis*, and *Zlivisporites blanensis*. The overlying younger interval 50-420m is associated with *Proxapertites cursus* assemblage zone 2, dated Paleocene age, defined by assemblage of *Constructipollenites ineffectus, Ctelophonites costatus, Longapertites sp,* and *Monocolpites marginatus.* The placement of Cretaceous-Tertiary (K/T) boundary in the studied interval was based on the surface that separates the relative richer lower sequence from the upper interval characterized by paucity of palynomorphs which is in consonance with the opinion of earlier researchers.

High resolution paleoenvironmental deductions carried out through relative frequency of land derived forms to marine derived forms shows that the lower interval; 420-600m is mainly of terrestrial deposits while interval 50-420m is characterized by alternation of continental and marine depositional environment. Frequency percentage distribution shows that 51% are land derived facies, 41% are dinoflagellates and 8% algae aggregate of fluviatile and marine influenced sedimentation for the interval 50-420m; while interval 420-600m shows 71%, 3% and 19% respectively. It is suggested that sea level changes in association with flunctuating climatic conditions are responsible for environmental variation. Furthermore, a quantitative technique using Palynomorph Marine Index (PMI) values shows that interval 420-600 indicate PMI value of about 100 which is equivalent to terrestrial deposit while the upper part (50-420m) shows alternation of continental and marine environment. However, PMI value greater than 200 (between 200-300) was interpreted to be marine setting. Hence, the paleoenvironment of deposition of Gombe Formation

PLATE 1

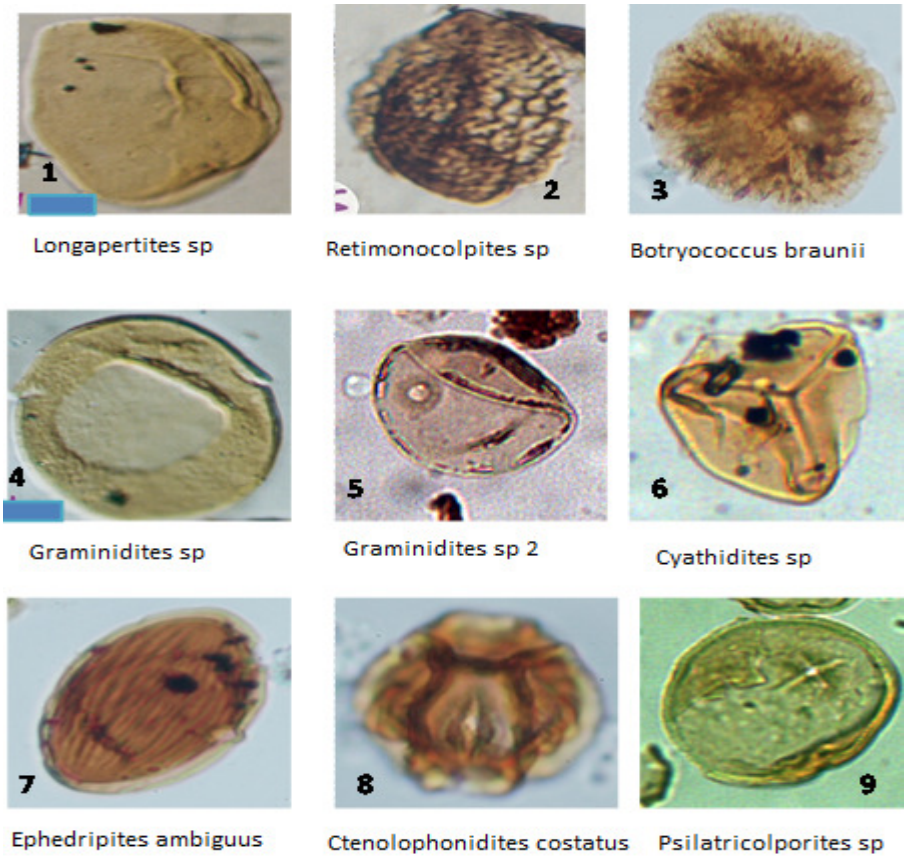
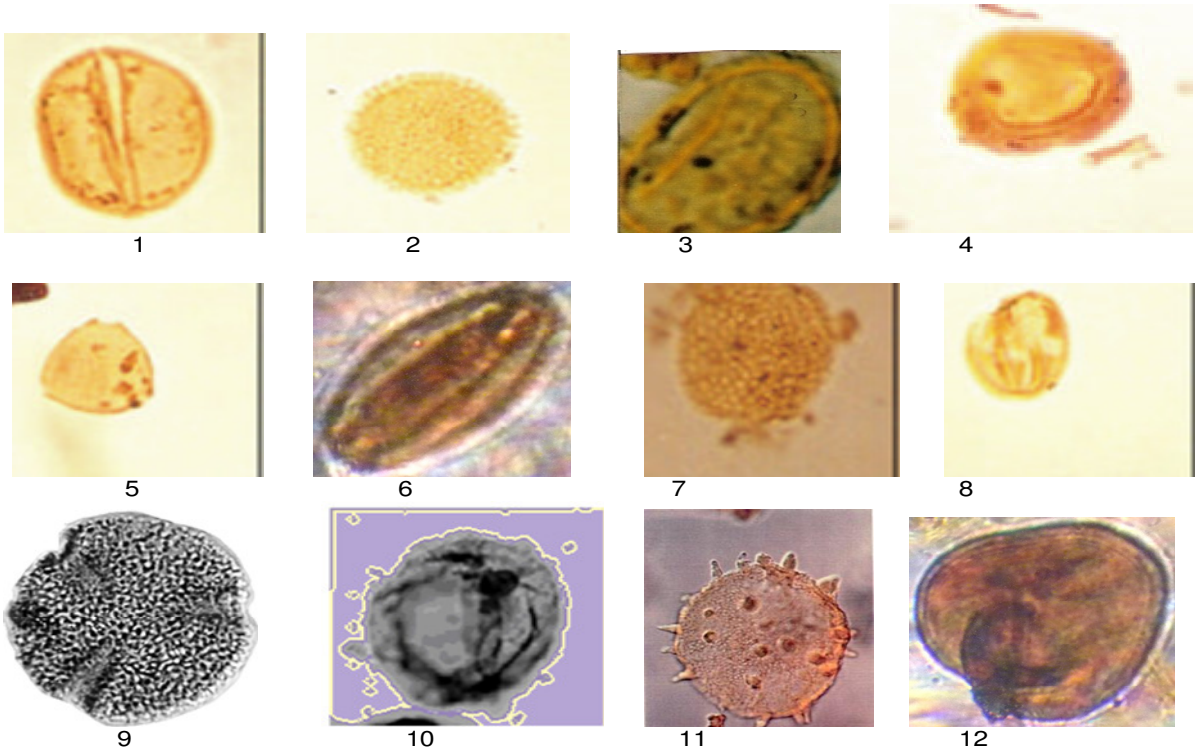


PLATE 2



1. Monocolpites marginatus
2. Constructipollenites ineffectus
3. Verrucatosporites usmensis
4. Cingulatisporites ornatus
5. Echitriporites trianguliformis
6. Tricolpites sp
7. Zlivisporites blanensis
8. Tricolporopollenites sp
9. Tricolporites sp
10. Leoisphaeridia sp
11. Spinizonocolpites baculatus
12. Cyathidites sp

flunctuates between continental and shallow marine environment.

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