

Chronostratigraphy and Lithostratigraphy of a section of Murshe-Well, Bornu Basin, Northeastern Nigeria

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ABSTRACT

Two hundred and ninety (290) and twenty one (21) samples were used respectively for litho-description and palynological analysis. Sedimentologically, the Gongila Formation contains mainly shale, sandy at the upper end; deposited in a deltaic to marine environment. Fika Formation is mainly shale with interbeds of silt and gypsum at different levels; the shale is dark grey to black in colour, deposited in a marine setting. Gombe Formation lies unconformably on Fika Shale with basal conglomeratic sandstone, overlain by light brown to light grey claystone deposited in continental environment; while the Kerrikerri Formation is mainly sandstone, conglomeratic at the base and overlain by bulky shale and claystone suggestive of lacustrine to fluvial settings.

Five palynological zones were established, including *Triorites africaensis* assemblage zone characterized by co-occurrence of *Classopollis brasiliensis*, *Triorites africaensis*, and *Retimonocolpites* sp; dated Turonian age. *Syncolporites* sp/*Milfordia* sp assemblage zone is dated Senonian to Campanian based on the assemblage of *Syncolporites* sp, *Milfordia* sp, *Mauritiidites crassibaculatus*, and *Aequitridites* sp. The *Spinizonocolpites baculatus* assemblage zone is defined by the co-occurrence of *Longapertites marginatus*, *Periretisyncolpites* sp, *Trichotomosulcites* sp, *Auriculiidites* sp, *Foveotritetes margaritae*, *Spinizonocolpites baculatus*, *Monocolpites marginatus*, *Striatopollis bellus* and *Retidiporites magdalenensis*; indicative of Maastrichtian age. The *Proxapertites cursus* assemblage zone is distinguished from the older Maastrichtian sediment based on the paucity of palynomorphs and appearance of *Verrutricolporites* sp. Zone P400 (70-315m) is dated Eocene-Younger based on the co-occurrence of *Monoporites annulatus*, *Retibrevitricolporites protrudens*, *Longapertites vernendenburgi* and *Lycopodium phlegmaria*.

Key Words: Lacustrine, Fluvial, Marine, Setting, Zone

34 Introduction

35 Palynological research work was employed to investigate the biostratigraphy of 
 36 well in Bornu Basin, southeastern Nigeria. Though, few palynologic 
 37 the basin compared to other basins Nigeria; **thus**, this research study was necessitated in order
 38 to understand the lithofacies  of the formation, the chronostratigraphy of the basin and their
 39 associated paleoenvironment of deposition.

40 The lithostratigraphy of the well is **well** documented and compare favourably with the
 41 work of Avbovbo et al (1986). The stratigraphic study of the Bornu Basin have been widely
 42 carried out by earlier workers such as Adegoke et al, (1978); Odusina, et al, (1983); Avbovbo
 43 et al, (1986); and Olugbenro, (1997) to mention a few 

44 Recent studies include detail studies **on** Chad Formation, describing the different three
 45 members contained in it and their environment of deposition (Ola-Buraimo, 2005);
 46 granulometric and paleoenvironment of Kerikerri Sandstone (Ola-Buraimo, 2009); others are
 47 the palynological investigation of Bima Formation dated Albian to Lower Cenomanian (Ola-
 48 Buraimo and Boboye, 2011); while detail lithofacies of the Bima Group and subdivision of
 49 their geologic ages (Ola-Buraimo and Oluwajana, 2012 ). Therefore, this present study is
 50 intended to augment earlier works done on this basis  

52 Geologic Setting

53 The geology of Bornu Basin has been widely investigated by earlier workers such as
 54 Falconer, (1911); Raeburn and Brynmor (1924); Carter et al (1963) and Barber, (1965 
 55 Formation of Bornu Basin was predicated on third failed arm of a triple junction formed
 56 during the Albian due to opening of the South Atlantic (Wright, 1968; Burke et al, 1970).
 57 Other authors that supported the plate tectonic theory include Genik, (1933); Kings, (1950);
 58 and Avbovbo et al, (198 

59 The stratigraphy of Bornu Basin have been widely studied, these include the work of
 60 Adegoke et al, (1978); Petters, (1978b); Kogbe, (1979); Petters (1981); Avbovbo et al,
 61 (1986); Ola-Buraimo, (2005) and Ola-Buraimo, (2009). The amount of biostratigraphic
 62 studies in this basin is incomparable to other sedimentary basins in Nigeria. Few works done
 63 include that of Barber and Jones, (1960); Carter et al, (1963); Reyment, (1965); Adegoke et
 64 al, (1978); Petters, (1982); Odusina et al, (1983); Wonzy and Kogbe, (1983); Popoff et el,
 65 (1986); Oti, (1990); Okosun(1995); Olugbemiro, (1997); Ola-Buraimo, (2005); Ola-Buraimo,

(2009); Ola-Buraimo and Boboye, (2011). However, few palynological studies were reported from the basin, including the work of Adegoke et al, (1978); Ola-Buraimo and Boboye, (2011); Ola-Buraimo and Oluwajana, (2012)

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)

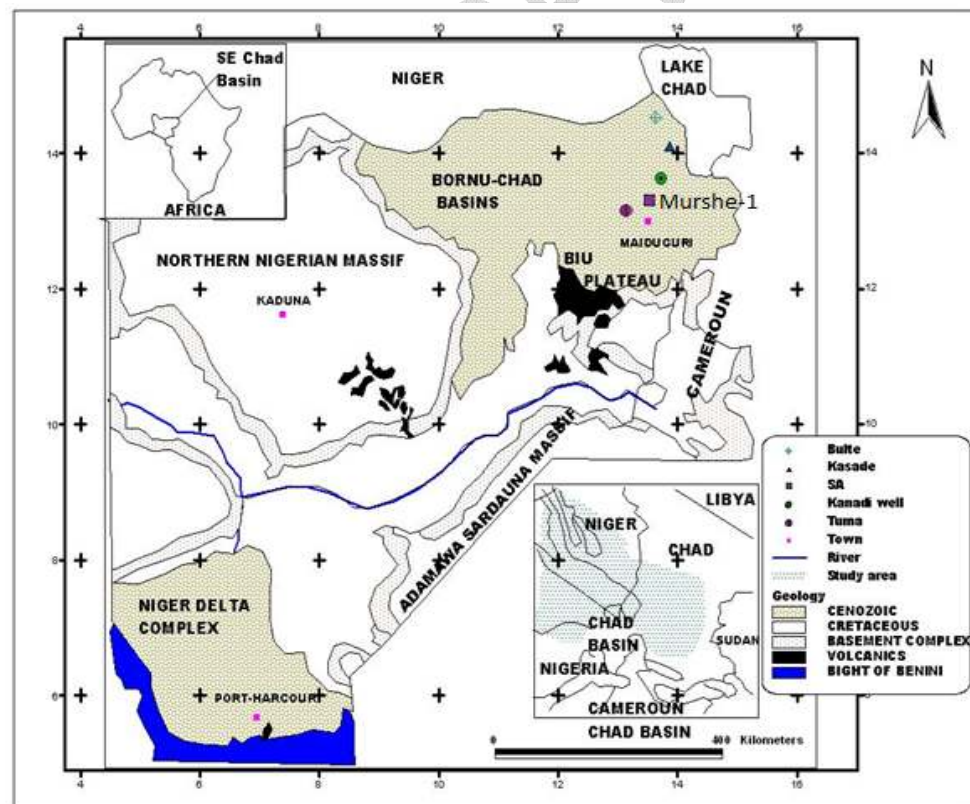


Figure 1: Geological map of Nigeria showing the location of Bornu Basin and the studied well (modified after Whiteman, 1982 and Genik, 1993)

118

119 MATERIALS AND METHODS

120 Ditch cutting samples of about 290 were arranged serially in order of depth. Lithology
121 description was carried out by looking at the sediments under the microscope; comparison of
122 the textural parameters with standard monograph plates of Western Atlas was carried out.
123 Textural features taken into consideration include, grain size, shape in term of roundness and
124 angularity. Others parameters include sorting, colour, lithology, post depositional effect such
125 as ferruginization; fossil contents, presence of accessory minerals and effect of dilute
126 hydrochloric acid on the samples which depicts the presence of carbonate. Samples for
127 palynological purpose were selected at 27.4m (90ft) interval, thoroughly washed with
128 distilled water through a 5µm polyester sieve in order to remove drilling mud contaminants
129 and then dried for 24 hours at 50°C.

130 Ten (10) grams of each sample was digested with 10% HCL to remove CaCO_3 . It was
131 later soaked with 60% hydrofluoric acid (HF) for 24hrs to digest the silica. The content was
132 sieve- washed (5µm) with water and later oxidized in Schulze solution (mixture of nitric acid
133 and potassium chlorate) for 30minutes, washed with 10% potassium hydroxide, followed by
134 heavy liquid separation with Zn_2Br_4 through centrifuging. The aliquots were dispersed with
135 polyvinyl alcohol, dried and then mounted on glass slides with DPX mountant. The
136 biostratigraphic study involved the analysis of pollen, spores, dinoflagellates and algae under
137 the microscope for chronostratigraphic biozonation. Important palynomorph pictures were
138 taken using Nikon Coolpix P6000 digital camera.

139

140 Result and Discussion

141 Sedimentology

142 Four formations within the stratigraphic section are marked out on the basis of
143 correlation with palynological ages derived from the palynological analysis of this research
144 work. The details of the stratigraphic units encountered in the well are discussed below (See
145 Figure 2)

146 Gongila Formation

147 The Gongila Formation is a transitional sequence that lies in-between the underlying marine
148 shale of Bima Formation and the typical marine setting of the overlying Fika Formation. The
149 Gongila Formation is characterized at the base by shale sequence (1880-1930m), black,

fissile, calcareous and fairly ferruginised in nature. The 50m thick marine shale is overlain by intercalated sand and shale; the light gray sandy shale heterolith is defined by fine to medium sand grains, well sorted sediment. The 60m heterolith facies (1820-1880m) forms the uppermost part of the Gongila Formation and deposited in a deltaic setting. The formation was deposited in a deltaic to marine environment and dated Turonian to Senonian age. It is remarkable that volcanic intrusive reported by earlier workers in this formation is not visible here, therefore, it is suggested that the intrusion was a local effect.

UNDER PEER REVIEW

Depth(m)	Litho-log	Description	Formation/ Age	Paleo-environment
70		Very light grey claystone	Kerikeri Eocene	Lacustrine To Proximal Fluvatile
		Light grey bulky shale		
280		Milky to pinkish coloured sandstone, conglomeratic in nature, size varies from fine to medium pebble, angular to rounded, poorly sorted		
320		Reddish brown, bulky mudstone		
385		Light brown to light grey bulky claystone with intercalated sandstone	Gombe Paleocene	Continental
525		Brownish coloured conglomeratic sandstone; fine to pebble in size, very poorly sorted.		
590		Dark grey to black fissile shale, rare coarse to pebble sized grains, calcareous with gypsum		
620		Black fissile silty shale		
840		Dark grey to black fissile shale	Fika Campanian-Maastrichtian	Marine
890		Black fissile shale with intercalated gypsum		
1185		Light grey sandy shale; sand size varies from fine to medium, well sorted		
		Black fissile shale, calcareous and fairly ferruginised		
1820		Light grey sandy shale; sand size varies from fine to medium, well sorted	Gongila Turonian-?senonian	Deltaic To Marine
1880		Black fissile shale, calcareous and fairly ferruginised		
1930				

Figure 2: Lithostratigraphy, Chronostratigraphy, Formation and Paleo-environment of Well M-1 Bornu Basin, Nigeria. (Not to scale)

181 Fika Shale

182 This formation varies in depth from 620-1820m with an estimated thickness of 1200m. This
183 seems to be the greatest thickness compared to the work of Carter et al, (1963); Okosun
184 (1995) and Olugbemiro (1997); but it compares favourably with the thickness derived from
185 seismic data of Avbovbo et al, (1986). The Fika Formation lies unconformably on the Gongila
186 Formation (Ola-Buraimo, 1990 Unpublished M.sc thesis). The formation is not entirely shaly
187 but rather shows intercalated gypsum at the lower to middle part of the sequence; while the
188 middle part is characterized by silty shale deposited between interval 840-890m and it is 50m
189 thick. The uppermost part is a shale facies, shows rare coarse to pebble sand grains;
190 calcareous and rare occurrence of gypsum serves as accessory mineral. The
191 paleoenvironment of deposition is suggested to be marginal to open marine while
192 transporting medium was of relatively high energy and erosive in nature (turbidity current)
193 which might be responsible for clast particles present in the shale sediment during deposition.

194 There is no trace of volcanic intrusive in this well. However, the huge thickness of 1200m
195 observed in the well section may agree with Avbovbo et al (1986) observation that the
196 Cretaceous beds thicken towards the centre of the basin. Thus, it is likely that this well M-1 is
197 located in the middle of the basin.

198 Gombe Formation

199 The Gombe Formation occupies interval 385-620m with a thickness of 235m. The
200 formation is characterized by a basal sandstone unit of about 30m (590-620m). The sand is
201 brownish coloured conglomerate, fine to pebble in grain size, and very poorly sorted. The
202 overlying interval 385-590m contains light brown to light grey bulky claystone with an
203 interbed of sand. The environment of deposition is suggested to be of distal continental to
204 proximal fluvial paleoenvironment.

205 Kerikeri Formation

206 The Kerikeri Formation is Eocene in age, lacustrine at the upper part to proximal
207 fluvial environment of deposition. The lower sandy part varies from depth 280-320m (40m
208 thick). The interval is milky to pinkish in colour, conglomeratic in nature; grain size varies
209 from medium to pebble, subangular to rounded, and poorly sorted. The basal sand marks the
210 unconformable contact with the older underlying Gombe Formation. The sandstone is
211 overlain by light grey claystone intercalated by light grey bulky shale. Therefore, the

212 Kerrikerri Formation is not entirely continental but rather lacustrine to continental in term of
213 environment of deposition

214 **Palynology**

215 Miospore recovery is moderate to barren at different intervals. However,
216 palynomorph preservation is good. Microplanktons are as well present in the well while their
217 presence is used to determine the paleoenvironment of deposition. Palynozonation
218 interpretation is generally based on the evolution of the miospores, their extinction and their
219 relative frequencies dependent on the ecology and other environmental factors. Thus, five
220 palynozones were erected based on the assemblages of diagnostic forms which were
221 compared with the works of earlier researchers including Jardine and Magloire, (1965);
222 Germaraad et al, (1968); Evamy et al, (1978); Lawal and Moullade, (1986). Details of the
223 basis of establishing the palynozones are given below:

224 **Zone:** Triorites africaensis assemblage zone 1

225 **Interval:** 1755-1930m

226 **Age:** Turonian

227 **Characteristics:** The base of the interval is placed at 1930m where the analysis commenced.
228 It is characterized by paucity of miospores and the appearance of *Classopollis brasiliensis*
229 and *Histrichosphaeridium* sp. The near base of the interval has the admixture of
230 dinoflagellates such as *Andalusiella* sp and *Senegalinium* sp; pollen such as *Liliacidites* sp
231 and *Inaperturopollenites* sp.

232 The top of the interval is marked by the top appearance of *Triorites africaensis* and
233 appearance of *Retimonocolpites* sp and *Monosulcites* sp. The interval is stratigraphically
234 equivalent to Gongila Formation (Figures 2 and 3).

235 **Zone:** Syncolporites/Milfordia sp assemblage zone 11

236 **Interval:** 1580-1755m

237 **Age:** Senonian-Campanian

238 **Characteristics:** This interval is composed of assemblage of palynomorphs that are depictive
239 of Senonian and Campanian ages. The interval 1665-1670m has new appearances of

Syncolporites sp, *Milfordia* sp, *Aequitridites* sp, *Monosulcites* sp and *Cyathidites* sp. Microplanktons such as *Senegalinium* sp 2, *Phelodinium bolonienae*, and *Dinogymnium undulosum* and microforaminiferal wall lining occurred at this interval.

The top of the interval is composed of the assemblage of *Mauritiidites crassibaculatus*, *Aequitriradites* sp, and *Retitricolpites operculatus*. Dinoflagellates such as *Senegalinium* sp, *Senegalinium bicavatum*, dinocyst and non pollen palynomorphs (NPP) are present at the topmost interval. Thus, the lower part of the interval is suggested to belong to Senonian age, equivalent stratigraphically to uppermost part of Gongila Formation while the upper part of the interval belongs to Campanian age based on the top appearance of *Mauritiidites crassibaculatus* and equivalent stratigraphically to lower part of Fika Formation (See Figures 2 and 3). This form has been used by Lawal and Moullade, (1986); Edet and Nyong, (1994); Ola-Buraimo et al, (2012) to date Asata/Nkporo Shale as Campanian age in Calabar Flank, Nigeria.

Zone: Spinozonocolpites baculatus assemblage zone 111

Interval: 620-1580m

Age: Maastrichtian

Characteristics: The base of the interval coincides with the top of the underlying zone 11 marked by top appearance of *Mauritiidites crassibaculatus*. However, the overlying interval is defined by new appearance of pollen assemblages including *Longapertites marginatus*, *Periretisyncolpites* sp, *Trichotomosulcites* sp, *Zlivisporites blanensis*, *Cyathidites* sp, and *Auriiculidites* sp. Other forms that characterize Maastrichtian age sediments according to the work of Van Hoeken klinkenberg (1964); Ogala et al, (2009); Ola-Buraimo and Adeleye, (2010) and Ola-Buraimo et al, (2012) are *Stephanocolpites* sp, *Foveotrilletes margaritae*, and *Ulmoideipites krempii*. Evamy et al, (1978) also reported the occurrence of the following forms in Maastrichtian as observed in this well such as *Retidioporites magdalenensis*, *Proxapertites cursus*, *Inaperturopollenites* sp, *Ctenolophonidites costatus*, *Spinizonocolpites baculatus*, *Monocolpites marginatus*, *Distaverrusporites simplex*, *Longapertites microfoveolatus*, *Tricolporopollenites* sp, *Striatricolpites catatumbus*, *Striatopollis bellus* and *Polyadopollenites* sp.

The top of the interval is defined by the top occurrence of *Cingulatisporites ornatus*, *Foveotricolporites* sp, *Bombacacidites* sp, *Ulmoideipites krempii*, *Aquilapollenites* sp,

Triporites cf iverseni, *Constructipollenites ineffectus*, *Foveotrilletes margaritae*, *Verrutrilletes bullatus* (Van Hoeken Klinkenberg, 1964), and *Retidiporites magdalenensis*. Apart from the fact that the palynomorph assemblages in this interval are conspicuously different from those in the adjoining intervals, the palynomorph abundance and diversity of the uppermost interval is quite richer than the overlying interval that is poor to barren. Such phenomenon had been observed by Lawal and Moullade, (1986) and Ola-Buraimo, (2012) (unpublished M.Phil/Ph.D thesis)



Within the interval, there are some pollen and spores that show a fairly continuous occurrence, among them are *Zlavisporites blanensis*, *Periretisyncolpites sp*, *Longapertites marginatus*, *Retidiporites magdalenensis*, and *Ulmoidites krempii*. The interval is well noted for occurrences of dinoflagellate cysts such as *Hiostrichosphaeridium atellatum* (Maier, 1959), *Phelodinium bolonienae*, *Andalusiella sp*, *Senegalinium sp*, *Histrichosphaera sergipensis*, *Andalusiella polymorpha*, *Cleistosphaeridium sp*, *Batiacasphaera sp*, and *Histrichodinium pulchrum*. The presence of the dinoflagelates known to dwell in salt water is an indication that the sediments might have been deposited in a marine environment; probably in a marginal marine setting due to the presence of peridinacean forms. Therefore, the interval (620-1580m) is conveniently dated Maastrichtian age and equivalent in part to Fika Formation (See Figures 2 and 3)

Zone: Proxapertites cursus assemblage zone 1v

Interval: 315-620m

Age: Paleocene

Characteristics: The interval is characterized by the paucity of palynomorphs. Though the miospore assemblage present is different from both the underlying and overlying intervals, it is still not well represented. The basal interval is barren while the top interval is marked by the assemblage of *Verruticolporites sp*, *Monosulcites sp*, *Leiotrilletes sp*, *Cf. Aquilapollenites sp* and *Cf. Cupaniedites reticulatus*. Other forms present are algae such as *Botryococcus braunii* and *Calcium oxalate crystals* (Ruta et al, 2007). The interval is tentatively dated Paleocene age based on the paucity of palynomorphs that characterize Paleocene age from Maastrichtian sediments. It is further based on the stratigraphic position of the interval which contains fossils that are distinctively different from the miospore assemblages of the

overlying and underlying intervals which contain stratigraphically diagnostic forms. The interval is correlable to Gombe Formation (See Figures 2 and 3)

Zone: Monoporites annulatus assemblage zone v

Interval: 70-315m

Age: Eocene-Younger

Characteristics: The interval is poor of palynomorph recovery. However, the base of the interval coincides with the top of the underlying zone. It is characterized by the first appearance of *Monoporites annulatus*. At interval 225-230m there is also new appearance of *Retibrevitricolporites protrudens* in association with other miospores such as *Proxapertites cursus* and *Monosulcites sp.* The upper part of the interval is marked by the occurrence of *Longapertites vernendenburgi* while the top is defined by the appearance of *Lycopodium phlegmaria* (See Figures 2 and 3).

The upper part of the interval shows appearance of microforaminiferal wall lining and dinoflagellate cysts. The appearance of fungal spore in the claystone is suggestive of deposition in a fluviomarine setting, probably a lacustrine environment. However, the interval is dated Eocene to Younger age on the basis of the co-occurrence of *Monoporites annulatus*, *Retibrevitricolporites protrudens* and *Lycopodium phlegmaria*.

Conclusion

Lithostratigraphy of the well section is composed at the base by Gongila Formation, defined by black grey fissile shale, intercalated by light grey sandy shale; dated Turonian-Senonian based on the establishment of *Triorites africaensis* assemblage zone 1 and partly of *Syncolporites sp/Milfordia spp* assemblage zone 11. This is characterized by co-occurrence of Turonian *africaensis*, *Classopollis brasiliensis*, and *Retimonocolpites sp.* The Gongila Formation was deposited in a deltaic to marine environment. Stratigraphically, the Gongila Formation is overlain by Fika Shale, characterized by black fissile shale with intercalated gypsum at the upper end. It belongs to the *Milfordia spp* assemblage zone 11 and *Spinizonocolpites baculatus* assemblage zone 111. The formation is dated Campanian to Maastrichtian based on the co-occurrence of *Milfordia spp*, *Mauritiidites crassibaculatus*, *Longapertites marginatus*, *Foveotriletes margaritae*, *Retidiporites magdalenensis*,

331 *Trichtomosulcites* sp, *Periretisyncolpites* sp, and *Auriiculidites* sp. The Fika Shale was
332 deposited in a typical marine system.

333 Gombe Formation overlies the Fika Shale. It is composed of basal brownish coloured
334 conglomeratic sandstone at the base, overlain by light grey bulky claystone associated with
335 intercalated sandstone and reddish mudstone at its top. Palynologically, the formation is
336 characterized by paucity of palynomorphs and dated Paleocene. Kerrikerri Formation is the
337 youngest in the interval analyzed; composed of conglomeratic sandstone at the base, overlain
338 successively by light grey bulky shale and light grey claystone. The formation is dated
339 Eocene age based on the co-occurrence of *Monoporites annulatus*, *Retibrevitricolporites*
340 *protrudens*, *Proxapertites cursus*, and *Longapertites vernendenburgi*. The Kerrikerri
341 Formation was deposited in a fluviomarine environment.



UNDER PEER REVIEW

		AGE		PALYNOZONE	
DEPTH[M]					
70-75	KERBERE	1			
125-180		1			
225-230		1	1	1	1
315-320		1	1	1	1
585-590	GOMBE				
620-625		1	1	2	
675-680		1	1	1	1
765-770		1	1		
945-950					
1025-1030					
1125-1130	FIKA		2	1	1
1215-1220		1	1	1	1
1305-1310		1			
1395-1400					
1485-1490		2	1		
1580-1585		3			
1665-1670		1			
1755-1760		1			
1845-1850	GONGOLA				
1925-1930					

		AGE		PALYNOZONE	
DEPTH[M]					
70-75	KERBERE	1			
125-180		1			
225-230		1	1	1	1
315-320		1	1	1	1
585-590	GOMBE				
620-625		1	1	2	
675-680		1	1	1	1
765-770		1	1		
945-950					
1025-1030					
1125-1130	FIKA		2	1	1
1215-1220		1	1	1	1
1305-1310		1			
1395-1400					
1485-1490		2	1		
1580-1585		3			
1665-1670		1			
1755-1760		1			
1845-1850	GONGOLA				
1925-1930					

		AGE		PALYNOZONE	
DEPTH[M]					
70-75	KERBERE	1			
125-180		1			
225-230		1	1	1	1
315-320		1	1	1	1
585-590	GOMBE				
620-625		1	1	2	
675-680		1	1	1	1
765-770		1	1		
945-950					
1025-1030					
1125-1130	FIKA		2	1	1
1215-1220		1	1	1	1
1305-1310		1			
1395-1400					
1485-1490		2	1		
1580-1585		3			
1665-1670		1			
1755-1760		1			
1845-1850	GONGOLA				
1925-1930					

		AGE		PALYNOZONE	
DEPTH[M]					
70-75	KERBERE	1			
125-180		1			
225-230		1	1	1	1
315-320		1	1	1	1
585-590	GOMBE				
620-625		1	1	2	
675-680		1	1	1	1
765-770		1	1		
945-950					
1025-1030					
1125-1130	FIKA		2	1	1
1215-1220		1	1	1	1
1305-1310		1			
1395-1400					
1485-1490		2	1		
1580-1585		3			
1665-1670		1			
1755-1760		1			
1845-1850	GONGOLA				
1925-1930					

		AGE		PALYNOZONE	
DEPTH[M]					
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125-180		1			
225-230		1	1	1	1
315-320		1	1	1	1
585-590	GOMBE				
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675-680		1	1	1	1
765-770		1	1		
945-950					
1025-1030					
1125-1130	FIKA		2	1	1
1215-1220		1	1	1	1
1305-1310		1			
1395-1400					
1485-1490		2	1		
1580-1585		3			
1665-1670		1			
1755-1760		1			
1845-1850	GONGOLA				
1925-1930					

		AGE		PALYNOZONE	
DEPTH[M]					
70-75	KERBERE	1			
125-180		1			
225-230		1	1	1	1
315-320		1	1	1	1
585-590	GOMBE				
620-625		1	1	2	
675-680		1	1	1	1
765-770		1	1		
945-950					
1025-1030					
1125-1130	FIKA		2	1	1
1215-1220		1	1	1	1
1305-1310		1			
1395-1400					
1485-1490		2	1		
1580-1585		3			
1665-1670		1			
1755-1760		1			
1845-1850	GONGOLA				
1925-1930					

		AGE		PALYNOZONE	
DEPTH[M]					
70-75	KERBERE	1			
125-180		1			
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315-320		1	1	1	1
585-590	GOMBE				
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675-680		1	1	1	1
765-770		1	1		
945-950					
1025-1030					
1125-1130	FIKA		2	1	1
1215-1220		1	1	1	1
1305-1310		1			
1395-1400					
1485-1490		2	1		
1580-1585		3			
1665-1670		1			
1755-1760		1			
1845-1850	GONGOLA				
1925-1930					

		AGE		PALYNOZONE	
DEPTH[M]					
70-75	KERBERE	1			
125-180		1			
225-230		1	1	1	1
315-320		1	1	1	1
585-590	GOMBE				
620-625		1	1	2	
675-680		1	1	1	1
765-770		1	1		
945-950					
1025-1030					
1125-1130	FIKA		2	1	1
1215-1220		1	1	1	1
1305-1310		1			
1395-1400					
1485-1490		2	1		
1580-1585		3			
1665-1670		1			
1755-1760		1			
1845-1850	GONGOLA				
1925-1930					

		AGE		PALYNOZONE	
DEPTH[M]					
70-75	KERBERE	1			
125-180		1			
225-230		1	1	1	1
315-320		1	1	1	1
585-590	GOMBE				
620-625		1	1	2	
675-680		1	1	1	1
765-770		1	1		
945-950					
1025-1030					
1125-1130	FIKA		2	1	1
1215-1220		1	1	1	1
1305-1310		1			
1395-1400					
1485-1490		2	1		
1580-1585		3			
1665-1670		1			
1755-1760		1			
1845-1850	GONGOLA				
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		AGE		PALYNOZONE	
DEPTH[M]					
70-75	KERBERE	1			
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315-320		1	1	1	1
585-590	GOMBE				
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675-680		1	1	1	1
765-770		1	1		
945-950					
1025-1030					
1125-1130	FIKA		2	1	1
1215-1220		1	1	1	1
1305-1310		1			
1395-1400					
1485-1490		2	1		
1580-1585		3			
1665-1670		1			
1755-1760		1			
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		AGE		PALYNOZONE	
DEPTH[M]					
70-75	KERBERE	1			
125-180		1			
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315-320		1	1	1	1
585-590	GOMBE				
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675-680		1	1	1	1
765-770		1	1		
945-950					
1025-1030					
1125-1130	FIKA		2	1	1
1215-1220		1	1	1	1
1305-1310		1			
1395-1400					
1485-1490		2	1		
1580-1585		3			
1665-1670		1			
1755-1760		1			
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		AGE		PALYNOZONE	
DEPTH[M]					
70-75	KERBERE	1			
125-180		1			
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585-590	GOMBE				
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765-770		1	1		
945-950					
1025-1030					
1125-1130	FIKA		2	1	1
1215-1220		1	1	1	1
1305-1310		1			
1395-1400					
1485-1490		2	1		
1580-1585		3			
1665-1670		1			
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		AGE		PALYNOZONE	
DEPTH[M]					
70-75	KERBERE	1			
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585-590	GOMBE				
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765-770		1	1		
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1215-1220		1	1	1	1
1305-1310		1			
1395-1400					
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DEPTH[M]					
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675-680		1	1	1	1
765-770		1	1		
945-950					
1025-1030					
1125-1130	FIKA		2	1	1
1215-1220		1	1	1	1
1305-1310		1			
1395-1400					
1485-1490		2	1		
1580-1585		3			
1665-1670		1			
1755-1760		1			
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585-590	GOMBE				
620-625		1	1	2	
675-680		1	1	1	1
765-770		1	1		
945-950					

Figure 3: Distribution chart of important palynomorphs, palynozones, formations and their corresponding geologic ages

PLATE 1

365

366 1 Liliacidites sp

367 2-4 Monosulcites sp

368 5 Retimonocolpites sp

369 6-8 Monocolpites marginatus

370 9-11 Leiotriletes sp

371 12 Cyathidites sp

372 13 Laevigatosporites sp

373 14 Zlivisporites sp

374 15 Syncolporites sp

375 16 Distaverrusporites sp

376 17 Verrucosisporites sp

377 18 Foveotriletes margaritae

378 19-22 Milfordia sp

379 23 Inaperturopollenites sp

380 24 Mauritiidites crassibaculatus

381 25 striatricolpites catatumbus

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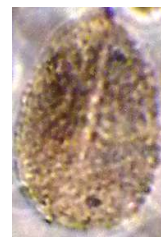
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388 Magnification at X400

PLATE 1



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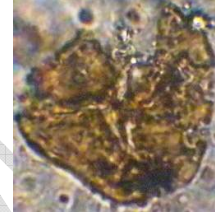
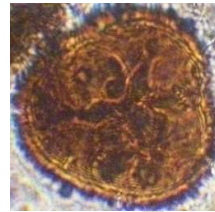
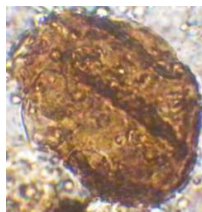
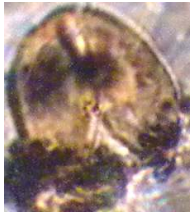
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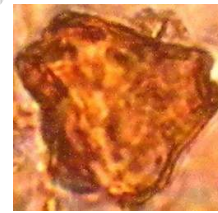
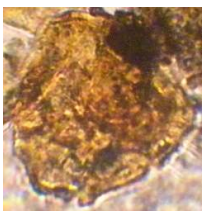
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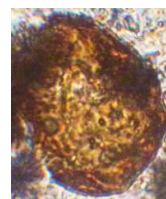
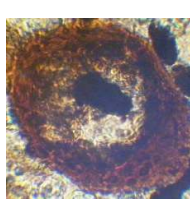
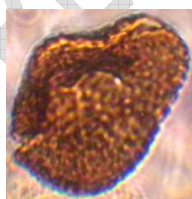
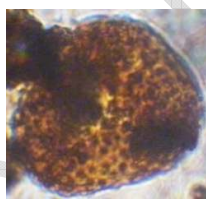
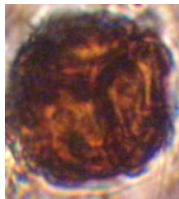
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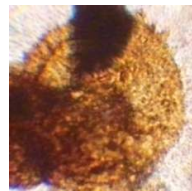
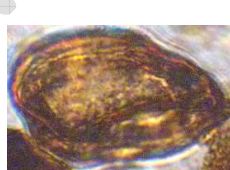
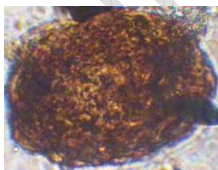
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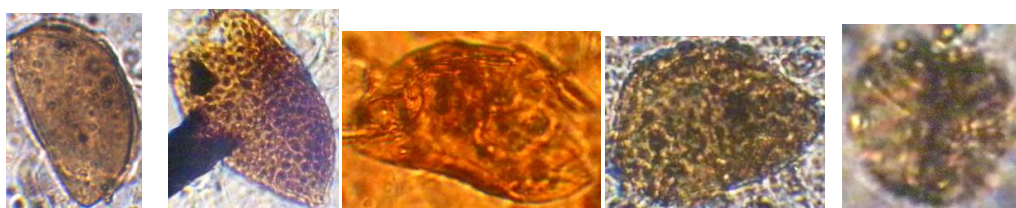
PLATE 2

- 1 *Longapertites verneendenburgi*
- 2 *Periretisyncolpites* sp
- 3-4 *Longapertites marginatus*
- 5 *Trichotomosulcites* sp
- 6-7 *Stephanocolpites* sp
- 8 *Ulmoideipites krempii*
- 9 *Ctenolophonidites costatus*
- 10 *Spinizonocolpites baculatus*
- 11 *Syncolporites* sp
- 12-14 *Tricolpites* sp
- 15 *Triorites africaensis*
- 16 *Triporites* sp
- 17 *Triporites* cf *iverseni*
- 18-19 *Tricolporopollenites* sp
- 20 *Polyadopollenites* sp
- 21 *Constructipollenites ineffectus*
- 22-24 *Retidiporites magdalenensis*
- 25 *Monoporites annulatus*

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Magnification at X400

PLATE 2



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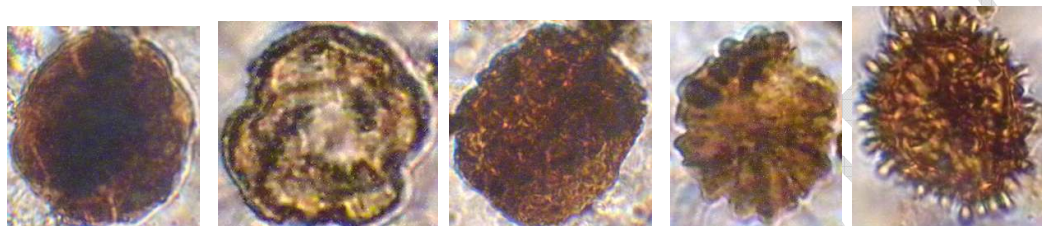
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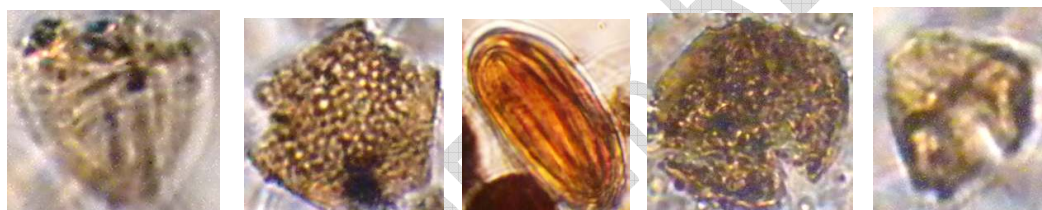
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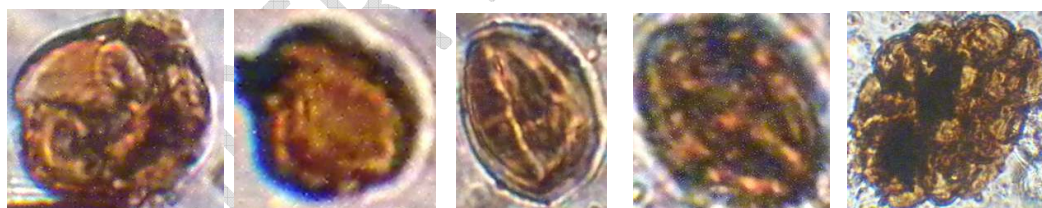
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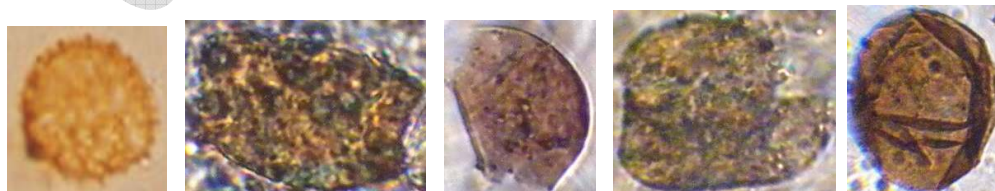
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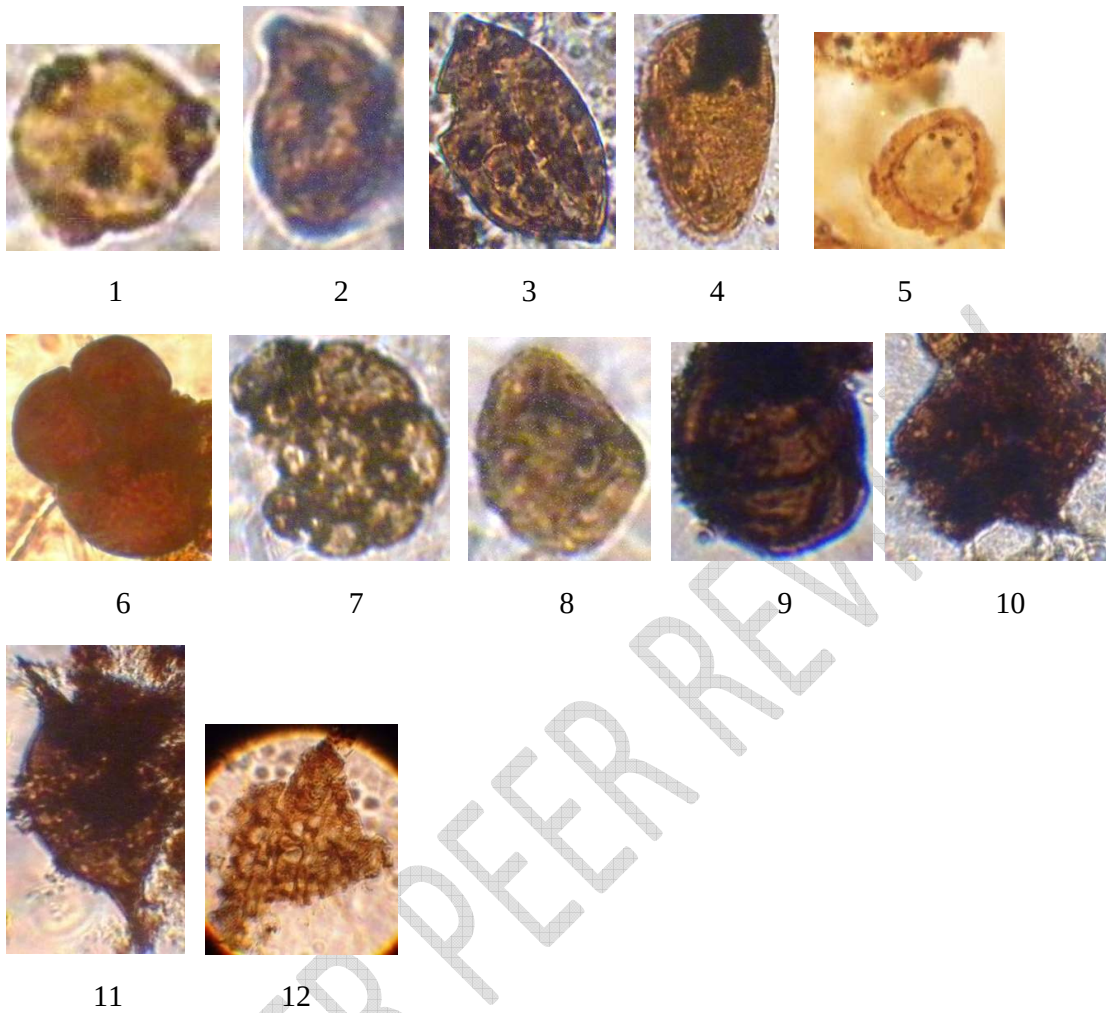
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444 Magnification at X400

PLATE 3



- 445
- 446 1 2 3 4 5
- 447 6 7 8 9 10
- 448
- 449 11 12
- 450
- 451 1 Retibrevitricolporites protrudens
- 452 2 Auriculiidites sp
- 453 3 Monosulcites sp
- 454 4 Longapertites microfoveolatus
- 455 5 Cingulatisporites ornatus
- 456 6-7 Microforaminiferal wall lining
- 457 8 Phelodinium bolonienae
- 458 9 Batiacasphaera sp
- 459 10 Senegalinium bicavatum
- 460 11 Andalusella polymorpha
- 461 12 Calcium oxalate crystal

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