

Chronostratigraphy and Biostratigraphy Lithostratigraphy of a section of the Murshe-1 Well, Bornu Basin, Northeastern Nigeria

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ABSTRACT

Incorporate comments in text into your 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 Nothing is new here? You might well stick to the title above.

. Five palynological zones were established, including *Triorites africaensis* assemblage zone 1 characterized by co-occurrence of *Classopollis brasiliensis*, *Triorites africaensis*, and *Retimonocolpites sp*; dated Turonian age. *Syncolporites sp*/Milfordia *sp* assemblage zone 11 is dated Senonian to Campanian based on the assemblage of *Syncolporites sp*, *Milfordia sp*, *Mauritiidites crassibaculatus*, and *Aequitridites sp*. The *Spinizonocolpites baculatus* assemblage zone 111 is defined by the co-occurrence of *Longapertites marginatus*, *Periretisyncolpites sp*, *Trichotomosulcites sp*, *Auriculiidites sp*, *Foveotriletes margaritae*, *Spinizonocolpites baculatus*, *Monocolpites marginatus*, *Striatopollis bellus* and *Retidiporites magdalenensis*; depictive of Maastrichtian age. The *Proxapertites cursus* assemblage zone 1v is distinguished from the older Maastrichtian sediment based on the paucity 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
Please update to reflect your work (Bornu Basin, Palynology, Lithostratigraphy, Biostratigraphy ETC.)

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37 Introduction

38 Palynological ~~research work technique~~ was employed to investigate the litho and
39 biostratigraphy of Murshe- 1 well in the Bornu Basin, northsoutheastern Nigeria. Compared
40 to other basins in Nigeria. Though, few palynological works were done have been done on the
41 Bornu Basin on the basin compared to other basins Nigeria; thus, this research This study was
42 necessitated in order to describe the understand the lithologyfacies of the and date the
43 formations penetrated by the Murshe 1 well. , the chronostratigraphy of the basin and their
44 associated paleoenvironment of deposition.

45 The lithostratigraphy of the well is well documented (which well? The one you are
46 about to study?) and compare favourably with the work of Avbovbo et al. (1986). Prevuiuos
47 work on the The stratigraphyie study of the Bornu Basin include have been widely carried out
48 by earlier workers such as Adegoke et al, (1978); Odusina, et al, (1983); Avbovbo et al,
49 (1986); and Olugbenro, (1997) to mention a few (please list the others, it helps the objective
50 of your work).

51 Recent studies include detail studies on the Chad Formation, (is the Chad Formation
52 your focus?) describinges the different three members contained in it and their environment
53 of deposition (Ola-Buraimo, 2005); granulometric and paleoenvironment of Kerrikerri
54 Sandstone (Ola-Buraimo, 2009); others are the palynological investigation of Bima
55 Formation (you are mixing a lot of things together, you started with Chad Formation) dated
56 Albian to Lower Cenomanian (Ola-Buraimo and Boboye, 2011); while detail lithofacies of
57 the Bima Group and subdivision of their (the group or formations within the group) geologic
58 ages (Ola-Buraimo and Oluwajana, 2012). Therefore, this present study is intended to
59 augment earlier works done on this basin.

60

61 Geologic Setting

62 The geology of the Bornu Basin has been widely investigated by earlier workers such
63 as Falconer, (1911); Raeburn and Brynmor (1924); Carter et al (1963) and Barber, (1965).
64 The fFormation of Bornu Basin was predicated on third and failed arm of a triple junction

Comment [AB1]: The English is poor, please
rewrite the whole paragraph.

65 | formed during the Albian ~~(please confirm this date) in response due~~ to opening of the South
66 | Atlantic (Wright, 1968; Burke et al, 1970). Other authors that supported ~~this e-plate tectonic~~
67 | theory include Genik, (1933); Kings, (1950); and Avbovbo et al, (1980).

68 | The stratigraphy of Bornu Basin have been widely studied, these include the work of
69 | Adegoke et al.; (1978); Petters; (1978b); Kogbe; (1979); Petters (1981); Avbovbo et al.;
70 | (1986); Ola-Buraimo; (2005) and Ola-Buraimo; (2009). The amount of biostratigraphic
71 | studies in this basin is incomparable to other sedimentary basins in Nigeria. ~~(repetition, you~~
72 | ~~mentioned this under introduction)~~ Few works done include that of Barber and Jones,
73 | (1960); Carter et al.; (1963); Reyment, (1965); Adegoke et al.; (1978); Petters; (1982);
74 | ~~(please follow preceding style for your references)~~ Odusina et al, (1983); Wonzy and Kogbe,
75 | (1983); Popoff et el, (1986); Oti, (1990); Okosun(1995); Olugbemiro, (1997); Ola-Buraimo,
76 | (2005); Ola-Buraimo, (2009); Ola-Buraimo and Boboye, (2011) ~~(please confirm that these~~
77 | ~~are all biostratigraphic and on the Bornu Basin)~~. However, few palynological studies were
78 | reported from the basin, including the work of Adegoke et al, (1978); Ola-Buraimo and
79 | Boboye, (2011); Ola-Buraimo and Oluwajana, (2012). ~~Palynology is a subset of~~
80 | ~~biostratigraphy, why this sentence).~~ More references are available including Boboye (2012).

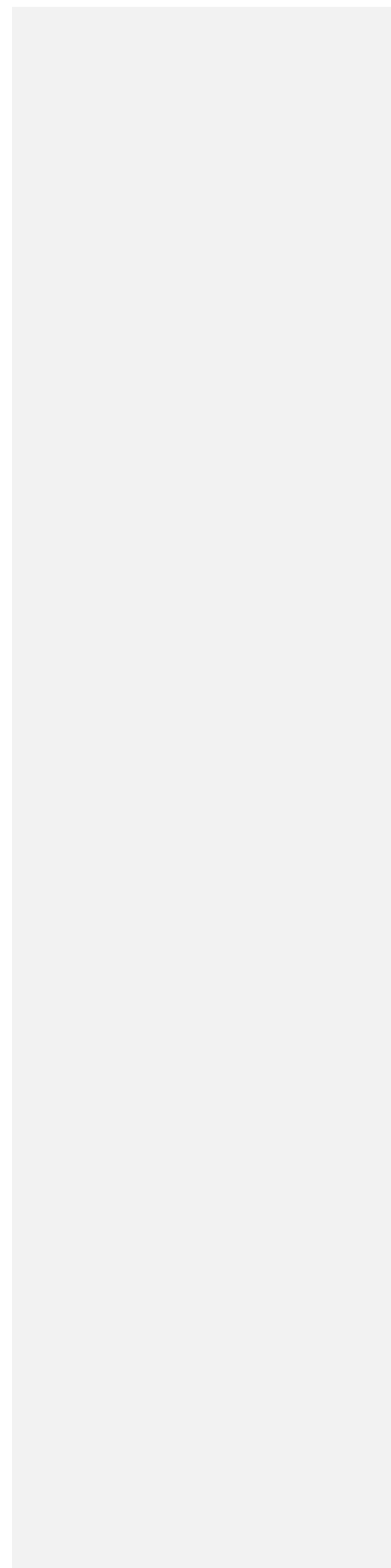
81 | Avbovbo et al; (1986) suggested six events leading to the evolution of the Bornu
82 | Basin. These include the period ~~(list the events and not the period, see preceding sentence)~~ of
83 | Pre-Albian, Albian –Maastrichtian, Maastrichtian-Danian which led to cessation and collapse
84 | as sub-crustal swells, associated with folding, faulting, sedimentation, erosion and volcanism.
85 | The fifth event was noted for stress redistribution and initiation of secondary situation;
86 | followed by Tertiary–Recent event characterized by continental –lacustrine sedimentation
87 | and volcanism.

88 |
89 | Create a section on stratigraphy of the Bornu Basin and separate it from tectonic
90 | evolution. A number of wells drilled in the basin have been studied and literature documents
91 | these.

92 | The Bima Formation is the oldest stratigraphic unit deposited under continental
93 | environment. The formation is diachronous and Albian-Turonian in age (Carter et al, 1963).
94 | Lithologically, it was described to be poorly sorted, sparsely fossiliferous, thickly bedded,
95 | cross stratified; sand size varies from feldspathic coarse to conglomerate. Avbovbo et al,
96 | 1986 identified marine shale sequence deposited over localized conglomerates and poorly
97 | sorted alluvial deposits lying unconformably on the basement. The distinct continental
98 | deposit (conglomerate) is termed the Pre-Bima dated Albian age (Oti, 1990).

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UNDER PEER REVIEW



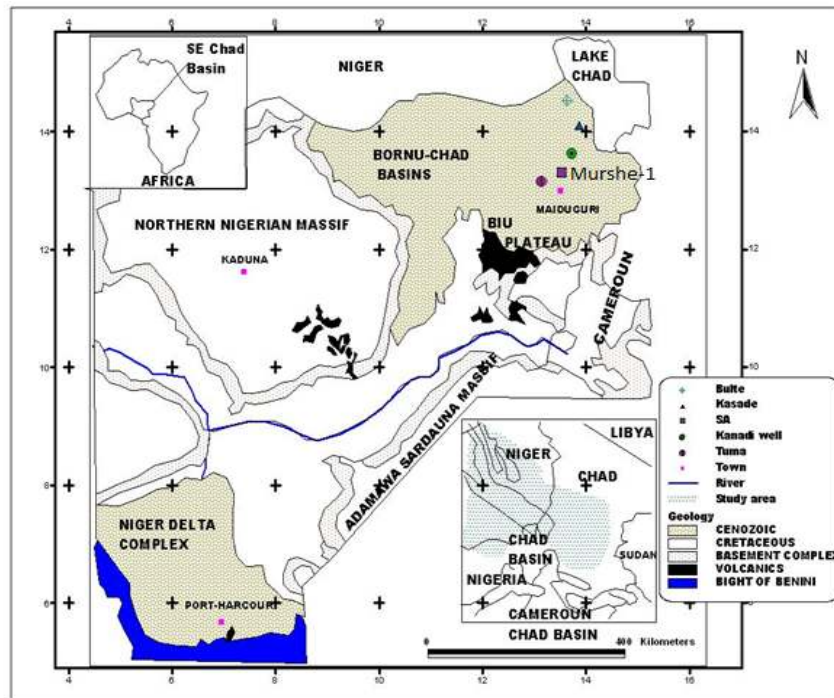


Figure 1: Geological map of Nigeria showing the location of Bornu Basin and the studied well (modified after Whiteman, 1982 and Genik, 1993) [Please reference inset map to Genik, 1993.](#)

MATERIALS AND METHODS

About 290 ditch cutting samples (what interval and depth range) from the Murshe well of about 290 were arranged serially in order of depth. Lithology description of the samples was carried out by looking at the sediments under the microscope; and comparison of the textural parameters were compared with standard monograph plates of Western Atlas was carried out. Textural features taken into consideration include, grain size, shape in term of roundness and angularity. (Standard practise os to wash off the drill mud before litho description, this is not reflected here) Others parameters include sorting, colour, lithology, post depositional effect such as ferruginization; fossil contents, presence of accessory minerals. _and effect of dDilute hydrochloric acid was used to test for the presence of carbonate in the samples on the samples which depicts the presence of carbonate. Samples for palynological purpose were selected at 27.4m (90ft) interval, thoroughly washed with

distilled water through a 5µm polyester sieve in order to remove drilling mud contaminants and then dried for 24 hours at 50°C.

About Ten (10) grams of each sample was digested with 10% Hydrochloric (HCL) acid to remove ~~CaCO₃ carbonates~~. ~~The samples were~~ It was later soaked ~~in~~with 60% hydrofluoric acid (HF) (please follow this convention for other acid names) for 24hrs to digest the silica. The content was sieve- washed (5µm) with ?distilled water and later oxidized in Schulze solution (mixture of nitric acid and potassium chlorate) for 30minutes, washed with 10% potassium hydroxide, followed by heavy liquid separation with Zn₂Br₄ and through centrifuging. The aliquots were dispersed with polyvinyl alcohol, dried and then mounted on glass slides with DPX (what is this) mountant. The biostratigraphic study involved the analysis of pollen, spores, dinoflagellates and algae under the microscope for chronostratigraphic biozonation. Important palynomorphs ~~pictures were taken photographed~~ using Nikon koolpix P6000 digital camera.

Result and Discussion

SedimentologyLithostratigraphy

Four known formations in the basin (this formations have been identified before) are marked out on the basis of correlation with palynological ages within the study interval in the Musrhe well within the stratigraphic section ~~are marked out on the basis of correlation with palynological ages derived from the palynological analysis of this research work~~. The details ~~of the stratigraphic units~~formations encountered in the well are discussed below (See Figure 2).

Gongila Formation

The Gongila Formation is a transitional sequence that lies in-between the underlying marine shale of Bima Formation and the typical marine setting of the overlying Fika Formation. (this should be under literature review) The Gongila Formation is characterized at the base by black, fissile, calcareous and fairly ferruginised 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 (Is this EOD from your work or the literature?). The formation was deposited in a deltaic to marine

180 | environment and dated Turonian to Senonian age. [\(If this age is from your work, please refer](#)
181 | [to it under biostratigraphy\).](#) It is remarkable that volcanic intrusive reported by earlier
182 | workers in this formation is not visible here, therefore, it is suggested that the intrusion was a
183 | local effect. [You do not have enough evidence to make this deduction. One control point in a](#)
184 | [large basin and you only studied selected cuttings in this well, not core samples. Other](#)
185 | [authors commented on the presence of intrusives even in the Murshe well.](#)

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UNDER PEER REVIEW

Depth(m)	Litho-log	Description	Formation/ Age	Paleo-environment
70		Very light grey claystone	Kerikeri Eocene	Lacustrine To Proximal Fluvial
		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	Gombe Paleocene	Continental
385		Light brown to light grey bulky claystone with intercalated sandstone		
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	Fika Campanian-Maastrichtian	Marine
620		Black fissile silty shale		
840		Dark grey to black fissile shale		
890		Black fissile shale with intercalated gypsum		
1185		Light grey sandy shale; sand size varies from fine to medium, well sorted	Gongila Turonian-Senonian	Deltaic To Marine
1820		Black fissile shale, calcareous and fairly ferruginised		
1880				
1930				

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

[M-1 should be written as Murshe 1](#)

[The description you gave for Gombe and Kerikeri formations suggest you might be dealing with the Chad Formation which you made no reference to here.](#)

[Are these EOD's from literature or this present work?](#)

[You need a legend on this map.](#)

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214 Fika Shale

215 This formation varies in depth from 620-1820m with an estimated thickness of 1200m. This
216 seems to be the greatest thickness compared to the work of Carter et al, (1963); Okosun
217 (1995) and Olugbemiro (1997) [this is absolutely not correct, see Boboye 2012 in NMGS and](#)
218 [Alalade 2013 in JAES](#); but it compares favourably with the thickness derived from seismic
219 data of avbovbo et al, (1986). The Fika Formation lies unconformably on the Gongila
220 Formation (Ola-Buraimo, 1990 Unpublished M.sc thesis [Did you establish this in your thesis](#)
221 [because we know them to be conformable, Avbovbo et al \(1986\)](#)). The formation is not
222 entirely shaly but rather shows intercalated gypsum at the lower to middle part of the
223 sequence; while the middle part is characterized by silty shale deposited between interval
224 840-890m ~~and it is 50m thick~~. The uppermost part is a shale facies, [that](#) shows rare coarse
225 [sand](#) to pebble ~~sand~~ grains, calcareous [what?](#) and rare occurrence of gypsum serves as
226 accessory mineral. The paleoenvironment of deposition is suggested to be marginal to open
227 marine while transporting medium was of relatively high energy and erosive in nature
228 (turbidity current) which might be responsible for clast particles present in the shale sediment
229 during deposition [\(this work or previous?\)](#).

230 [There is no trace of volcanic intrusive in this well. However, the huge thickness of 1200m](#)
231 [observed in the well section may agree with Avbovbo et al \(1986\) observation that the](#)
232 [Cretaceous beds thicken towards the centre of the basin. Thus, it is likely that this well M-1 is](#)
233 [located in the middle of the basin.](#)

234 [You make statements that have no basis in this work.](#)

235 Gombe Formation

236 The Gombe Formation occupies interval 385-620m with a thickness of 235m. The
237 formation is characterized by a basal sandstone unit of about 30m (590-620m). The sand is
238 brownish coloured conglomerate, fine to pebble in grain size, and very poorly sorted. The
239 overlying interval 385-590m contains light brown to light grey bulky claystone with an

Comment [AB2]: These are all repetitions. The centre of the basin is in the Lake Chad area

240 interbed of sand. The environment of deposition is suggested to be of distal continental to
241 proximal fluvial paleoenvironment ([this work or literature?](#)).

242 **Kerikerri Formation**

243 The Kerikerri Formation is Eocene in age, lacustrine at the upper part to proximal
244 fluvial environment of deposition. The lower sandy part ~~varies from~~ [is from depth 280 to-](#)
245 [320m \(40m thick\)](#). The ~~interval sand~~ is milky to pinkish in colour, conglomeratic [\(then it is](#)
246 [not sand?\)](#) in nature; grain size varies from medium to pebble, subangular to rounded, and
247 poorly sorted. The basal sand marks the unconformable [\(did you see this in the cuttings](#)
248 [samples?\)](#) contact with the older underlying Gombe Formation. The sandstone is overlain by
249 light grey claystone intercalated by light grey bulky shale. Therefore, the Kerikerri
250 Formation is not entirely continental but rather lacustrine to continental in term of
251 environment of deposition [\(no basis for this in this work\)](#).

252 **Palynology**

253 [How does this work differ from that of Boboye 2012. This should be the basis for](#)
254 [writing this one. There is no comparison or reference to that work anywhere in this](#)
255 [paper.](#)

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

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

266 **Interval:** 1755-1930m

267 **Age:** Turonian

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

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

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

277 **Interval:** 1580-1755m

278 **Age:** Senonian-Campanian

279 **Characteristics:** This interval is composed of assemblage of palynomorphs that are depictive
280 of Senonian and Campanian ages. The interval 1665-1670m has new appearances of
281 *Syncolporites* sp, *Milfordia* sp, *Aequitriradites* sp, *Monosulcites* sp and *Cyathidites* sp.
282 Microplanktons such as *Senegalinium* sp 2, *Phelodinium bolonienae*, and *Dinogymnium*
283 *undulosum* and microforaminiferal wall lining occurred at this interval.

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

294 **Zone:** Spinozonocolpites baculatus assemblage zone 111

295 **Interval:** 620-1580m

296 **Age:** Maastrichtian

297 **Characteristics:** The base of the interval coincides with the top of the underlying zone 11
298 marked by top appearance of *Mauritiidites crassibaculatus*. However, the overlying interval
299 is defined by new appearance of pollen assemblages including *Longapertites marginatus*,
300 *Periretisyncolpites* sp, *Trichotomosulcites* sp, *Zlivisporites blanensis*, *Cyathidites* sp, and
301 *Auriiculidites* sp. Other forms that characterize Maastrichtian age sediments according to the
302 work of Van Hoeken klinkenberg (1964); Ogala et al, (2009); Ola-Buraimo and Adeleye,
303 (2010) and Ola-Buraimo et al, (2012) are *Stephanocolpites* sp, *Foveotrilletes margaritae*, and
304 *Ulmoideipites krempii*. Evamy et al, (1978) also reported the occurrence of the following
305 forms in Maastrichtian as observed in this well; such as *Retidiporites magdalenensis*,
306 *Proxapertites cursus*, *Inaperturopollenites* sp, *Ctenolophonidites costatus*, *Spinizonocolpites*
307 *baculatus*, *Monocolpites marginatus*, *Distaverrusporites simplex*, *Longapertites*
308 *microfoveolatus*, *Tricolporopollenites* sp, *Striatricolpites catatumbus*, *Striatopollis bellus* and
309 *Polyadopollenites* sp.

310 The top of the interval is defined by the top occurrence of *Cingulatisporites ornatus*,
311 *Foveotricolporites* sp, *Bombacacidites* sp, *Ulmoideipites krempii*, *Aquilapollenites* sp,
312 *Tripurites cf iverseni*, *Constructipollenites ineffectus*, *Foveotrilletes margaritae*, *Verrutrilletes*
313 *bullatus* (Van Hoeken Klinkenberg, 1964), and *Retidiporites magdalenensis*. Apart from the
314 fact that the palynomorph assemblages in this interval are conspicuously different from those
315 in the adjoining intervals, the palynomorph abundance and diversity of the uppermost interval
316 is quite richer than the overlying interval that is poor to barren. Such phenomenon had been
317 observed by Lawal and Moullade, (1986) and Ola-Buraimo, (2012)—(unpublished
318 M.Phil/Ph.D thesis).

319 Within the interval, there are some pollen and spores that show a fairly continuous
320 occurrence, among them are *Zlivisporites blanensis*, *Periretisyncolpites* sp, *Longapertites*
321 *marginatus*, *Retidiporites magdalenensis*, and *Ulmoidites krempii*. The interval is well noted
322 for occurrences of dinoflagellate cysts such as *Hiostrichosphaeridium atellatum* (Maier,
323 1959), *Phelodinium bolonienae*, *Andalusiella* sp, *Senegalinium* sp, *Histrichosphaera*
324 *sergipensis*, *Andalusiella polymorpha*, *Cleistosphaeridium* sp, *Batiacasphaera* sp, and
325 *Histrichodinium pulchrum*. The presence of the dinoflagelates known to dwell in salt water is
326 an indication that the sediments might have been deposited in a marine environment;
327 probably in a marginal marine setting due to the presence of peridinacean forms. Therefore,
328 the interval (620-1580m) is conveniently dated Maastrichtian age and equivalent in part to
329 Fika Formation (See Figures 2 and 3)

330 **Zone:** Proxapertites cursus assemblage zone iv

331 **Interval:** 315-620m

332 **Age:** Paleocene

333 **Characteristics:** The interval is characterized by the paucity of palynomorphs. Though the
334 miospore assemblage present is different from both the underlying and overlying intervals, it
335 is still not well represented. The basal interval is barren while the top interval is marked by
336 the assemblage of *Verruticolporites sp*, *Monosulcites sp*, *Leiotriletes sp*, *Cf. Aquilapollenites*
337 *sp* and *Cf. Cupaniedites reticulatus*. Other forms present are algae such as *Botryococcus*
338 *braunii* and *Calcium oxalate crystals* (Ruta et al, 2007). The interval is tentatively dated
339 Paleocene age based on the paucity of palynomorphs that characterize Paleocene age from
340 Maastrichtian sediments. It is further based on the stratigraphic position of the interval which
341 contains fossils that are distinctively different from the miospore assemblages of the
342 overlying and underlying intervals which contain stratigraphically diagnostic forms. The
343 interval is correlable to Gombe Formation (See Figures 2 and 3)

344 **Zone:** Monoporites annulatus assemblage zone v

345 **Interval:** 70-315m

346 **Age:** Eocene-Younger

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

354 The upper part of the interval shows appearance of microforaminiferal wall lining and
355 dinoflagellate cysts. The appearance of fungal spore in the claystone is suggestive of
356 deposition in a fluviomarine setting, probably a lacustrine environment [\(what is the](#)
357 [relationship between fluviomarine and lacustrine?\)](#). However, the interval is dated Eocene to
358 Younger age on the basis of the co-occurrence of *Monoporites annulatus*,
359 *Retibrevitricolporites protrudens* and *Lycopodium phlegmaria*.

360

361 **Conclusion**

362 | Lithostratigraphy of the well [\(which well\)](#) section is composed at the base by Gongila
363 | Formation, defined by ~~black-dark~~ grey fissile shale, intercalated by light grey sandy shale;
364 | dated Turonian-?Senonian based on the establishment of *Triorites africaensis* assemblage
365 | zone 1 and partly of *Syncolporites sp/Milfordia spp* assemblage zone 11. This [\(former or](#)
366 | [later\)](#) is characterized by co-occurrence of *Turonian africaensis*, *Classopollis brasiliensis*,
367 | and *Retimonocolpites sp*. The Gongila Formation was deposited in a deltaic to marine
368 | environment. Stratigraphically, the Gongila Formation is overlain by Fika Shale,
369 | characterized by black fissile shale with intercalated gypsum at the upper end [\(this is not](#)
370 | [what you described for gypsum in the text\)](#). It belongs to the *Milfordia spp* assemblage zone
371 | 11 and *Spinizonocolpites baculatus* assemblage zone 111. The formation is dated Campanian
372 | to Maastrichtian based on the co-occurrence of *Milfordia spp*, *Mauritiidites crassibaculatus*,
373 | *Longapertites marginatus*, *Foveotriletes margaritae*, *Retidiporites magdalenensis*,
374 | *Trichtomosulcites sp*, *Periretisyncolpites sp*, and *Auriiculidites sp*. The Fika Shale was
375 | deposited in a ~~typical~~ marine system.

376 | [The](#) Gombe Formation overlies the Fika Shale. It is composed of basal brownish
377 | coloured conglomeratic sandstone at the base, overlain by light grey bulky claystone
378 | associated with intercalated sandstone and reddish mudstone at its top. Palynologically, the
379 | formation is characterized by paucity of palynomorphs and dated Paleocene. [The](#) Kerrikerri
380 | Formation is the youngest in the interval analyzed; composed of conglomeratic sandstone at
381 | the base, overlain successively by light grey bulky shale and light grey claystone. The
382 | formation is dated Eocene age based on the co-occurrence of *Monoporites annulatus*,
383 | *Retibrevitricolporites protrudens*, *Proxapertites cursus*, and *Longapertites vernendenburgi*.
384 | The Kerrikerri Formation was deposited in a fluviomarine environment.

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PLATE 1

409

1 Liliacidites sp

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2-4 Monosulcites sp

411

5 Retimonocolpites sp

412

6-8 Monocolpites marginatus

413

9-11 Leiotriletes sp

414

12 Cyathidites sp

415

13 Laevigatosporites sp

416

14 Zlivisporites sp

417

15 Syncolporites sp

418

16 Distaverrusporites sp

419

17 Verrucosisporites sp

420

18 Foveotriletes margaritae

421

19-22 Milfordia sp

422

23 Inaperturopollenites sp

423

24 Mauritiidites crassibaculatus

424

25 striaticolpites catatumbus

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431 Magnification at X400

PLATE 1

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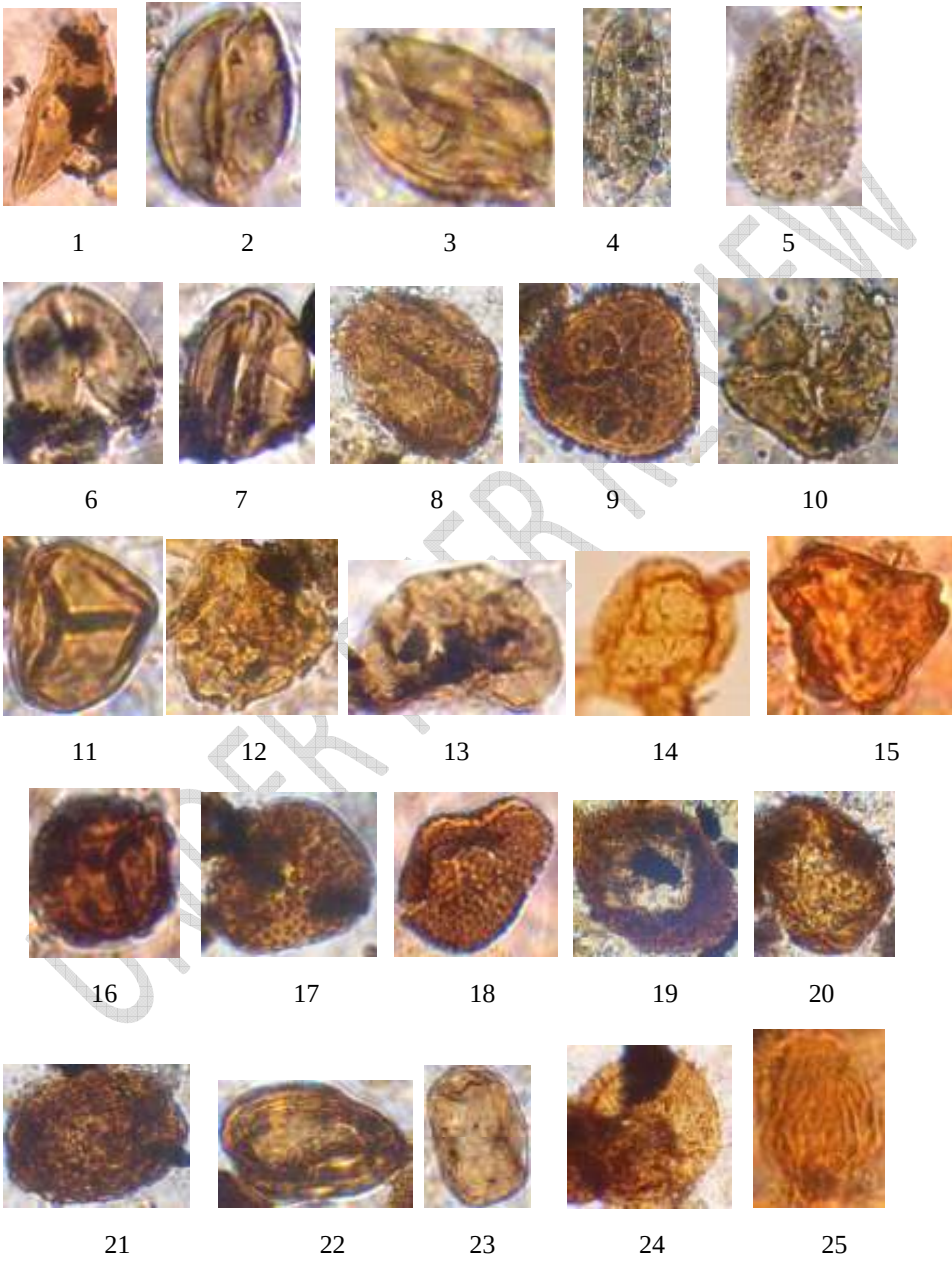
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PLATE 2

- 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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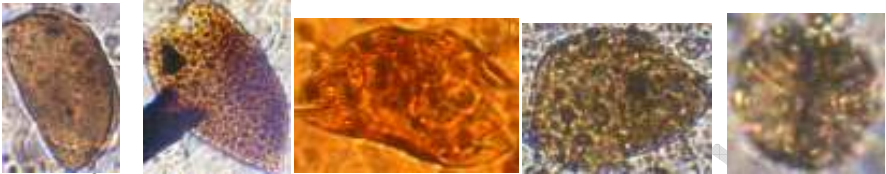
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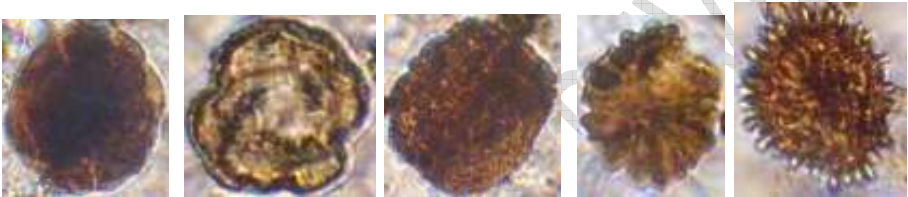
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Magnification at X400 PLATE 2



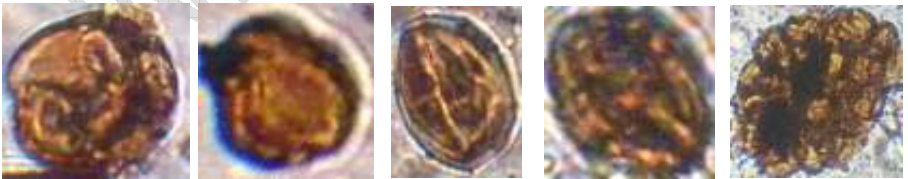
1 2 3 4 5



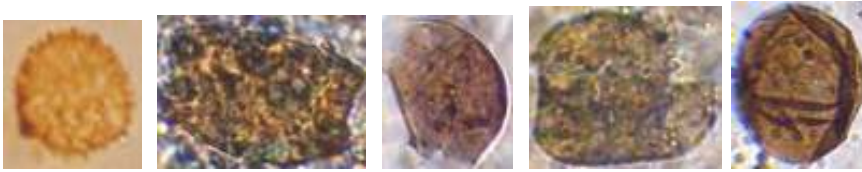
6 7 8 9 10



11 12 13 14 15



16 17 18 19 20



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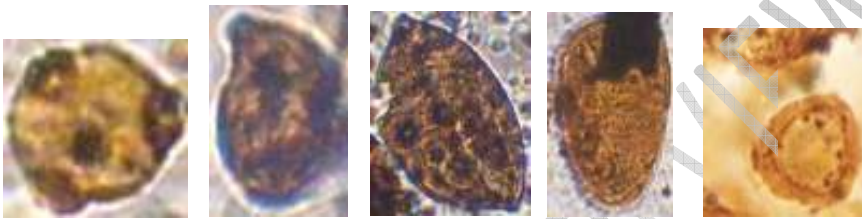
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Magnification at X400

PLATE 3



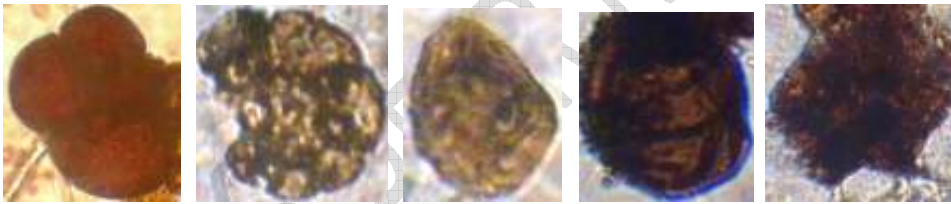
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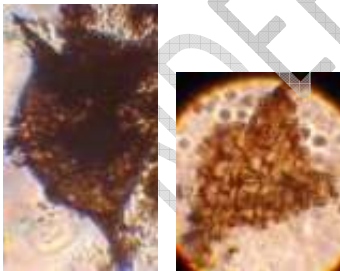
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- 1 Retibrevitricolporites protrudens
- 2 Auriculiidites sp
- 3 Monosulcites sp
- 4 Longapertites microfoveolatus
- 5 Cingulatisporites ornatus
- 6-7 Microforaminiferal wall lining

500	8	Phelodinium bolonienae
501	9	Batiacasphaera sp
502	10	Senegalinium bicavatum
503	11	Andalusiella polymorpha
504	12	Calcium oxalate crystal

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