British Journal of Applied Science & Technology
3(2): 361-375, 2013

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Biostratigraphy of Section of Murshe-1 Well, Bornu Basin, Northeastern Nigeria

A. O. Ola-Buraimo[1*]

[1]Department of Chemical and Geological Sciences, College of Natural Sciences Al-Hikmah University, Ilorin, Nigeria.

Author's contributions

This work was carried out by the author. He designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. The author managed the analyses of the study, managed the literature searches, read and approved the final manuscript.

Research Article

Received 28th November 2012
Accepted 18th February 2013
Published 12th March 2013

ABSTRACT

Biostratigraphic work using palynology was undertaken in order to re-assess the lithofacies, chronostratigraphy and paleoenvironment of deposition of sediments in Murshe-1 well, Bornu Basin, northeastern Nigeria. Two hundred and ninety ditch cutting samples obtained from the exploratory well Murshe-1 located in Bornu Basin were used for lithologiacal description. Twenty one (21) samples were selected at 27.4m interval for palynological analysis. The samples were analyzed under microscope for lithologic and palynological description. The latter were taken through sediment digestion and floatation of macerals. Various lithofacies relationship is present such as black fissile shale, sandy shale, intercalated fissile shale with gypsum, conglomeratic sandstone, mudstone and claystone; while five palynological zones are established. The palynological zones established are *Triorites africaensis* assemblage zone 1 characterized by the co-occurrence of *Classopollis brasiliensis, Triorites africaensis*, and *Retimonocolpites sp*; dated Turonian. Zone 2 is dated Senonian to Campanian based on the assemblage of *Syncolporites sp, Milfordia sp, Mauritiidites crassibaculatus*, and *Aequitridites sp*. The *Spinizonocolpites baculatus* assemblage zone 3 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 Maastrichian age. The *Proxapertites cursus* assemblage zone 4, dated Paleocene is distinguished from the older Maastrichian

**Corresponding author: E-mail: rolaburaimo@yahoo.com;*

sediment based on the paucity of palynomorphs and the appearance of *Verrutricolporites sp*. Zone 5 is dated Eocene-Younger based on the co-occurrence of *Monoporites annulatus, Retibrevitricolporites protrudens, Longapertites vernendenburgi and Lycopodium phlegmaria*.

Keywords: Bornu Basin; palynology; lithostratigraphy; biostratigraphy; chronostratigraph; palynological zone; marginal marine.

1. INTRODUCTION

Lithostratigraphy and biostratigraphy study of Murshe-1 well was carried out to contribute to the understanding of the stacking pattern and chronostratigraphy framework of the Bornu Basin, northeastern Nigeria. Palynological technique was employed to investigate the biostratigraphy of Murshe -1 well (Fig. 1). Intensive stratigraphic studies have not yet been carried out on the basin compared to other basins such as The Niger Delta, Anambra Basin, Benue Trough and Dahomey Basin in Nigeria. Previous work on the straigraphic study of the basin include [1,2,3,4]. Other published biostratigraphy works on the basin include [5] who investigated the Upper Cretaceous Gongila and Pinginga Formations using ammonite zones in the Upper Cenomanian-Lower and Middle Turonian sediments.

Recent geologic studies on the Bornu Basin include differentiations of Chad Formation into members and their associated environment of deposition [6]; granulometric studies of Kerrikerri sandstone [7]; Palynological investigation of Bima Formations dated Albian–Lower Cenomanian [8]; detailed lithofacies and palynological study of Bima Group and age definition of the formations within [9]; 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 [10,11]; Albian-Eocene palynological biostratigraphy study of three wells in Bornu Basin [12]. Despite the amount of work done on the basin, stratigraphic relationship among Formations have not been well articulated and intensive palynological study on Gongila Formation and other units is still inadequate. Therefore, this study is aimed to augment and reassess both lithological and relative stratigraphic age and paleoenvironment of deposition of sediments encountered in Murshe-1 well stratigraphic section.

2. GEOLOGIC SETTING

Geologic investigation of the Bornu Basin started with [13,14,15,16]. The formation of Bornu Basin was predicated on third and failed arm of a triple junction formed during the Early Cretaceous in response to opening of the South Atlantic [17,18,19]. Other authors that supported this theory include [20,21,22,3,23].

Tectonic framework of Bornu Basin and its evolution was divided into four phases:

- Phase 1- Pan-African crustal consolidation (750-550Ma) RRR,
- Phase 2- Early rift stage (130-95Ma) RRR,
- Phase 3- Late rift stage (98-75Ma) RRR, and
- Phase 4- Post rift stage (66-0Ma) RRR.

These phases were described to have led to the cessation and collapse as sub-crustal swells, associated with folding, faulting, sedimentation, erosion and volcanism [20]. Another associated event is stress redistribution and initiation of secondary situation; followed by Tertiary-Recent event characterized by continental-lacustrine sedimentation and volcanism [3]. The geologic evolution of Bornu Basin and Benue Trough are related [2].

The stratigraphy of Bornu Basin was divided into group and formations ranging in age from Albian to Recent [1,24,25,26,27,9]. Bima Formation is the oldest stratigraphic unit deposited under continental environment. The formation is diachronous and is Albian-Turonian in age [14]. Lithologically, it was described to be poorly sorted, sparsely fossiliferous, thickly bedded, cross stratified; sand size varies from feldspathic coarse to conglomerate [3].

Avbobvo et al. [3] 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 and is dated Albian [28,8,9]. The Gongila Formation is a transitional sequence that lies in-between the underlying marine shale of Bima Formation and typical marine setting of the overlying Fika Formation. Other Formations that overlie Fika Formation include Gombe, Kerrikerri and Chad; their lithological descriptions have been well defined [12,11].

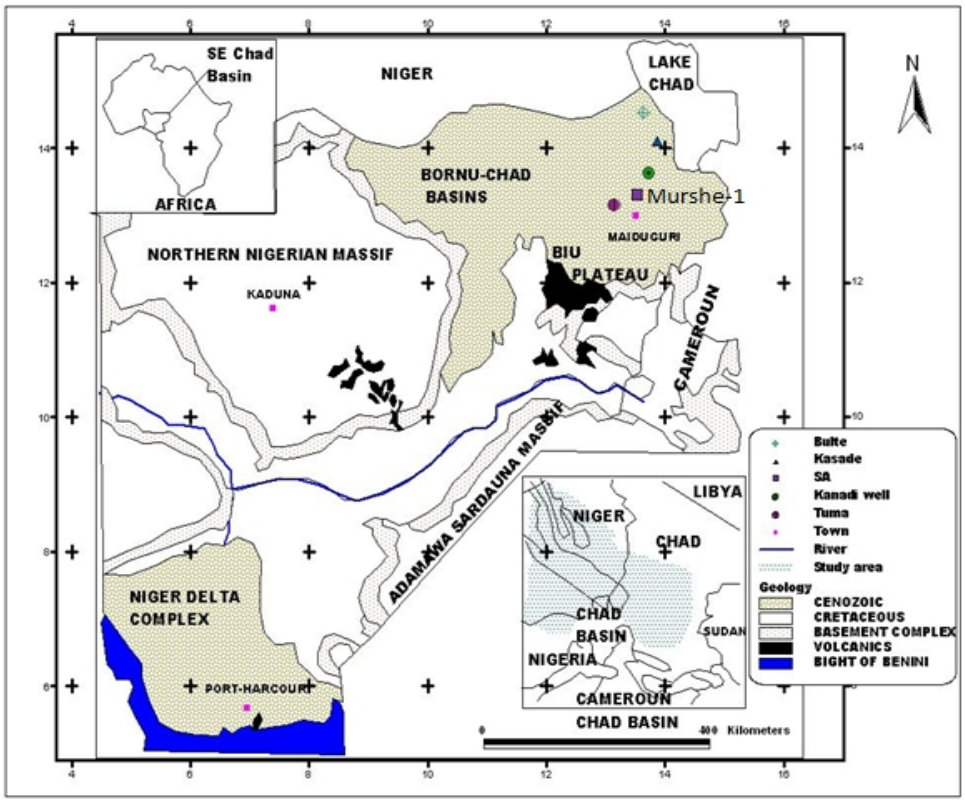


Fig. 1. Geological map of Nigeria showing the location of Bornu Basin and the studied well; upper inset shows the larger Chad Basin in Africa, while the lower inset describes the lithostratigraphy of the area (modified after Genik, 1992).

3. MATERIALS AND METHODS

Two hundred and ninety (290) ditch cuttings ranging in depth from 70-1930m from the Murshe-1 well were arranged serially in order of depth. The samples were initially washed in order to remove the 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 sorting through the use of Western Atlas textural monograph chat, 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 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 24hrs at 50ºC.

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. Important palynomorphs were photographed using Nikon P6000 digital camera.

4. RESULTS AND DISCUSSION

4.1 Lithostratigraphy

The formations encountered in the well are discussed as follows: (Table 1).

4.1.1 Gongila formation

The Gongila Formation is characterized at the base by black, fissile, calcareous and fairly ferruginised shale sequence (1880-1930m). The 50m thick marine shale is overlain by intercalated sand and shale. The light grey sandy shale is defined by fine to medium sand grains, well sorted sediment. The 60m heterolith facies (1820-1880m; Table 1) forms the uppermost part of the Gongila Formation, deposited in a prograding deltaic setting in this well. It is remarkable that volcanic intrusive reported by earlier workers in this formation is not visible in the studied well, therefore, it is suggested that the intrusion was a local effect.

4.1.2 Fika shale

The Fika Shale varies in depth from 620-1820m with an estimated thickness of 1200m. This seems to be the greatest thickness compared to the work of [14,27,4]; but it compares favourably with the thickness derived from seismic data of [3]. The Fika Formation lies unconformably on the Gongila Formation. The formation is not entirely shaly but rather shows intercalated gypsum at the lower to middle part of the sequence; while the middle part is characterized by silty shale deposited between interval 840-890m (50m thick). The

uppermost part is a shale facies, shows rare coarse to pebble sand grains; calcareous and rare occurrence of gypsum serves as accessory mineral (Table 1). The paleoenvironment of deposition is suggested to be marginal to open marine while transporting medium was of relatively high energy and erosive in nature (turbidity currents) which might be responsible for clast particles present in the shale during deposition.

4.1.3 Gombe formation

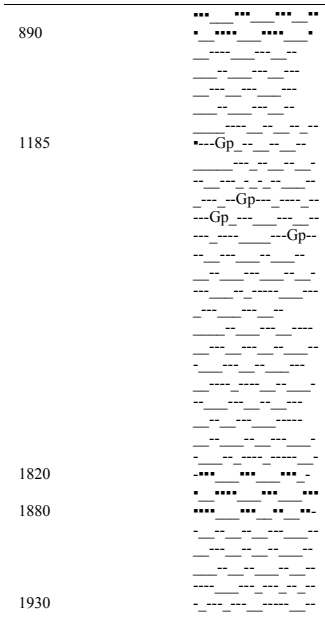
The Gombe Formation occurs at interval of 385-620m with a thickness of 235m. The formation is characterized by a basal sandstone unit of about 30m (590-620m). The sand is a brownish coloured conglomerate, fine to pebbly in grain size, and very poorly sorted. The overlying interval 385-590m contains light brown to light grey bulky claystone with an interbed of sand (Table 1). The environment of deposition is suggested to be of distal continental to proximal fluviatile.

4.1.4 Kerrikerri formation

The Kerrikerri Formation is composed lacustrine at the upper part to proximal fluviatile environment of deposition. The lower sandy part is from depth 280-320m (40m thick). The sand is milky to pinkish in colour, conglomeratic in nature; poorly sorted with grain size varying from medium to pebble, subangular to rounded. The basal sandstone marks the unconformable contact with the older underlying clayey Gombe Formation (Table 1). The sandstone is overlain by a light grey claystone intercalated by light grey bulky shale.

Table 1. Summary of the lithostratigraphy, chronostratigraphy, formation and Paleo-environments of Murshe-1 well, Bornu Basin, Nigeria. (not to scale)

Depth(m)	Litho-log	Description	Formation /Age			Paleo-environment
70		Very light grey claystone				Lacustrine To Proximal Fluviatile
		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	Kerrikerri	Eocene		
320						
385		Reddish brown, bulky mudstone Light brown to light grey bulky claystone with intercalated sandstone				Continental
525						
590		Brownish coloured conglomeratic sandstone; fine to pebble in size, very poorly sorted.	Gombe	Paleocene		
620						
840		Dark grey to black fissile shale, rare coarse to pebble sized grains, calcareous with gypsum	Fika	Campani an-Maastric htian		Marine



890	Black fissile silty shale Dark grey to black fissile shale			
1185	Black fissile shale with intercalated gypsum			
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				

4.2 Palynological Assessment

Miospore recovery is moderate to barren at different intervals. However, the palynomorph are well preserved. Microplanktons are as well present in the well and their presence is used to determine the paleoenvironment of deposition. Palynozonation interpretation is generally based on the evolution of the miospores, their extinction and their relative frequencies dependent on the ecology and other environmental factors. Thus, five palynozones were erected based on the assemblages of diagnostic forms which were compared with the works of earlier researchers including [29,30,31,32]. Details of the basis of establishing the palynozones are given below:

Zone: Triorites africaensis assemblage zone 1
Interval: 1755-1930m
Age: Turonian

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

The top of the interval is marked by the top appearance of *Triorites africaensis* and appearance of *Retimonocolpites sp.* and *Monosulcites sp*. The interval is stratigraphically equivalent to Gongila Formation (Tab. 1).The assemblages contained here are in part similar to the zone described for Turonian age sediments in Bornu Basin [12]; but different from it by not associated with Albian to Lower Cenemanian forms such as *Afropollis jardinus, Steevesipollenites sp.,* abundance of Cretacaeiporites spp and *Galeacornea sp.* reported in Kasade and Bulte wells.

Zone: Syncolporites/Milfordia sp assemblage zone 2
Interval: 1580-1755m
Age: Senonian-Campanian

Characteristics: This interval is composed of assemblage of palynomorphs that are depictive 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.

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 Table1). This form has been used by [32,33,34,11,12] for different Campanian deposits in Nigeria.

Zone: Spinozonocolpites baculatus assemblage zone 3
Interval: 620-1580m
Age: Maastrichian

Characteristics: The base of the interval coincides with the top of the underlying zone 2 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 present and similar to the work of [35,36,37,34,11] are *Stephanocolpites sp, Foveotriletes margaritae,* and *Ulmoideipites krempii*. The occurrence of the typical Maastrichtian forms such as *Retidiporites magdalenensis, Proxapertites cursus, Inaperturopollenites sp, Ctenolophonidites costatus, Spinizonocolpites baculatus, Monocolpites marginatus, Distaverrusporites simplex, Longapertites microfoveolatus, Tricolporopollenites sp, Striatricolpites catatumbus, Striatopollis bellus* and *Polyadopolenites sp* were also reported in the work of [31,11,12].

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, Foveotriletes margaritae, Verrutrilletes bullatus* [35], 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 [32] and [11].

Some pollen and spores show a fairly continuous occurrence within the stratigraphic interval; among them are *Zlivisporites blanensis, Periretisyncolpites sp, Longapertites marginatus, Retidiporites magdalenensis, and Ulmoidites krempii*. The interval is well noted for occurrences of dinoflagellate cysts such as *Hiostrichosphaeridium atellatum*, *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 (Table 1)

Zone: Proxapertites cursus assemblage zone 4
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, Leiotriletes sp, Cf. Aquilapollenites sp and Cf. Cupaniedites reticulatus*. Other forms present are algae such as *Botryococcus braunii* and *Calcium oxalate crystals* [38]. 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 an equivalent of the Gombe Formation (Table 1). The age of the stratigraphic interval is in contrary to the work of [12] where he assigned the Paleocene to Fika Formation instead of Gombe Formation in the reported work of the three well (Tuma, Kasade and Bulte) in Bornu Basin, Nigeria.

Zone: Monoporites annulatus assemblage zone 5
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* (Fig. 2).

The upper part of the interval shows appearance of microforaminiferal wall lining and dinoflagelate cysts. The appearance of fungal spore in the claystone is suggestive of deposition in a fluviomarine setting [36,37]. However, the interval is dated Eocene to Younger age on the basis of the co-occurrence of *Monoporites annulatus, Retibrevitricolporites protrudens* and *Lycopodium phlegmaria.* The stratigraphic interval is equivalent to Kerri-kerri Formation. This Formation is not reported in [12] for the three wells (Tuma-1, Kasadi and Bulte-1 well) studied in Bornu Basin, Nigeria. However, it has reported present in Tuma-1 well adjacent to Murshe-1 well of this study in Bornu Basin, Nigeria [11].

5. CONCLUSION

Lithostratigraphy of the Murshe-1 well section is composed at the base by Gongila Formation, defined by dark 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 2. The latter is characterized by co-occurrence of *Triorites 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 rare occurrence of gypsum at the upper end. It belongs to the *Milfordia spp* assemblage zone 2 and *Spinizonocolpites baculatus* assemblage zone 3. The formation is dated Campanian to Maastrichian based on the co-occurrence of *Milfordia spp, Mauritiidites crassibaculatus, Longapertites marginatus, Foveotriletes margaritae, Retidiporites magdalenensis*, *Trichtomosulcites sp, Periretisyncolpites sp,* and *Auriiculidites sp*. The Fika Shale was deposited in a marine system.

The Gombe Formation dated Paleocene overlies the Fika Shale. It is composed of brownish coloured conglomeratic sandstone at the base, overlain by light grey bulky claystone associated with intercalated sandstone and reddish mudstone at its top. Palynologically, the formation is characterized by paucity of palynomorphs and dated Paleocene. The Kerri-kerri Formation is the youngest in the interval analyzed; composed of conglomeratic sandstone at the base, overlain successively by light grey bulky shale and light grey claystone. The formation is dated Eocene based on the co-occurrence of *Monoporites annulatus, Retibrevitricolporites protrudens, Proxapertites cursus,* and *Longapertites vernendenburgi*. The Kerrikerri Formation was deposited in a fluvio-marine environment. The study has provided additional information on the lithofacies of various Formations present in the basin and has as well indicated the presence of Gombe and Kerri-kerri Formations, their respective biozones and ages for the basin.

Plate 1

1 Liliacidites sp
2-4 Monosulcites sp
5 Retimonocolpites sp
6-8 Monocolpites marginatus
9-11 Leiotriletes sp
12 Cyathidites sp
13 Laevigatosporites sp
14 Zlivisporites sp
15 Syncolporites sp
16 Distaverrusporites sp
17 Verrucosisporites sp
18 Foveotriletes margaritae
19-22 Milfordia sp
23 Inaperturopollenites sp
24 Mauritiidites crassibaculatus
25 Striatricolpites catatumbus

Plate 1. Magnification at X 400 plate 1

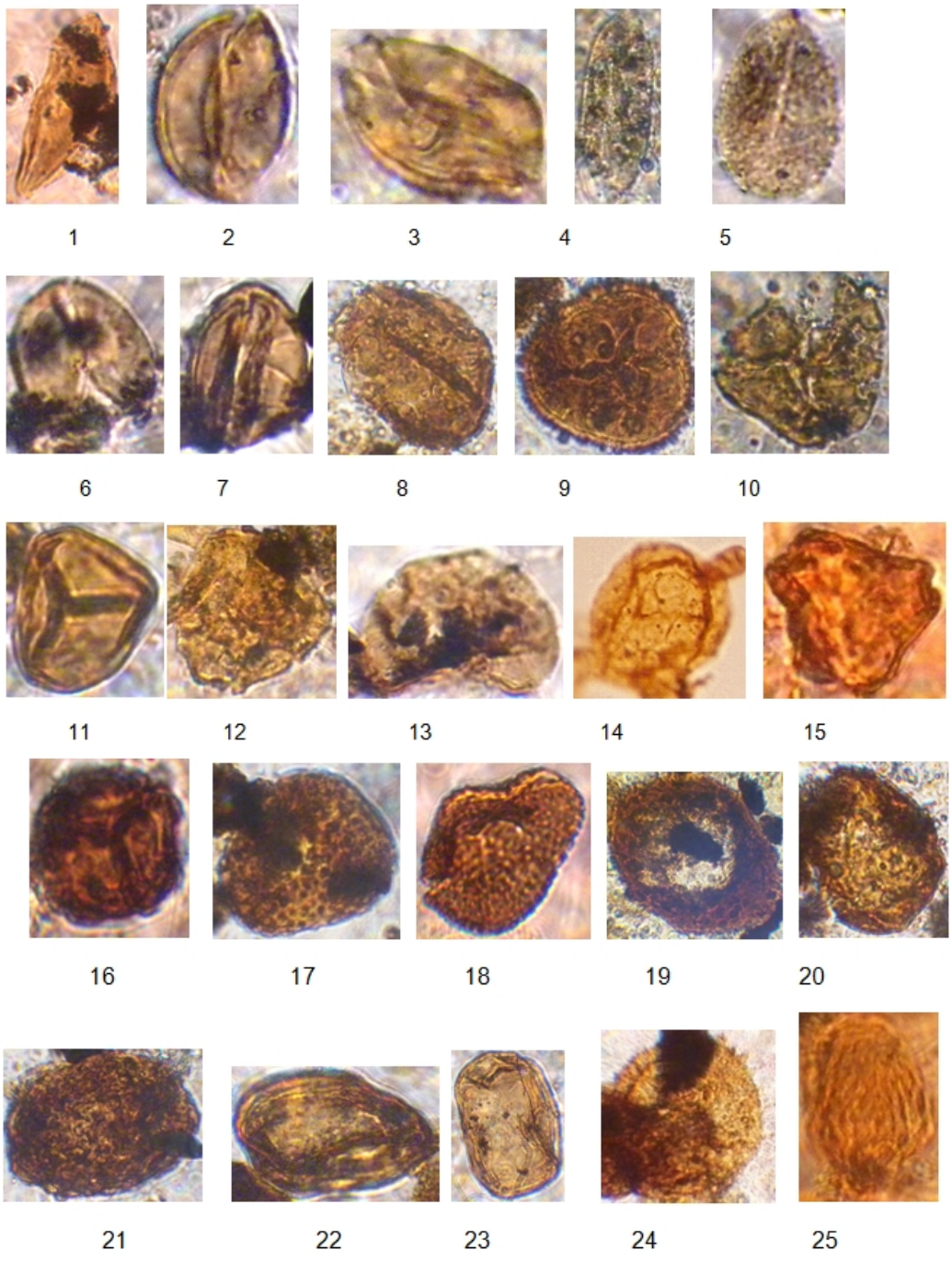
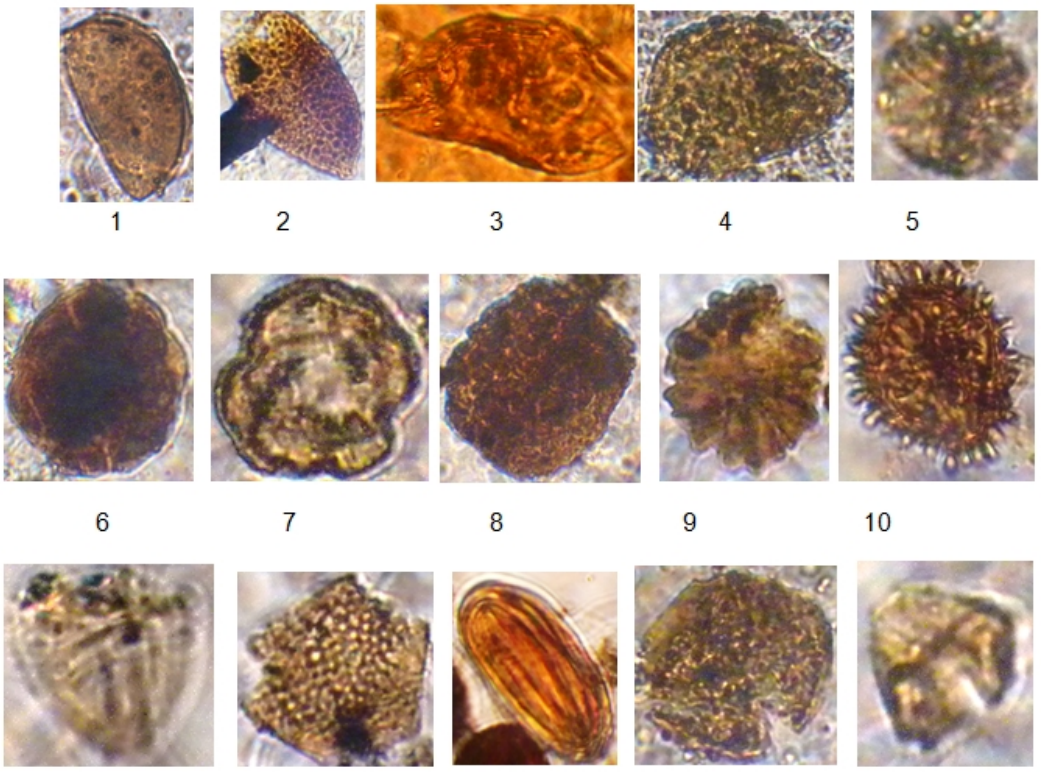


Plate 2

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

Plate 2. Magnification at X 400 plate 2



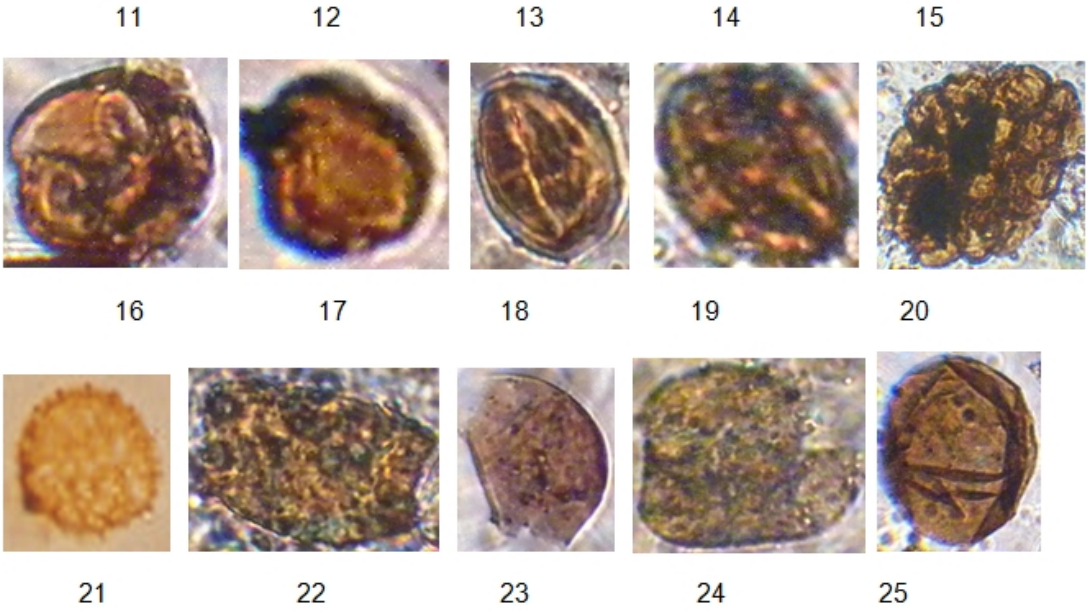
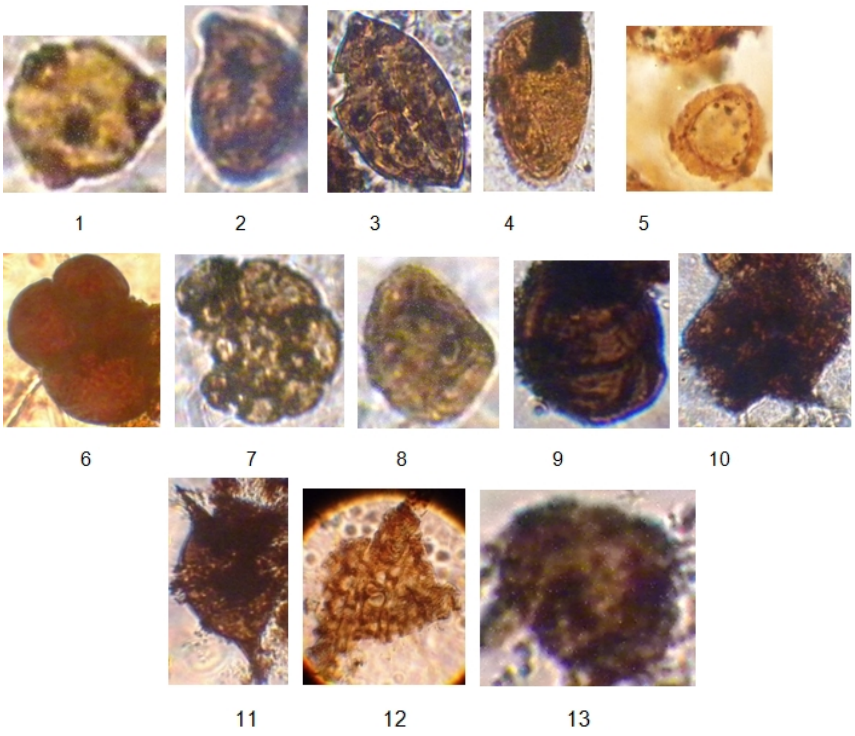


Plate 3

1 Retibrevitricolporites protrudens
2 Auriculiidites sp
3 Monosulcites sp
4 Longapertites microfoveolatus
5 Cingulatisporites ornatus
6-7 Microforaminiferal wall lining
8 Phelodinium bolonienae
9 Batiacasphaera sp
10 Senegalinium bicavatum
11 Andalusiella polymorpha
12 Calcium oxalate crystal
13 Classopollis brasiliensis

Plate 3. Magnification at X 400 plate 3



ACKNOWLEDGEMENTS

The author is grateful to Palystrat Limited for its endless support in making this research work a reality. He also appreciate the cooperation of Geological Survey Agency for providing ditch cutting samples used and granting permission to publish these findings. I am indeed grateful to Loule Jean Pierre and other reviewer for their objective contributions in raising the standard of this paper.

COMPETING INTEREST

Author has declared that no competing interests exist.

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