Palynofloral Assemblages and their Paleoclimatic Implication for Maiganga Coal Mine, Gombe Formation, Upper Benue Trough, Nigeria

U.S. Onoduku, E. A. Okosun and Y. B. Alkali
Department of Geology, School of Natural and Applied Sciences
Federal University of Technology, P.m.b 65, Minna
E-mail: onoduku.usman@futminna.edu.ng

Abstract
Three of the 24 boreholes that penetrated Gombe Formation have been studied for palynofloral assemblages. The aim is to establish their microfloral assemblages, age, paleoclimate and biozonation. The standard maceration method was employed for the palynological analyses. The studied boreholes (BA-7, BA-16 and BA-17) are considerably rich in palynomorphs which permitted adequate quantitative deductions. Majority of the pollen and spores observed from the study included Proteaciditessigalii, Retidiporitesmagdalensis, Monoporitesannulatus, Cingulastisporitesornatus, Rugulatisporitescaperatus, Scabratriporitesannellus, Proteaciditeslongispinosis, Distaverrusporites simplex andFoveotrilete margaritae. The recovered marker species have been used to date the studied section Maastrichtian age and this agreed with several previous workers. The analyses of the palynofacies were used to interpret the paleoclimate of the studied section as well as zoning the sections into two palyzones, Proteaciditessigalii-Echitriporitestrianguliformis zone and Cyathiditesspp-Laevigatosporiteshaardtii zone. The paleoclimatic conditions were inferred to belong to the Late Cretaceous Palmae province.

Keywords: Palynofloral, Paleoclimate, Gombe Formation, Maiganga Coal Mine, Biostratigraphy

Introduction

Palynological studies have become valuable tools and universally accepted methods of evaluating the stratigraphy and source rock potentiality of sedimentary basins. Palynology deals with the study of plant remains in the sedimentary successions and their applications in biostratigraphy.
A lot of contributions to the understanding of depositional environments and stratigraphy of the Gombe Formation(Maiganga coal mine inclusive) have been made by several previous workers (Lawal and Moullade,1987,Ojo andAkande, 2004 and Onoduku, 2013). The previous studies indicated a Late Senonian to Maastrichtian age for the Gombe Formation.

According to Onoduku(2013),despite the works of the earlier workers, there still exist stratigraphic gaps that require further studies to be filled up. These gaps include the non inclusion of the coal facies in the stratigraphy of Gombe Formation. These gaps may be attributable to lack of subsurface samples and data which were not available to the earlier authors as occasioned by lack of available boreholes that penetrated Gombe Formation as at the time of their studies. The search for coal and its subsequent mining in the Maiganga area which commenced in October, 2007, has however paved way for access to subsurface samples and data from the Gombe Formation. Hence, this study was undertaken to fill the missing stratigraphic gaps.
The present study area is located within the Gombe Formation, precisely at Maiganga coal mine, near Kumo in Akko LGA.The Gombe Formation had been mapped as a unit by

several workers (e.g. Falconer, 1911; Berber et al., 1954; Reyment and Barber, 1956 and Carter et al., 1963). The Formation consists of estuarine and deltaic sandstones, siltstones, shales and limestones. There are thin coal beds reported by the above earlier workers and this has been confirmed by the successful exploration and on-going exploitation of the coal deposit at Maiganga coal mine which serve as the source of samples for this study. The exact age of the formation as at that time is unknown but a tentative assignation of Upper (Campanian) Senonain-Masstrichtian has been suggested. Its type locality is Gombe according to the earlier workers.

The Gombe Formation is made of 3 major lithofacies which were later proved as separate distinguishable members. At its base, the Gombe Formation consists of rapidly alternating thin beds of silty shales, sometimes with plant remains and fine to medium-grained sand stones with some intercalated thin flaggy Ironstones. Passing upwards, the Gombe sandstone beds become more persistent and make up the greater of what was referred to as "bedded facies" by Zaborski (1997). South of Gombe, the Upper part of the Gombe Formation was termed "Red Sandstones Facies" by Zaborski (1997) probably due to its reddish colouration. Dike (1995) had reported coal horizons within the Gombe Formation and this was later proved by other workers. Infact, the coal seams are presently being mined by the Ashaka Cement Company.

According to Hamidu (2012), the type locality of the Gombe formation was designated as the "Kware Stream" by Carter et al. (1963) which is about 3 km south of Gombe where 300 m of sediments were described as exposed. He however asserted that the 1:250,000 scale geological map (sheet 36 Gombe) provided in Carter et al. (1963) is inadequate to determine with certainty which of the "Kware" streams in the area actually contains the type section. He concluded, based on his field findings, that the type section for the Gombe Formation proposed by Carter et al. (1963) actually belongs to the Arowa member (a member of the Gombe Formation).

The Study Area

The area chosen for this study is located within the Maiganga coal mine, Gombe state. Maiganga coal mine falls within the Gombe Formation in the Upper Benue Trough of Nigeria. The Maiganga coal mine is bounded by latitudes 009°00' 00"N to 12°00' 00"N and longitudes 10°00' 00"E to 12°00' 00"E (Figure 1.1).The coal mine is accessible through the Gombe–Yola Road. The mine is located at 8km, off Gombe –Yola Road at 22 km junction in Akko Local Government Area of Gombe State. The villages in the vicinity of the mine include Kumo, Duba Fulani, Kalshingi.

Geological Setting (Stratigraphy) of Benue Trough

The Benue Trough is considered most important and hence, the most studied of all the Cretaceous sedimentary basins in Nigeria probably due to its peculiar formational history and its potentiality for hydrocarbon generation, ranking second to the oil prolific Niger Delta (Obaje et al., 1994). At its northeastern end which conforms to the segment commonly known as the Upper Benue Trough, it bifurcates into an E-W trending Yola arm and N-S trending Gongola arm Figure 1.(Zaborski et al.,1997).

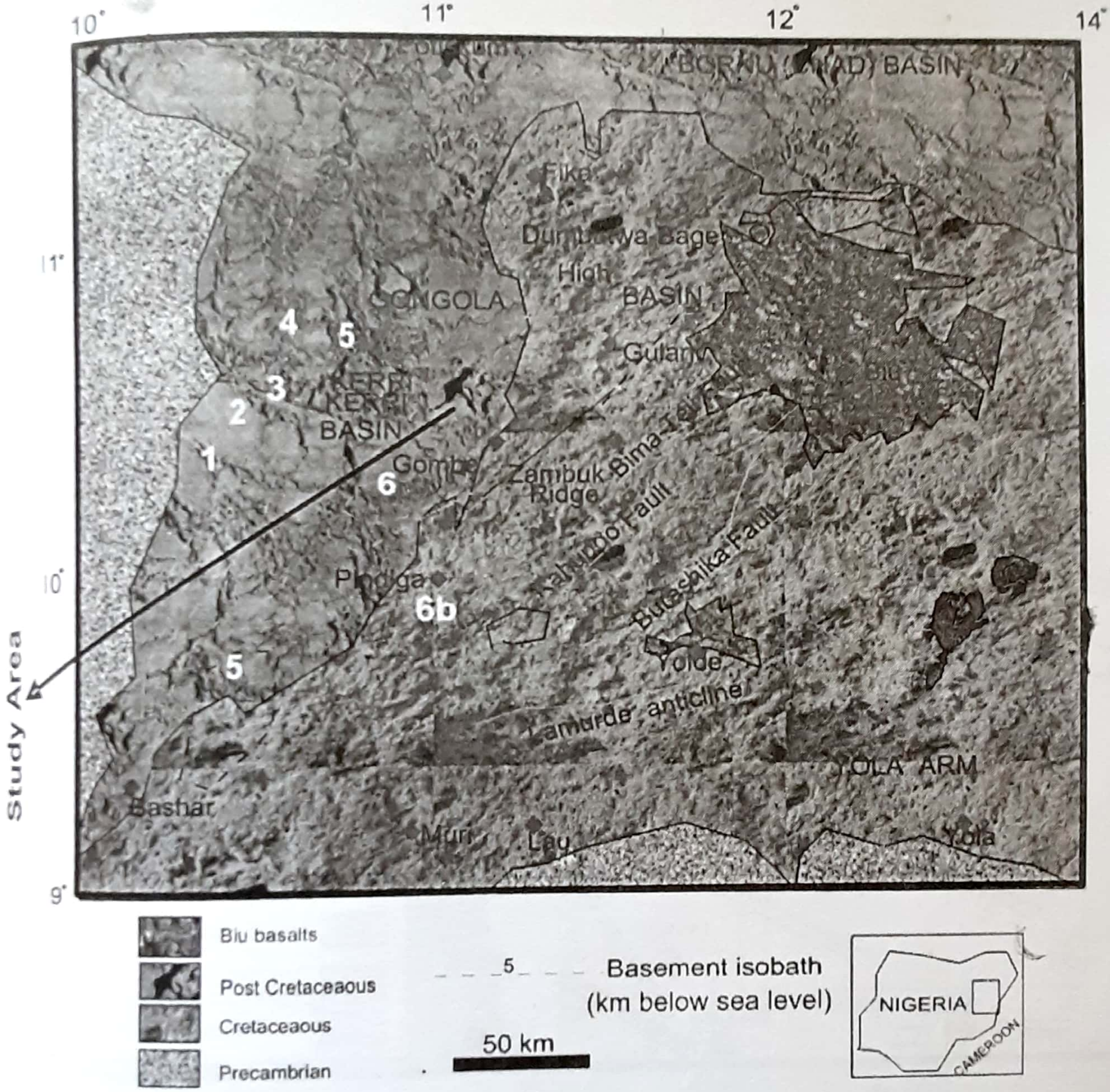


Fig. 1: Map of Benue Trough (arrow showing the studied area, Modified after Zaborski et al., 1997).

The Benue Trough is geographically divided into three; The Upper, Middle and Lower Benue Troughs (Figure 2). The geology and stratigraphy of the three sub-basin segments have been well described and documented (e.g. Obaje et al., 2006, Zaborski et al., 1997).

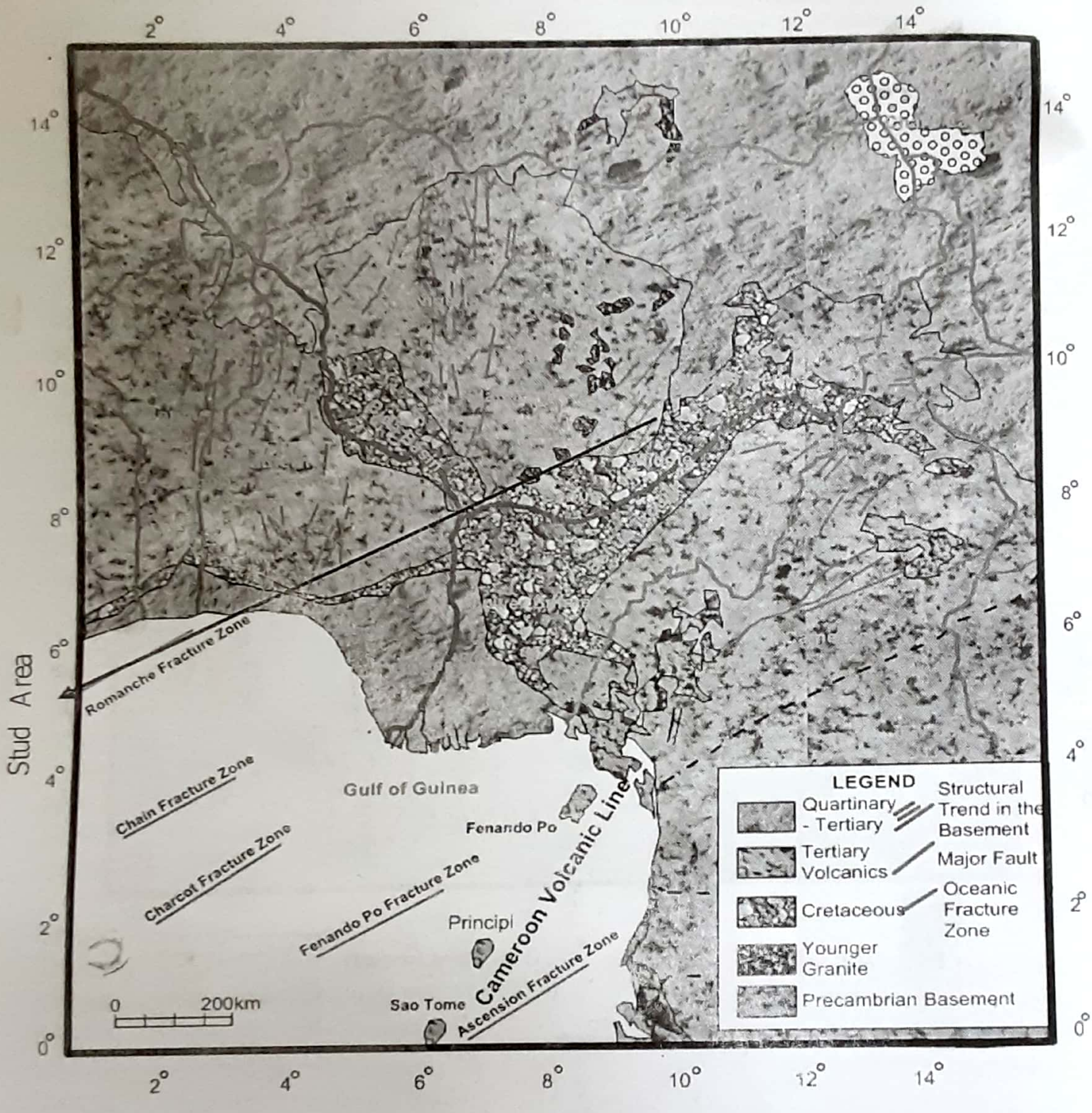


Fig. 2: Geological sketch map of the Benue Trough (Modified after Odebode, 2010)

For the purpose of this study, the stratigraphy of the Gongola sub-basin that hosts the Gombe Formation will be discussed and this is adopted from the work of Zaborski et al. (1997), Carter et al. (1963) and Popoff et al. (1986). The lithostratigraphic successions for the Gongola basin have been established by these workers. Their schemes are as shown in Figure 3.

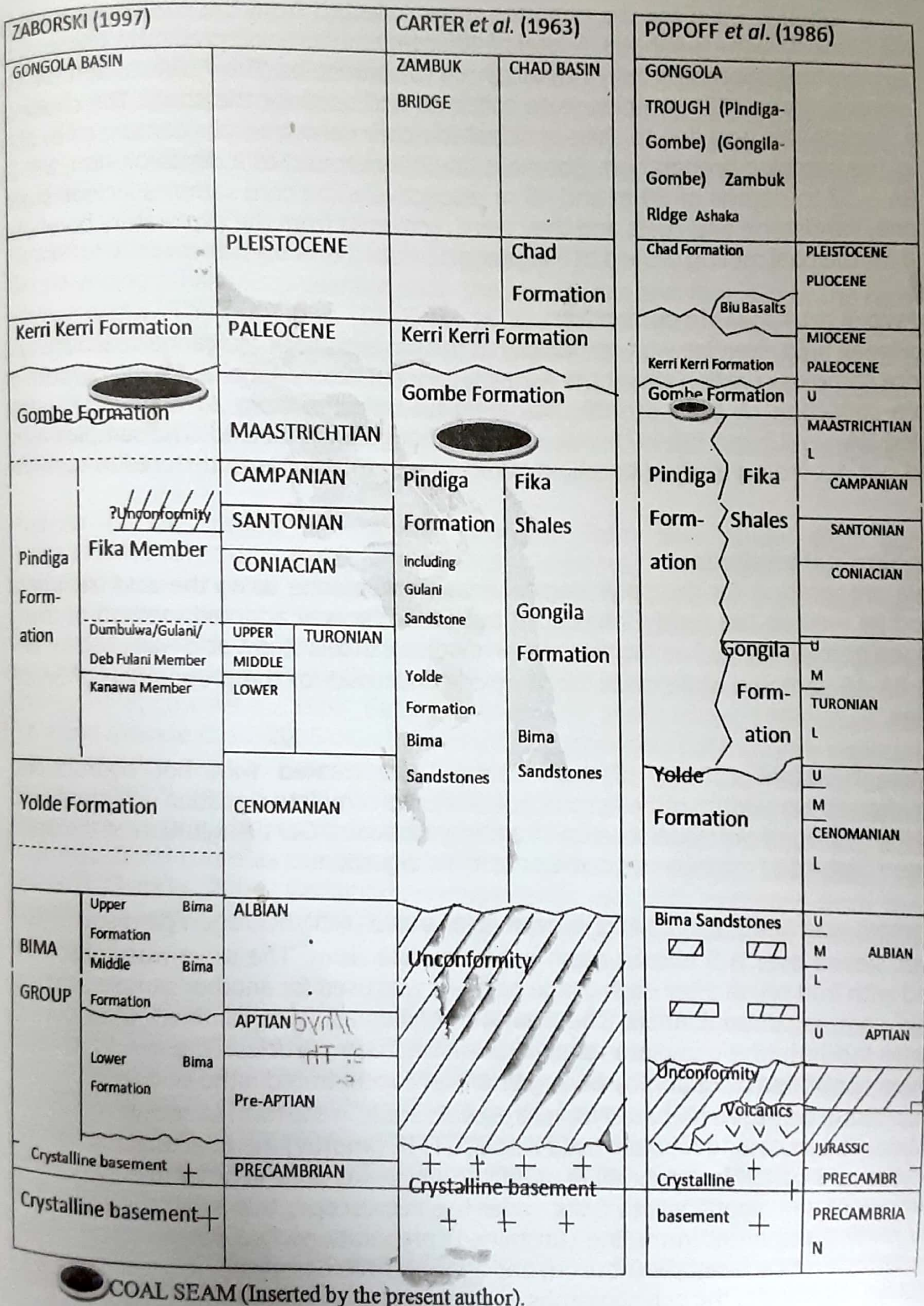


Fig. 3: Lithostratigraphic successions for the Gongola sub-basin (Modified after Zaborski, 1997)

Materials and Methods

The core samples used for the analyses were collected from the core store room at Ashaka Cement Factory, Ashaka. A total of 400 samples were collected from Twenty-four (24) exploratory boreholes out of which three (3) boreholes (BA–7, BA–16 and BA–17) with seventy-three (73) samples were collected and used for the study. The choice of these 3 boreholes was due to their anticipated richer palynomorphs content as evident during the samples preparation. Borehole BA–7 penetrated to a depth of 48m, BA–16 and BA – 17 to depths of 60 m and 45 m respectively.The core samples include shale, siltstone, sandstone and coals and they were recovered from the exploratory boreholes drilled for the coal mining project at Maiganga.

Field work and sample collection

A two-week field exercise was carried out at the project site at Maiganga coal mine and the core samples curation site at the Ashaka Cement Factory Ashaka, for the purpose of sample collection. A total of 400 core samples collected from 24 exploratory wells (labeled BA 1 – 23 and BA 44?) were sampled, bagged and labeled. The samples were sorted out according to their borehole numbers, depths ranges and stored in separate bags.

Palynological analysis

Sample preparation for the palynological analysis was done using the acid treatment method as well as the newly introduced but yet to be well adopted method of using hydrogen peroxide (H_2O_2) as the maceration medium. In this study, acid was used for BA-7 and BA-16 samples while hydrogen peroxide was used for the preparation of BA-17 samples.

A constant weight (20 g) of each sample was treated with hot hydrochloric acid/hydrogen peroxideto remove carbonates prior to complete digestion in hydrofluoric acid (HF)/hydrogen peroxide solution in a fume cupboard. Gentle agitation of the acid/ hydrogen peroxide / mixture was carried out to aid digestion.

The sample was heated to boiling in hydrochloric acid (HCl)/hydrogen peroxide (H_2O_2) and wet sieved over a 5 micron mesh polypropylene sieve. The sieve was constantly cleaned with iron brush after each usage before it was used for another sample solution to avoid sample contamination. The Branson sonifier 250 was routinely used during sieving to facilitate the complete removal of silt and clay particles. The sieved residue was given controlled oxidation by boiling briefly in concentrated nitric acid (HNO_3). The sample residue was then prepared for microscopic study in the form of strewn mount on glass slide. The mounting medium used was LOCTITE (impruv) manufactured by Loctite corporation, USA. Staining of the slide using infranin O was done in order to enhance the appearance of any dinoflagellate cysts under the microscope; this is because they are usually fairly transparent in routine (unstained) preparations.Two palynological slides were prepared for each sample (horizon) and analyzed microscopically in order to ensure a complete coverage of the palynomorphs present.

Result and Discussion.

Palynomorphs

The results of the palynological analysis are as shown in the form of distribution charts in appendix A. whileFigures 4 to 6show the palynomorph distributionfor the analyzed palynoforms. Photomicrographs of some of the palynomorphs are shown in Appendix B. The interpretations of the palynomorphs follow the style of several previous authors, e.g. (Lawal and Moullade, 1987; Lawal, 1982; Ojo and Akande, 2004; and Ojo and Akande et al., 2006).

Microfloral assemblage and biostratigraphy

The palynological results presented show the abundance and diversity of the recovered palynomorphs. The boreholes (BA-7, BA-16 and BA-17) that penetrated the Gombe Formation within the studied area are considerably rich in palynomorphs as to permit adequate quantitative analysis and deductions. The pollen and spores assemblage include angiosperms, gymnosperms andpteridophytes. (Appendix B, plates 1 to 7). A total of 1,151 palynomorph counts were observed within the studied samples, out of which pollen account for 62.29 %, spores, 35.88 % and algae 0.87 %.

Majority of the pollen and spores observed from this study area such as Proteaciditessigalii, Retidiporitesmagdalensis, Monoporitesannulatus, Cingulatisporitesornatus, Rugulatisporitescaperatus, Distaverrusporites simplex, Foveotriletesmargaritae, ScabratriporitesannellusandProteaciditeslongispinosus have been recorded from the Maastrichtian sediments of Nigerian basins and other part of west Africa like Senegal, Ivory Coast, Brazil, Gabon, Angola, Egypt and Morocco(Jan Du Chene, 1978; Lawalet al., 1987; Salard- Cheboldaeff, 1990; Oloto, 1994;Ojo & Akande, 2004 and Akande et al., 2005). On the basis of the recovered palynoforms especially the marker species such as listed above and in conjunction with the work of Lawal and Moulade (1987) and Ojo and Akande (2004), the studied boreholes have been zoned into two assemblage zones as described below (Figures 4 to 6). These zones, based on their microfloral contents can be correlated with those of Lawal and Moullade, 1987 and Ojo and Akande, 2004. Retidiporites magdalensis was also reported from the Late Maastrichtianshale near Auchi in the Anambra Basin (Okosun, personal communication, July14, 2012).

Ojo et al. (2004) identified and listed two palyzones for the Gombe Formation based on their study. These are the Assemblage Zone I (Spinizonocolpites-Echitriporites-Milfordia sp.Assemblage Zone) and the Assemblage Zone II (Proxapertitesoperculatus-RetidiporitesechimonocolpitesAssemblage Zone). Lawal and Moullade on the other hand named the whole section spinizonocolpitesbaculatus Zone. In this study, the analysed section of the Gombe Formation have been dated Early Maastrichtian to Late Maastrichtian.

Assemblage Zone I (Proteaciditessigalii – Echitriporitestrianguliformis Assemblage Zone).

Interval: 47 – 23.22 m (BA-7), 57 – 22 m (BA-16), 46 - 21 m (BA-17)

Age: Early Maastrichtian

Diagnosis: This zone is defined by the basal and abundant occurrence of Proteaciditessigalii, Retidiporitesmagdalensisand Echitriporites trianguliformis.

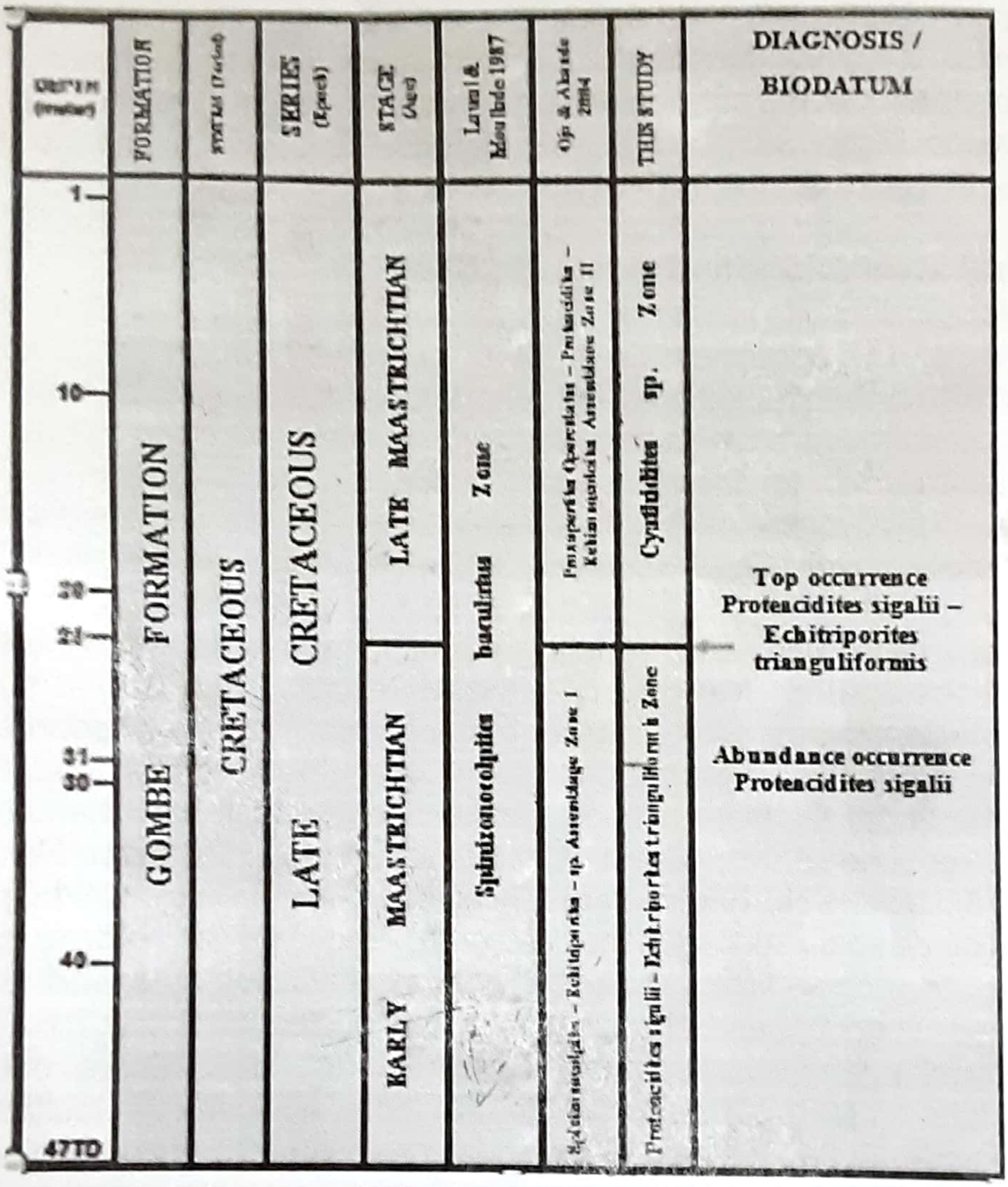


Fig. 4: Palynomorph Zones recognized in BA – 7 Borehole

The upper limit of this zone coincides with the disappearance of Retidiporites magdalensis, MonoporitesannulatusandBrevicolporitesguinetii and the abundant top occurrence of Cyathidites sp. This zone is also associated with Perfotricolpitesdigitatus, Retibrevitricolpitestriangulatus, Ctenolophoriditescostatus, Retitricolporitesirregularis, Proxapertitescursus, Psilamonocolpitesmarginatus, Psilatricolporitescrasus, Proteaciditessp, Rugulatisporitescaperatus, Sapotaceoidaepollenitessp, Proxapertitescursus and Auriculiidites sp. (Appendix A). This zone corresponds to the lower part of the Spinizonocolpitesbaculatus zone of Lawal and Moullade (1987) and the Spinizonocolpites – Echitriporites – Milfordia sp. assemblage zone of Ojo and Akande (2004). Majority of the palynoforms that constitute this zone have been reported by the above earlier workers and have dated the lower part of the Gombe Formation Early Maastrichtian and accordingly, based on the similarity of the palynoforms that constitute the study area with those of the earlier workers, the present study zone is dated Early Maastrichtian.

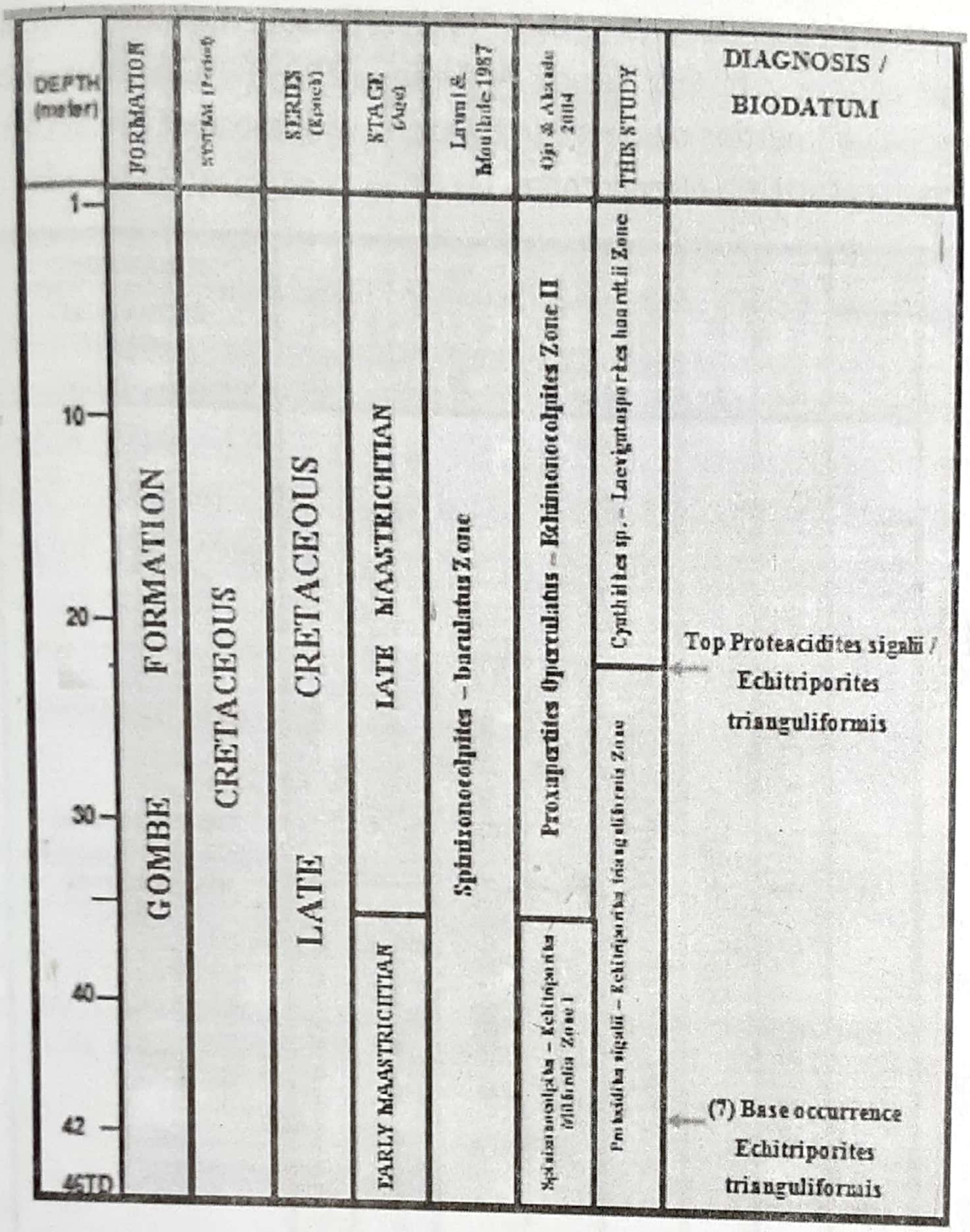


Fig. 5: Palynomorph Zones recognized in BA – 16 Borehole

Assemblage Zone II (Cyathiditessp – Laevigatosporiteshaardtii Assemblage Zone).

Intervals: 23.22 – 4 m (BA-7), 22 – 1.0 m (BA-16) and 21 – 1.0m (BA-17)

Age: Late Maastrichtian

Diagnosis: This zone is defined by the occurrence of Cyathidites sp. and other palynoforms that range from the lower zone such as Longapertitessp, Longapertitesvandeenburgii, Tricolporopollenitessp, Sapotaceoidaapollenitessp, Acrostichumaureum, Proxapertitescursus, Laevigatosporitessp and Inaperturopollenites sp. This zone is generally not rich in palynomorphs as the lower zone. This may probably be due to the relative sandy nature of the lithofacies when compared to the lower zone which contains shaly/mudstone which are rich in palynomorphs. This zone is equivalent to the upper Spinizonocolpitesbaculatus zone of

Lawal and Moullade (1987) and the Proxapertitesoperculatus – Echimonocolpites assemblage zone of Ojo and Akande (2004). On the basis of the correlateablepalynomorphs observed in this zone with those of the earlier workers, the zone have been dated Late Maastrichtian.

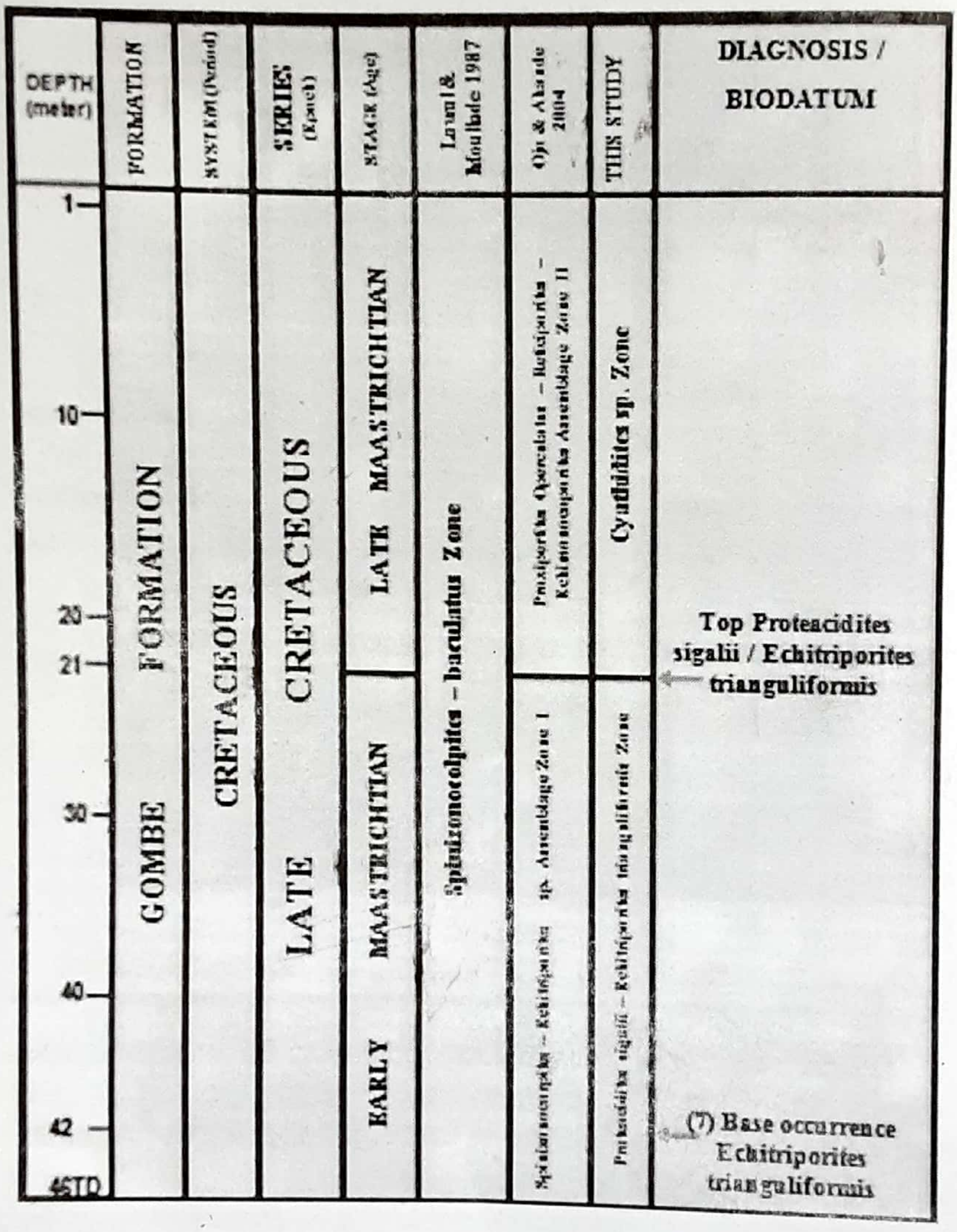


Fig. 6: Palynomorph Zones recognized in BA – 17 Boreholes

Paleoclimatic interpretation

The Paleoclimatic scenario of the studied section of the Gombe Formation is examined based on the pollen/spores data which offer clues for paleoclimatic deductions. Several studies have indicated that the major differences in vegetation across the globe at various geological times are due to variation in climates (Akande et al., 2005). According to Akande et al. (2005), Hergreen and Chlonova (1981) established eight microfloral provinces, the pre-Albian West Africa- South America province **(WASA)**, the boreal Lower Cretaceous province of the north hemisphere, the middle Cretaceous (Albian to

Cenomanian) Africa- South America province (ASA), the Upper Cretaceous Normapolles province and Aquillapollenites province , the late Cretaceous Palmae province of Africa and northern south America, the Godwana province and Senonian Northofagidites province. The Cretaceous microfloral province as discussed by Hergreen and Chlonova (1981) shows that West Africa belongs to the late Cretaceous Palmae province. This position is supported by the recovered pollen and spores in the studied area. Palmae pollen and spores such asAcrostichumaureum, Proxapertitescursus, Retidiporitesmagdalensis, Longerpertites, Auriculidiitesreticulatus, Echitriporitestrianguliformis, E.longispinosus, Gleicheniiditessenonicusrecovered from the studied section of Gombe Formation in this study indicate that the sediments belong to the Late Cretaceous Palmae Province. This correlates strongly with the Maastrichtian Patti Formation of the Lower Bida Basin and the Maastrichtian sediments of the northeastern and southern Nigeria (Jan Du Chene, 1978; Ojo & Akande, 2004; Ojo et al., 2004). The pollen and spores suggest a tropical climatic condition for the deposition of the Gombe Formation.

Conclusion

This study which was based on sub-surface cores of the Gombe Formation has improved the existing knowledge of the palynology and paleoclimate of the formation. The results of the analyses have shown that the Gombe Formation is a heterogeneous unit characterized by diverse palynomorphs. The formation was datedEarly to Late Maastrichtian on the basis of the palynomorphs. The pollen and spores belong to the Late Cretaceous Palmae Province.

References

Akande, S. O., Ojo, O. J., Erdtmann, B. D. &Hetenyi, M. (2005). Paleoenvironments, Organic Petrology and Rock-Eval studies on source rock facies of the LowerMaastrichtian Patti Formation, Southern Bida Basin, Nigeria. *Journal of AfricanEarth Sciences*, 41 (2005).394 – 406.

Carter, J. D., Barber, W. and Tait, E. A. (1963). The Geology of parts of Adamawa, Bauchi and Bornu Provinces in North – Eastern Nigeria. *GSN Bulletin*.56 – 59

Hergreen, G. F. W. & Chlonova, A. F. (1981).Cretaceous Microfloral Provinces. *Pollen et Spores*, 23, 441 – 556.

Jan Du Chene, R. E., Adegoke, O. S., Adediran, S. A. & Peters, S. W. (1978).Palynology and Foraminifera of the Lokoja Sandstone (Maastrichtian), Bida Basin, Nigeria.Revista Espanola de Micropaleontologia10: 379 – 393.

Lawal, O. (1982). Biostratigraphie, Palynologie et Paleoenvironments des Formation Cretaces de la itauteBenoue; Nigeria – North-Oriental. Doctorat de Specialite.Universite de Nice. 198.

Lawal, O. &Moullade, M. (1987).Palynological Biostratigraphy of Cretaceous Sediments in the Upper Benue Basin. *Revae de Micropaleontologie*, 29: 61 – 83.

Obaje, N. G., Ligouis, B. &Abaa, S. I. (1994). Petrographic Composition andDepositional Environments of Cretaceous Coals and Coal Measures in the middleBenue Trough of Nigeria. *Int. Journal, of Coal Geology*, 26 (1994), 233 – 260.

Obaje, N. G.,Attah, D. O., Opeloye, S. A. & Moumouni, A. (2006). Geochemical evaluation of the hydrocarbon prospects of sedimentary basins in Northern Nigeria. *Geochemical Journal*, 40, 227 – 243.

Ojo, O. J. &Akande, S. O. (2004). Palynology and Paleoenvironmental studies of the Gombe Formation, Gongola Basin, *Nigeria. Journal of Mining and Geology*, 40 (2), 143 – 149.

Ojo, O. J. &Akande, S. O. (2006). Sedimentological and Palynological studies of the Patti Formation, South Eastern Bida Basin, Nigeria: Implications for Paleoenvironments and Paleogeography. *NAPE Bulletin*, 19 (1). 61 – 77.

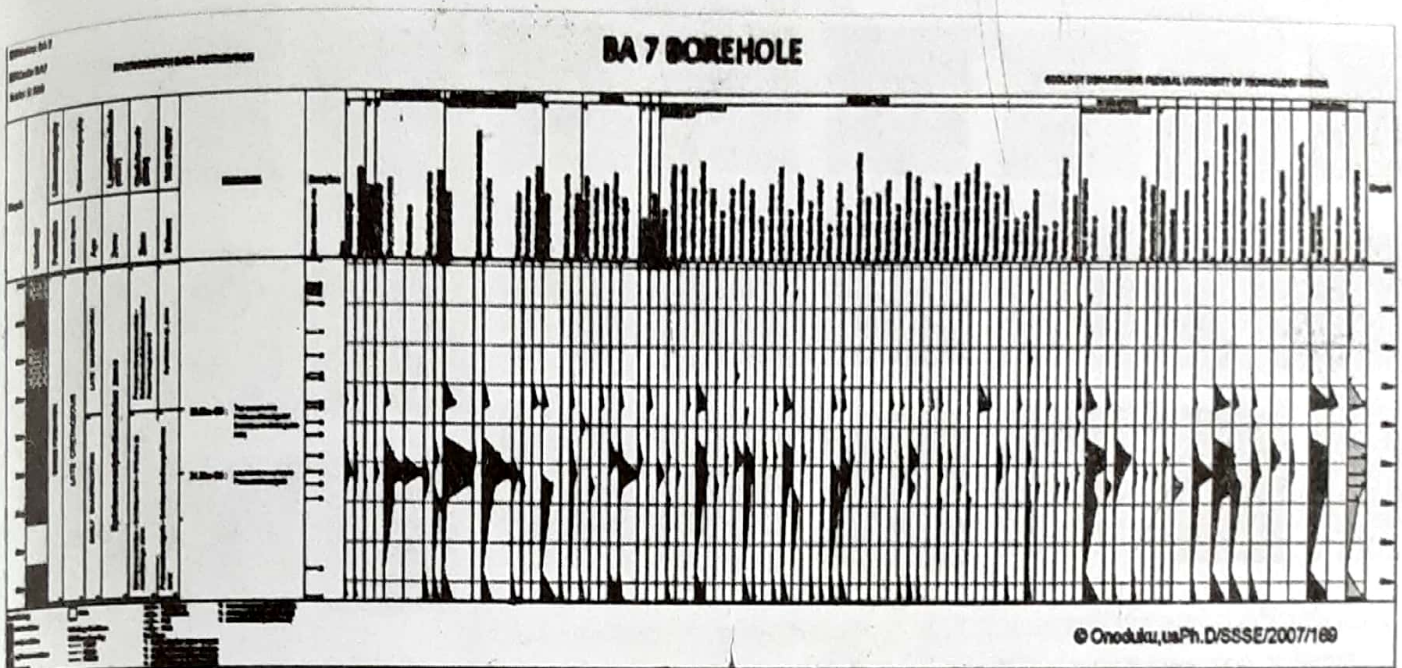
Oloto, I. N. (1994).Nigerian Maastrichtian to Miocene Dinoflagellate and Miospore Biozonation. *A Summary .Journal of Mining and Geology*, 30 (1), 61 – 73.

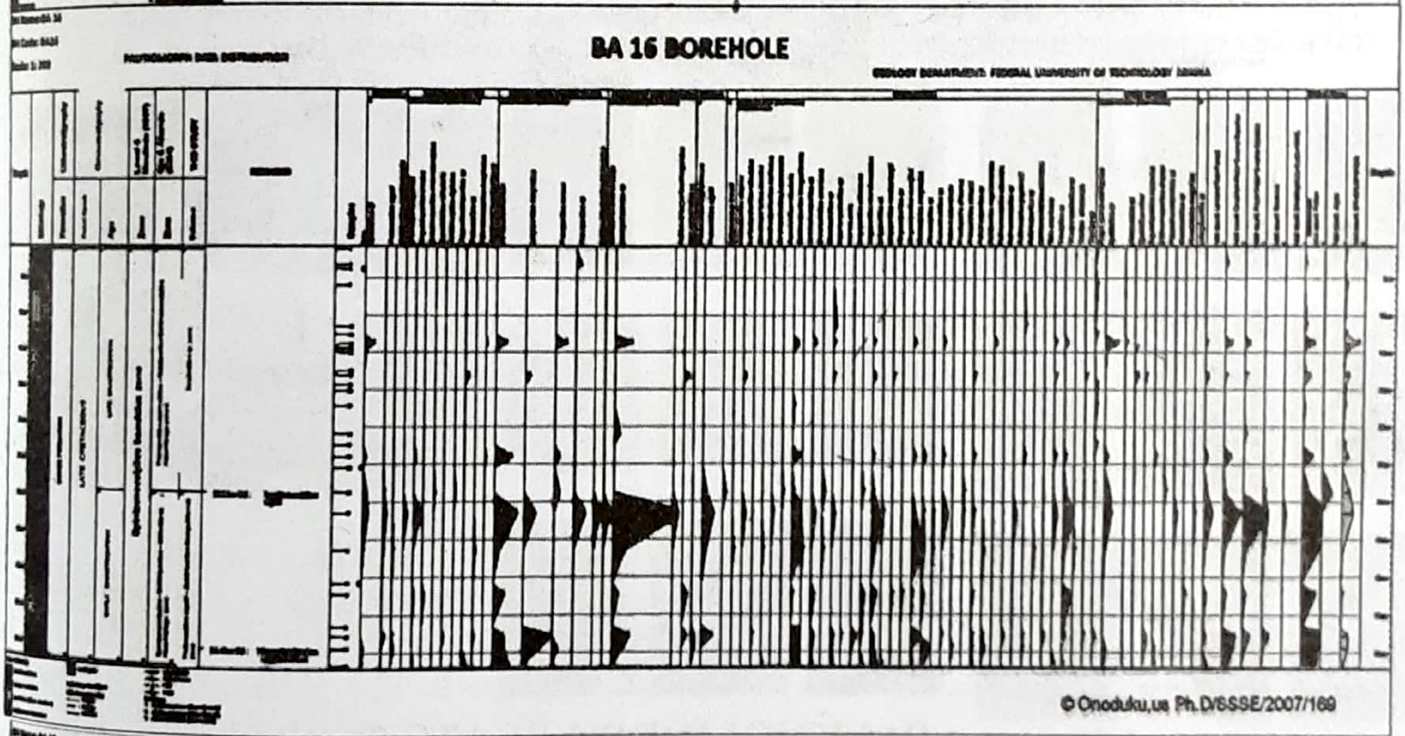
Popoff, M., Wiedmann, J. &Easz, I. (1986).The Upper Cretaceous Gongola and Pindiga Formation, Northern Nigeria. Subdivisions, Age, Stratigraphic Correlations and Paleogeographic Implications.EclogaeGeologicaeHelvetiae, 79, 343 – 363.

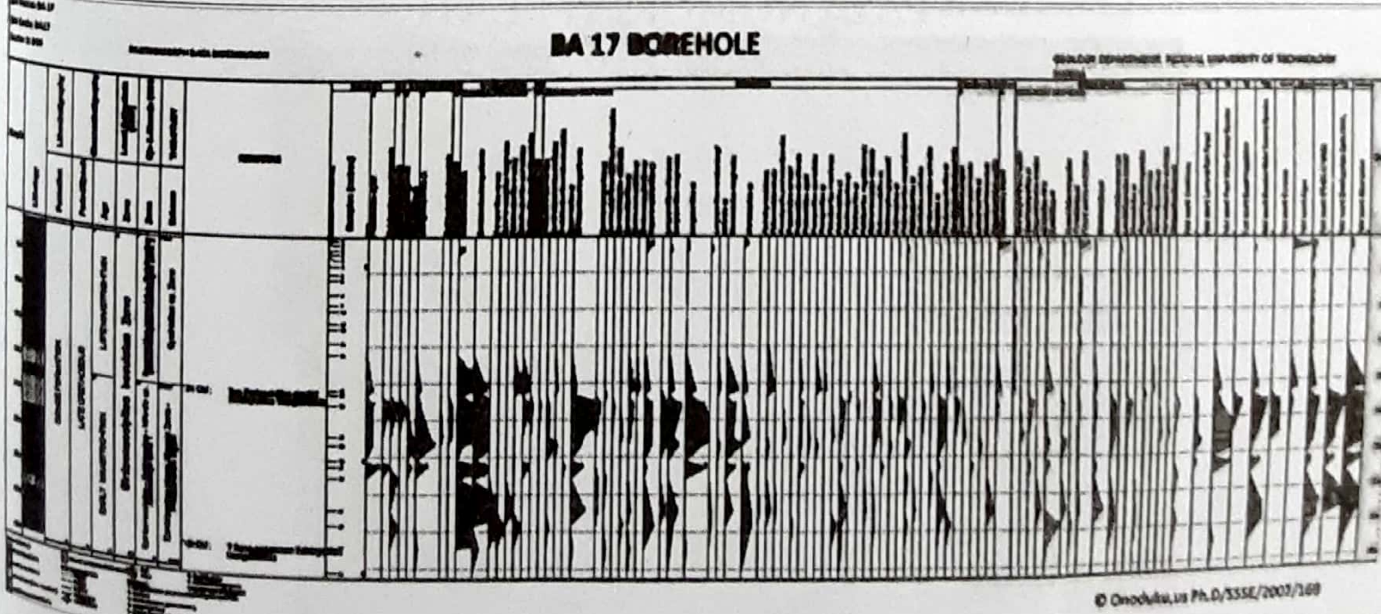
Salard-Cheboldaeff, M. (1990).Intertropical African Palynostratigraphy from Cretaceous to Late Quarternary Times: *Journal of African Earth Sciences*, 11, 1 – 24.

Zaborski, P. M., Ugoduluwa, F., Idornigie, A., Nnabo, P. &Ibe, K. (1997).Stratigraphy and Structure of the Cretaceous Gongola Basin, Northeastern Nigeria.Bulletin des Centres de Recherches Exploration, *Production Elf – Aquitaine*, 21. 153 – 185

Appendix A: Palynological distribution charts for the studied boreholes

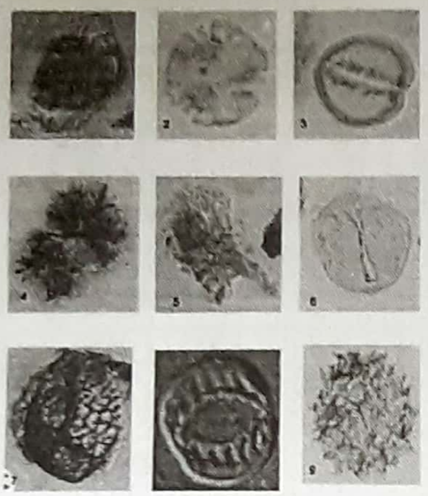




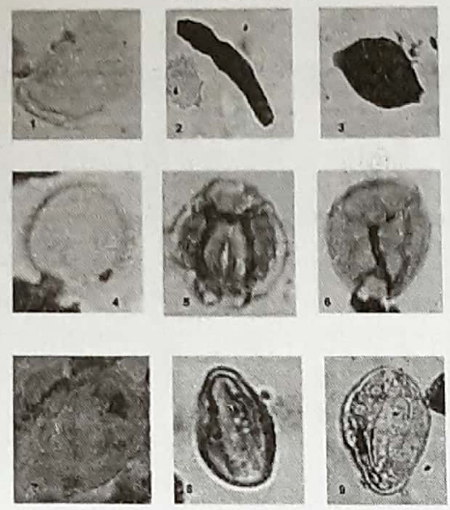


Appendix B: Photomicrographs of some palynomorphs observed.

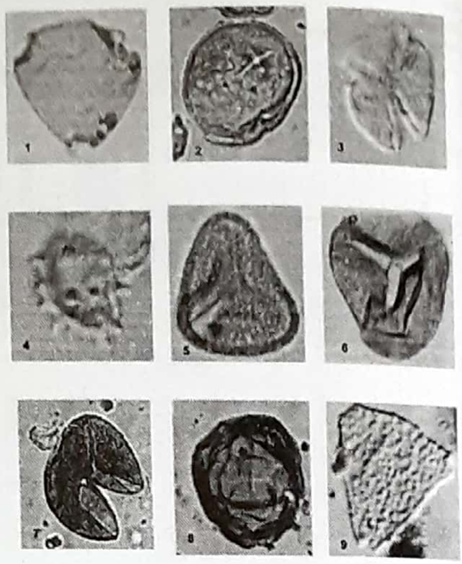
PALYNOMORPH PLATE 1



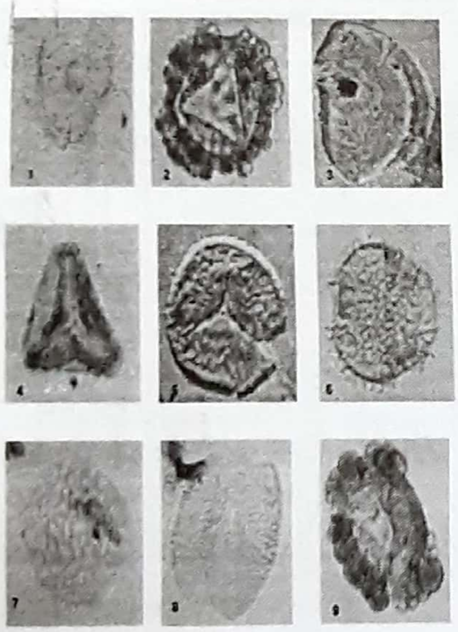
PALYNOMORPH PLATE 2



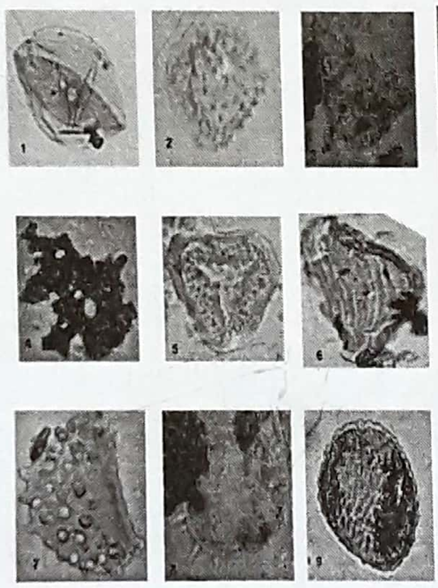
PALYNOMORPH PLATE 3



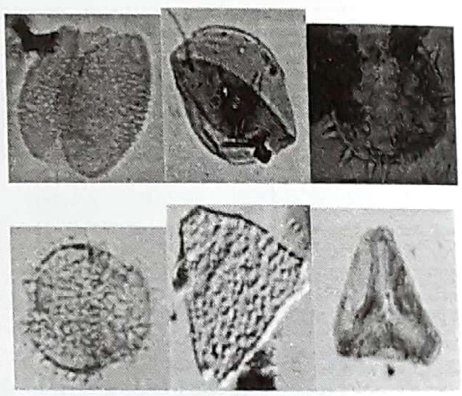
PALYNOMORPH PLATE 4



PALYNOMORPH PLATE 5



PALYNOMORPH PLATE 6



PALYNOMORPH PLATE 7

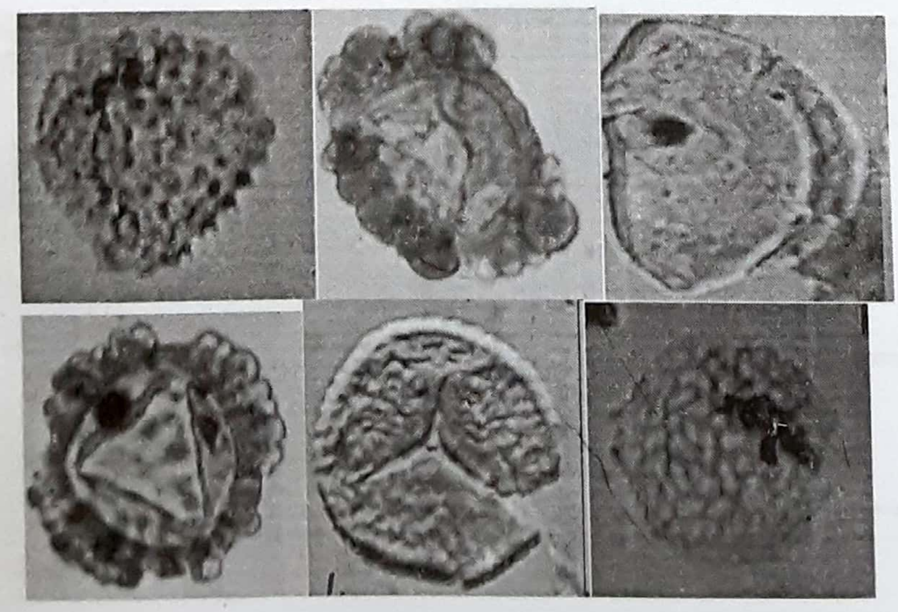


PLATE 1

1.Ephedripitesambiguous
2.Psilatricolporitescrassus
3.Monocolpollenites sphaeroidiites
4.Botryococcusbraunii (A)
5.Botryococcusbraunii (B)
6.Monocolpites marginatus
7.Retimonocolpites sp.
8.Tubistephanocolpitescylindricus
9.Pediastrum sp.

PLATE 2

1.Laevigatosporiteshaardtii
2. Fungal spore (A)
3. Fungal spore (B)
4.Arecipitescrassimuratus
3.Ctenolophonidiitescostatus
6.Zlivisporeitesblanensis
7.Proxapertitescursus
8.Sapotaceoidaepollenites sp.
9.Germmamonoporites sp.

PLATE 3

1.Cupanieiditessp.
2.Psilatricolporitescrassus
3.Tricolporopollenitessp.
4.DroseriditesSenonicus
5.Foveotriletesmargaritae
6.Cyathiditessp.
7.Osmundaciditessp.
8.Leoisphaeridiasp.
9.Proteaciditessigalii

PLATE 4

1.Nematosphaeropsissp.
2.Cingulatisporitesornatus
3.Longapertitesmicrofoveolatus
4.Glecheniditessenonicus
5.Rugulatisporitescaperatus
6.Retitricolporitesirregularis
7.Auriculiiditessp.
8.Longapertiteschlonovae
9.Distaverrusporites simplex

PLATE 5

1.Monoporitesannulatus
2.Echitriporitestrianguliformis
3.Auriculopollenitessp.
4. Charredgraminaecuticle
5. Polypodiaceoisporitessp.
6.Gnetaceaepollenitessp.
7. Verrucatosporitesusmensis
8. Spinizonocolpitesechinatus
9.Verrucatosporitessp.

PLATE 6

1.Longapertiteschlonovae
2.Monoporites annulatus
3.Spinizonocolpitesechinatus
4.Retitricolporitesirregularis
5.ProteaciditesSigalii
6.GlecheniiditesSenonicus

PLATE 7

1.Distaverrusporites simplex
2. Longapertitesmicrofoveolatus
3.Cingulatisporites Ornatus
4. Echitriporitestrianguliformis
5. Rugulatisporitescaperatus
6. Auriculiiditessp.