

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

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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*, *Scabratiporitesannellus*, *Proteaciditeslongispinosis*, *Distaverrusporites simplex* and *Foveotrilete 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 *Cyathiditespp-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 and Akande, 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).

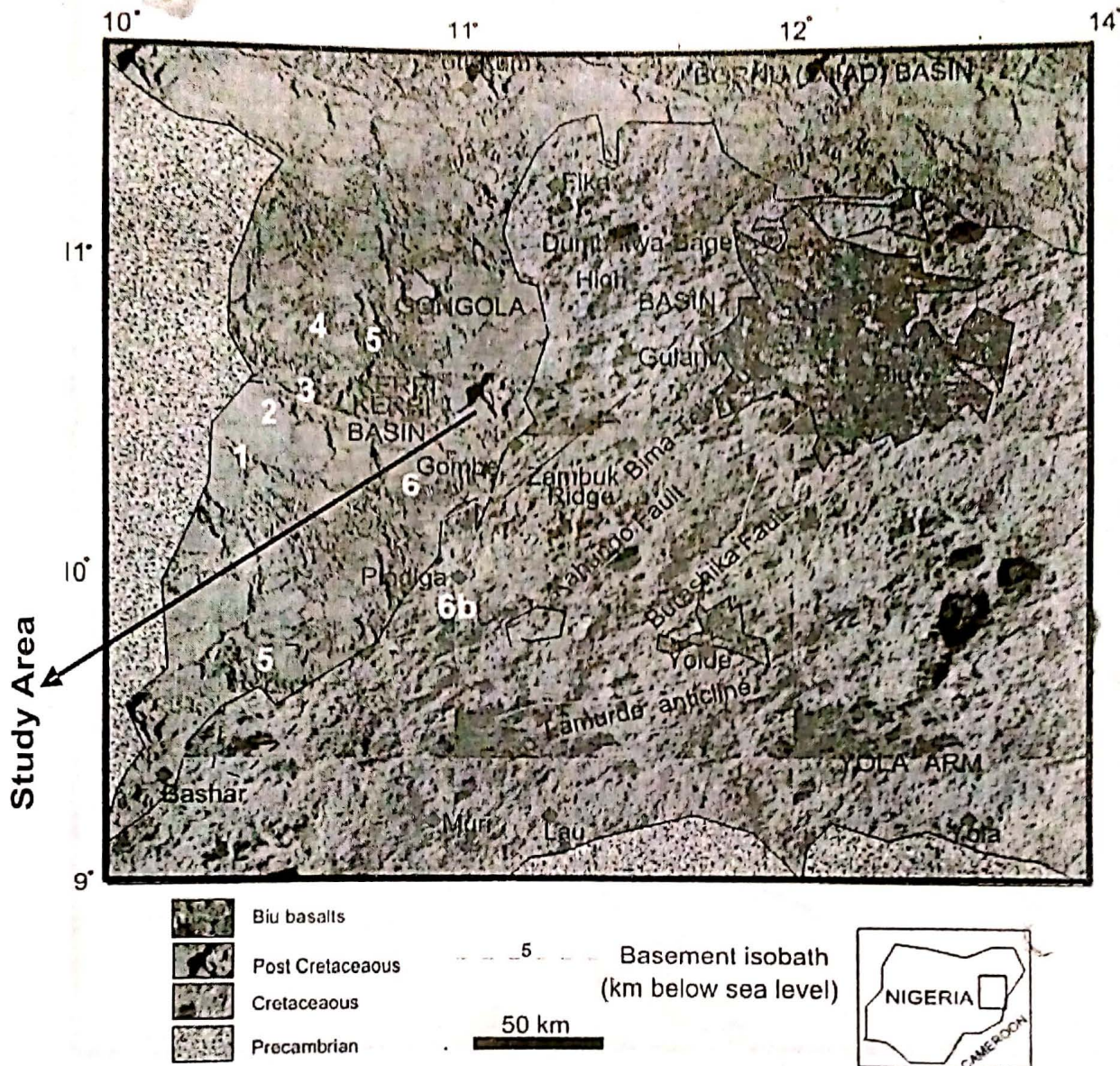


Fig. 1: Map of Benue Trough (arrow showing the studied area, Modified after Zaborski et al., 1997).

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).

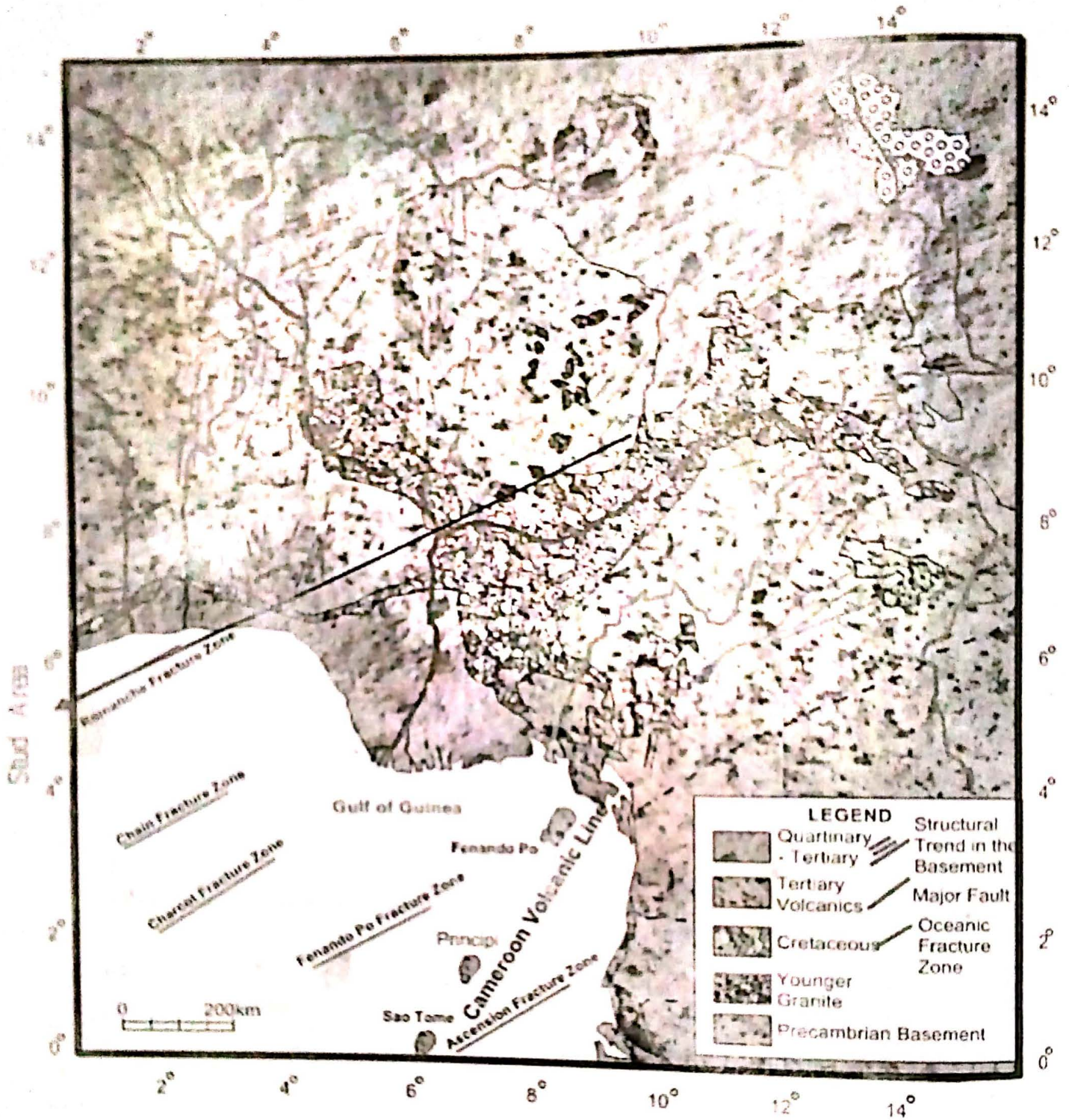
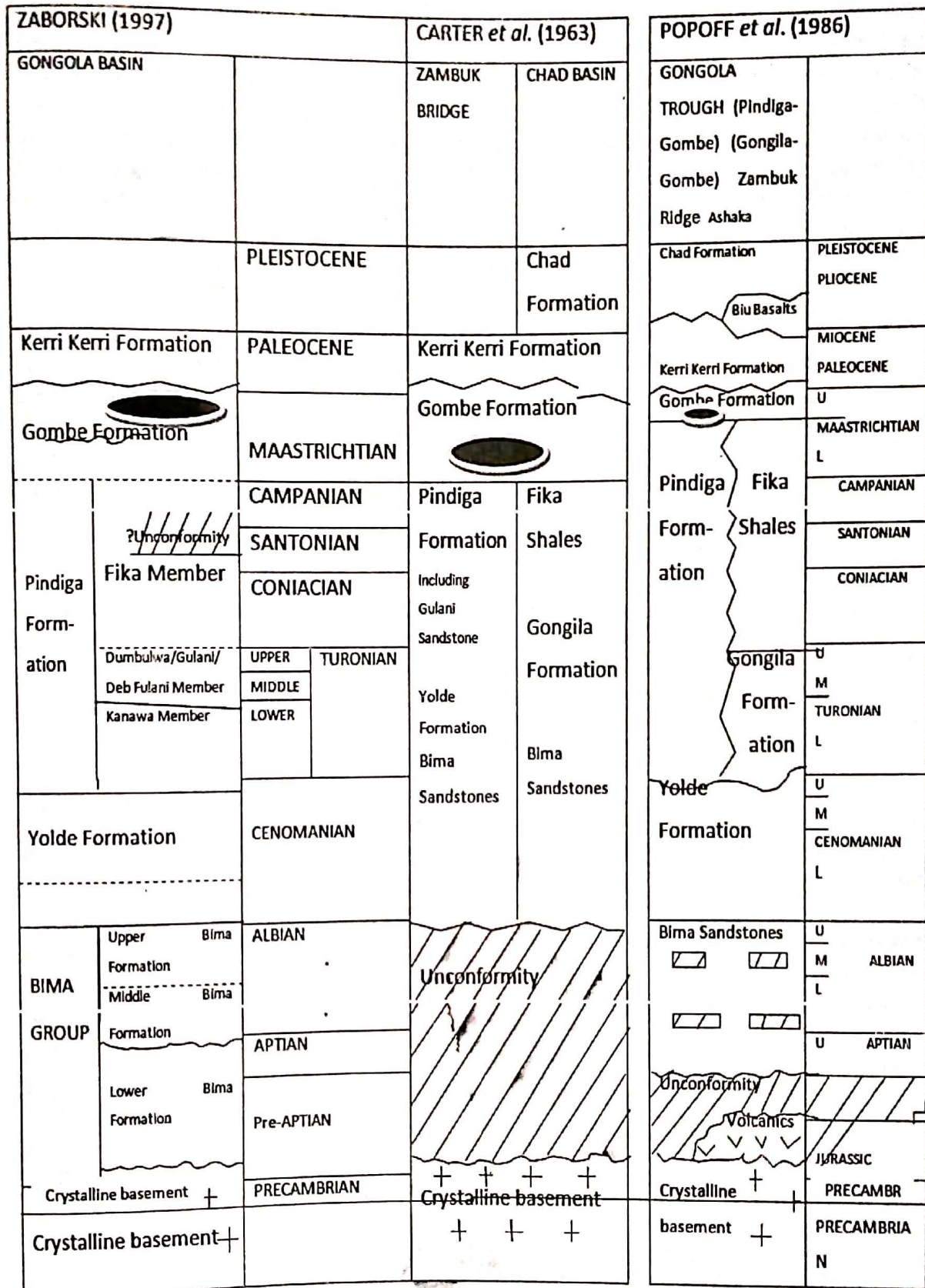


Fig. 2: Geological sketch map of the Benue Trough (Modified after Odebo, 2010)

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.



COAL SEAM (Inserted by the present author).

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 peroxide to 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. while Figures 4 to 6 show the palynomorph distribution for 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 and pteridophytes. (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 *Proteacidites sigalii*, *Retidiporites magdalensis*, *Monoporites annulatus*, *Cingulatisporites ornatus*, *Rugulatisporites scaperatus*, *Distaverrusporites simplex*, *Foveotriletes margaritae*, *Scabratriporites annellus* and *Proteacidites longispinosus* 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- Cheboldaef, 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 Maastrichtian shale near Auchi in the Anambra Basin (Okosun, personal communication, July 14, 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 (*Proxapertites operculatus-Retidiporites echimonocolpites* Assemblage Zone). Lawal and Moullade on the other hand named the whole section *spinizonocolpites baculatus* Zone. In this study, the analysed section of the Gombe Formation have been dated Early Maastrichtian to Late Maastrichtian.

Assemblage Zone I (*Proteacidites sigalii* – *Echitriporites trianguliformis* 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 *Proteacidites sigalii*, *Retidiporites magdalensis* and *Echitriporites trianguliformis*.

FORMATION	SERIES (Epochs)	STAGE (Age)	Lawal & Moullade 1987	Ojo & Akande 2004	THIS STUDY	DIAGNOSIS / EIODATUM
GOMBE FORMATION	CRETACEOUS	LATE MAASTRICHTIAN	buculatus Zone	Proxapertites cursorius - Proteacidites - Echitriporites trianguliformis - Assemblage Zone II	Cyathidites sp. Zone	Top occurrence <i>Proteacidites sigalii</i> - <i>Echitriporites trianguliformis</i>
		EARLY MAASTRICHTIAN				

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

The upper limit of this zone coincides with the disappearance of *Retidiporites magdalensis*, *Monoporites annulatus* and *Brevicolporites guinetii* and the abundant top occurrence of *Cyathidites* sp. This zone is also associated with *Perforicolpites digitatus*, *Retibrevitricolpites triangulatus*, *Ctenolophoridites costatus*, *Retitricolporites irregularis*, *Proxapertites cursorius*, *Psilamonocolpites marginatus*, *Psilatricolporites crasus*, *Proteacidites* sp., *Rugulatisporites scaperatus*, *Sapotaceoidaepollenites* sp., *Proxapertites cursorius* and *Auriculiidites* sp. (Appendix A). This zone corresponds to the lower part of the *Spinizonocolpites baculatus* zone of Lawal and Moullade (1987) and the *Spinizonocolpites - Echitriporites - Milfordia* sp. assemblage zone of Ojo and Akande (2004). Majority of the palynofoms 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 palynofoms that constitute the study area with those of the earlier workers, the present study zone is dated Early Maastrichtian.

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

DEPTH (m)	FORMATION	SYSTEM (AGE)	SERIES (STAGE)	Palynomorphs	Lawal & Moullade 1987	Top & Akande 2004	THIS STUDY	DIAGNOSIS / BIODATUM
1	GOMBE FORMATION	CRETACEOUS	LATE CRETACEOUS	LATE MAASTRICHTIAN	Epicretaculites - Isoperculatus Zone	Proxapertites operculatus - Echimonocolpites - Echinocolpites Assemblage Zone II	Cyclidites sp. Zone	Top Proteacidites sigali / Echitriporites trianguliformis
10								
20	GOMBE FORMATION	CRETACEOUS	LATE CRETACEOUS	EARLY MAASTRICHTIAN	Epicretaculites - Isoperculatus Zone	Proxapertites operculatus - Echimonocolpites - Echinocolpites Assemblage Zone I	Cyclidites sp. Zone	(7) Base occurrence Echitriporites trianguliformis
21								
30	GOMBE FORMATION	CRETACEOUS	LATE CRETACEOUS	EARLY MAASTRICHTIAN	Epicretaculites - Isoperculatus Zone	Proxapertites operculatus - Echimonocolpites - Echinocolpites Assemblage Zone I	Cyclidites sp. Zone	(7) Base occurrence Echitriporites trianguliformis
40								
42	GOMBE FORMATION	CRETACEOUS	LATE CRETACEOUS	EARLY MAASTRICHTIAN	Epicretaculites - Isoperculatus Zone	Proxapertites operculatus - Echimonocolpites - Echinocolpites Assemblage Zone I	Cyclidites sp. Zone	(7) Base occurrence Echitriporites trianguliformis
45								

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 as *Acrostichumaureum*, *Proxapertitescursus*, *Retidiporitesmagdalensis*, *Longerpertites*, *Auriculidiitesreticulatus*, *Echitriporitestrianguliformis*, *E.longispinosus*, *Gleicheniiditessenonicus* recovered 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

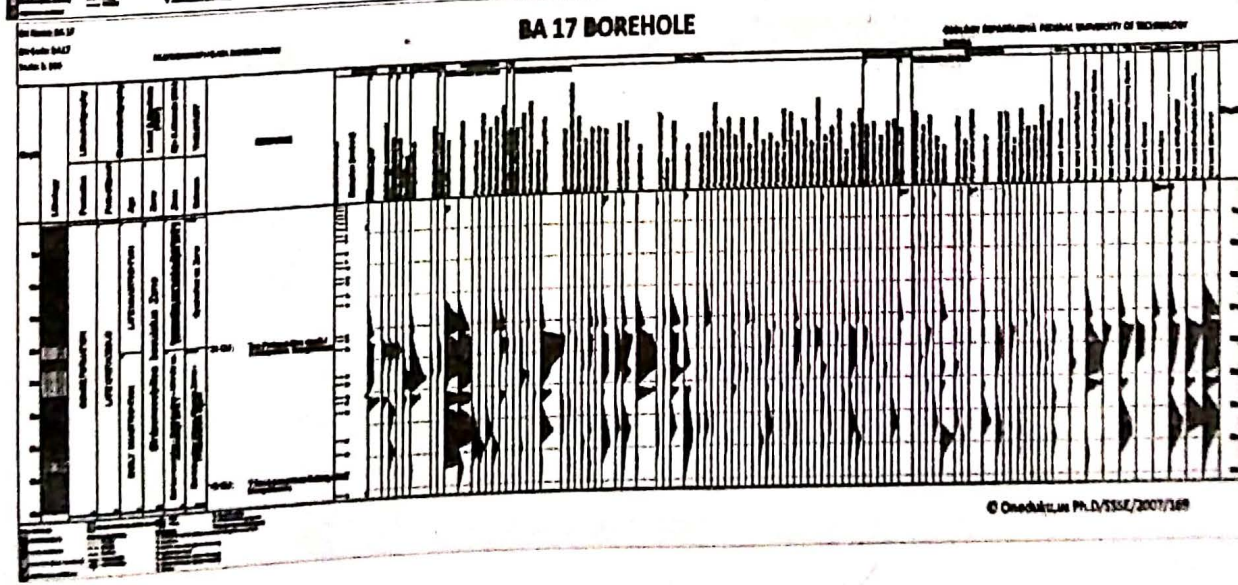
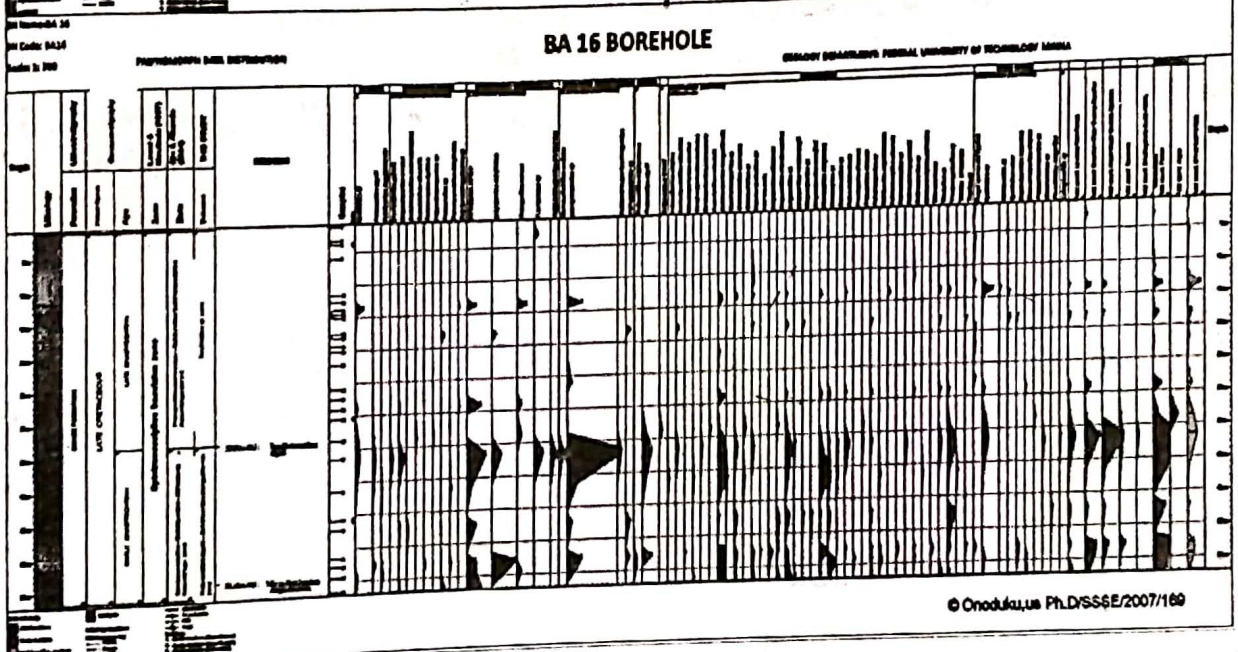
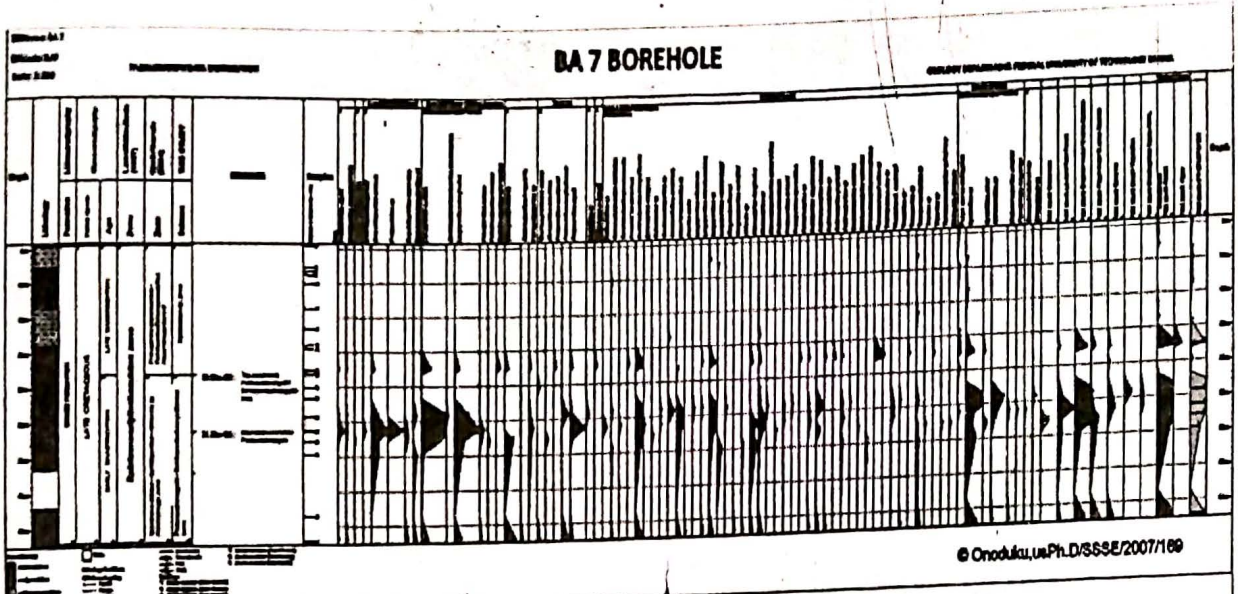
This study which was based on sub-surface cores of the Gombe Formation has improved the existing knowledge of the palynology and paleoclimate of the formation. The results of the analyses have shown that the Gombe Formation is a heterogeneous unit characterized by diverse palynomorphs. The formation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

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Appendix A: Palynological distribution charts for the studied boreholes



Appendix B: Photomicrographs of some palynomorphs observed.

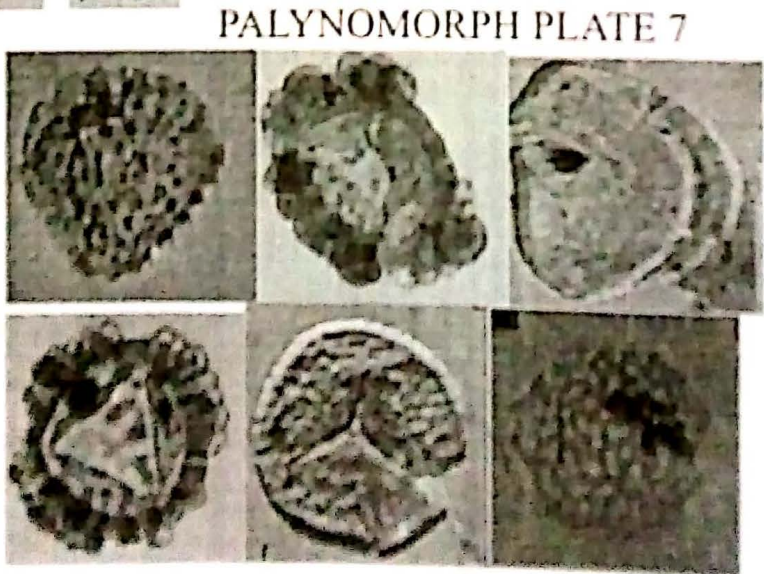
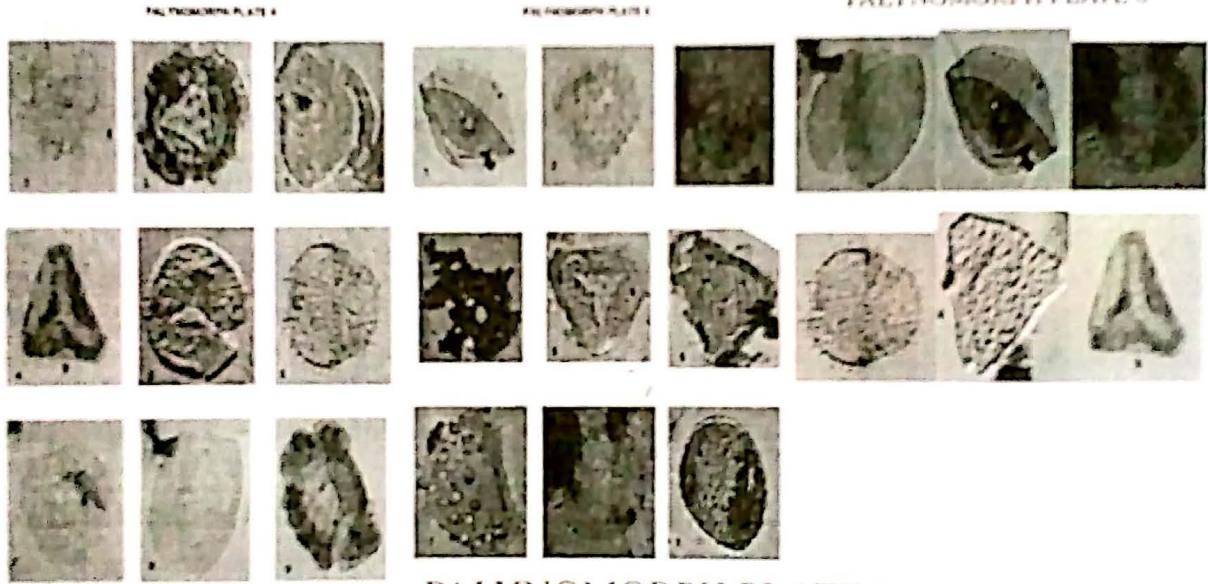
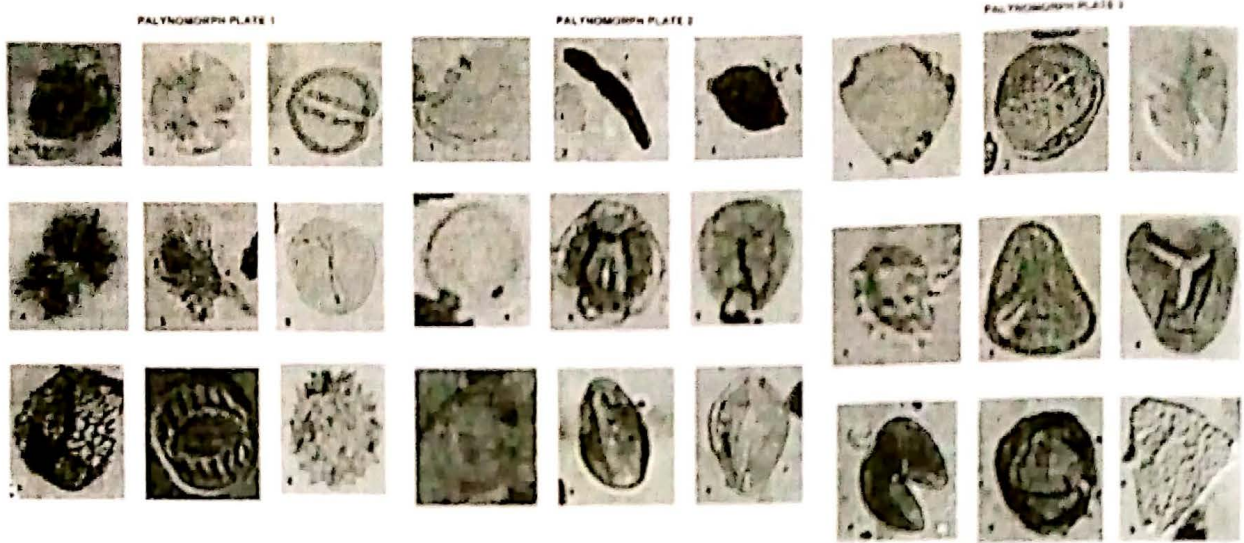




PLATE 1

- | | | |
|-----------------------------|-------------------------------------|------------------------------------|
| 1. Ephedripites ambiguous | 2. Psilatricolporites crassus | 3. Monocolpollenites sphaeroidites |
| 4. Botryococcus braunii (A) | 5. Botryococcus braunii (B) | 6. Monocolpites marginatus |
| 7. Retimonocolpites sp. | 8. Tubistephanocolpites cylindricus | 9. Pedastrum sp. |

PLATE 2

- | | | |
|-------------------------------|---------------------------------|----------------------------|
| 1. Laevigatosporites haardtii | 2. Fungal spore (A) | 3. Fungal spore (B) |
| 4. Arecipites crassimuratus | 3. Ctenolophonidites costatus | 6. Zlivisporites blanensis |
| 7. Proxapertites cursus | 8. Sapotaceoidae pollenites sp. | 9. Germmamonomorites sp. |

PLATE 3

- | | | |
|---------------------------|-------------------------------|-----------------------------|
| 1. Cupanieidites sp. | 2. Psilatricolporites crassus | 3. Tricolporopollenites sp. |
| 4. Droseridites Senonicus | 5. Foveotriletes margaritae | 6. Cyathidites sp. |
| 7. Osmundacidites sp. | 8. Leolsphaeridiasp. | 9. Proteacidites sigalii |

PLATE 4

- | | | |
|----------------------------|--------------------------------|----------------------------------|
| 1. Nematospaeropsis sp. | 2. Cingulatisporites ornatus | 3. Longapertites microfoveolatus |
| 4. Glechenidites senonicus | 5. Rugulatisporites scaperatus | 6. Retitricolporites irregularis |
| 7. Auriculiidites sp. | 8. Longapertites schlonovae | 9. Distaverrusporites simplex |

PLATE 5

- | | | |
|---------------------------------|-----------------------------------|-----------------------------|
| 1. Monoporites annulatus | 2. Echitriporites trianguliformis | 3. Auriculopollenites sp. |
| 4. Charred graminaceous cuticle | 5. Polypodiaceoisorites sp. | 6. Gnetaceae pollenites sp. |
| 7. Verrucatosporites usmensis | 8. Spinizonocolpites echinatus | 9. Verrucatosporites sp. |

PLATE 6

- | | | |
|----------------------------------|--------------------------|--------------------------------|
| 1. Longapertites schlonovae | 2. Monoporites annulatus | 3. Spinizonocolpites echinatus |
| 4. Retitricolporites irregularis | 5. Proteacidites sigalii | 6. Glecheniidites senonicus |

PLATE 7

- | | | |
|-----------------------------------|----------------------------------|------------------------------|
| 1. Distaverrusporites simplex | 2. Longapertites microfoveolatus | 3. Cingulatisporites ornatus |
| 4. Echitriporites trianguliformis | 5. Rugulatisporites scaperatus | 6. Auriculiidites sp. |