HUMAN PALAEOECOLOGY IN AFRICA

ESSAYS IN HONOUR

OF

M. ADEBISI SOWUNMI

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Oyelaran, P.A., R.A. Alabi
and P.A. Adeonipekun

PART 1: THE PRECURSOR

CHAPTER 1

Palynology and Palynofacies of the Maastrichtian Gombe Formation, Northern Benue Trough, Nigeria

Onoduku, U. S. and Okosun, E. A.

ABSTRACT

The palynoforms and palynodebris of the Gombe Formation as revealed from the analysis and study of core samples obtained from boreholes drilled within the Maiganga Coal mine are herein documented. The boreholes were drilled for coal exploration. A total of 73 core samples (70 formation samples and 3 coal samples) from 3 boreholes were analyzed and studied for their palynoforms content. The samples were prepared following the conventional acid maceration method. The 3 boreholes (BA-7, BA-16 and BA-17) are considerably rich in palynomorphs and palynodebris. The dominant pollen and spores include *Proteacidites sigalii, Retidiporites magdalensis, Monoporites annulatus, Cingulastisporites ornatus, Rugulatisporites caperatus, Scabratriporites annellus, Proteacidites longispinosis, Distaverrusporites simplex* and *Foveotrilete margaritae*. Palynodebris found were Amorphous Plant Matter (PM I), Vitrinitic Brown and Black Wood (PM II), Cuticle and Membraneous Debris (PM III) and Platy Tricheidal Debris (PM IV). The recovered marker species were used to date the studied sections as Early-Late Maastrichtian. The results of the analysis were used to zone the studied sections into two palyzones, namely; *Proteacidites sigalii - Echitriporites trianguliformis* and *Cyathidites* spp – *Laevigatosporites haardtii* range zones. The paleoclimatic conditions were interpreted based on the palynoformsto belong to the Late Cretaceous Palmae province.

Keywords: Palynofacies, Gombe Formation, Maiganga Coal Mine, Palynodebris, Paleoclimatic Condition, Palynomorphs.

1.0 Introduction

The coal exploration works in the Maiganga area of Gombe state which commenced in October, 2007, paved way for access to subsurface samples from the Gombe Formation (Onoduku, 2013). This study utilized the available subsurface samples for analysis. The study area is located within the Nothern Benue Trough, precisely at Maiganga coal mine (Fig. 1). The Gombe Formation had been mapped as a unit by several workers (Falconer, 1911, Reyment, 1956, Carter, *et al.*, 1963 and Zaborski *et al.*, 1997). The formation consists of siltstones, shales and limestone. The thin coal beds reported by some of the above workers have been confirmed by the on-going exploration/exploitation of the coal deposit at Maiganga coal mine.

The Gombe Formation is made of three major lithofacies. At its base, the formation consists of rapidly alternating thin beds of silty shales, sometimes with plant remains and fine to medium-grained sandstones with some intercalated thin flaggy ironstones. Passing upwards, it grades into sandstone beds which become more persistent and make up the greater part of what was referred to as "bedded facies" by Zaborski *et al.* (1997). South of Gombe, the upper part of the formation was termed "Red Sandstones Facies" by Zaborski, *et al.* (1997), probably due to its reddish colouration. The Gombe Formation is sandwiched between the overlying Kerrikerri Formation and the underlying Pindiga Formation and it hosts the coal deposit earlier reported by Dike (1995) as shown in Figure 2. The aim of this study is to improve on the biozonation, paleoclimate, paleoenvironment and age of the Gombe Formation through Palynomorph and Palynofacies characterization using subsurface and coal samples.

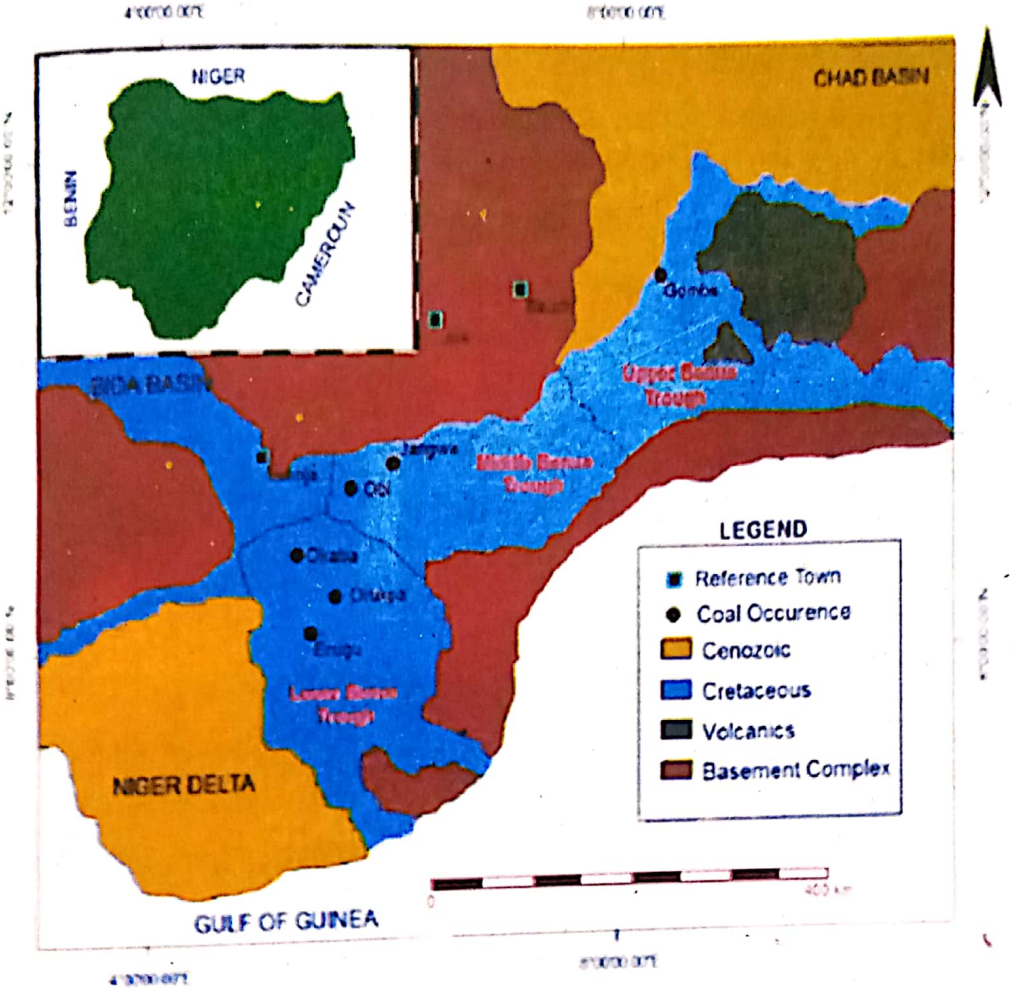


Figure1: Geological map of Nigeria showing coal deposits and the study area (modified after Onoduku, 2013)

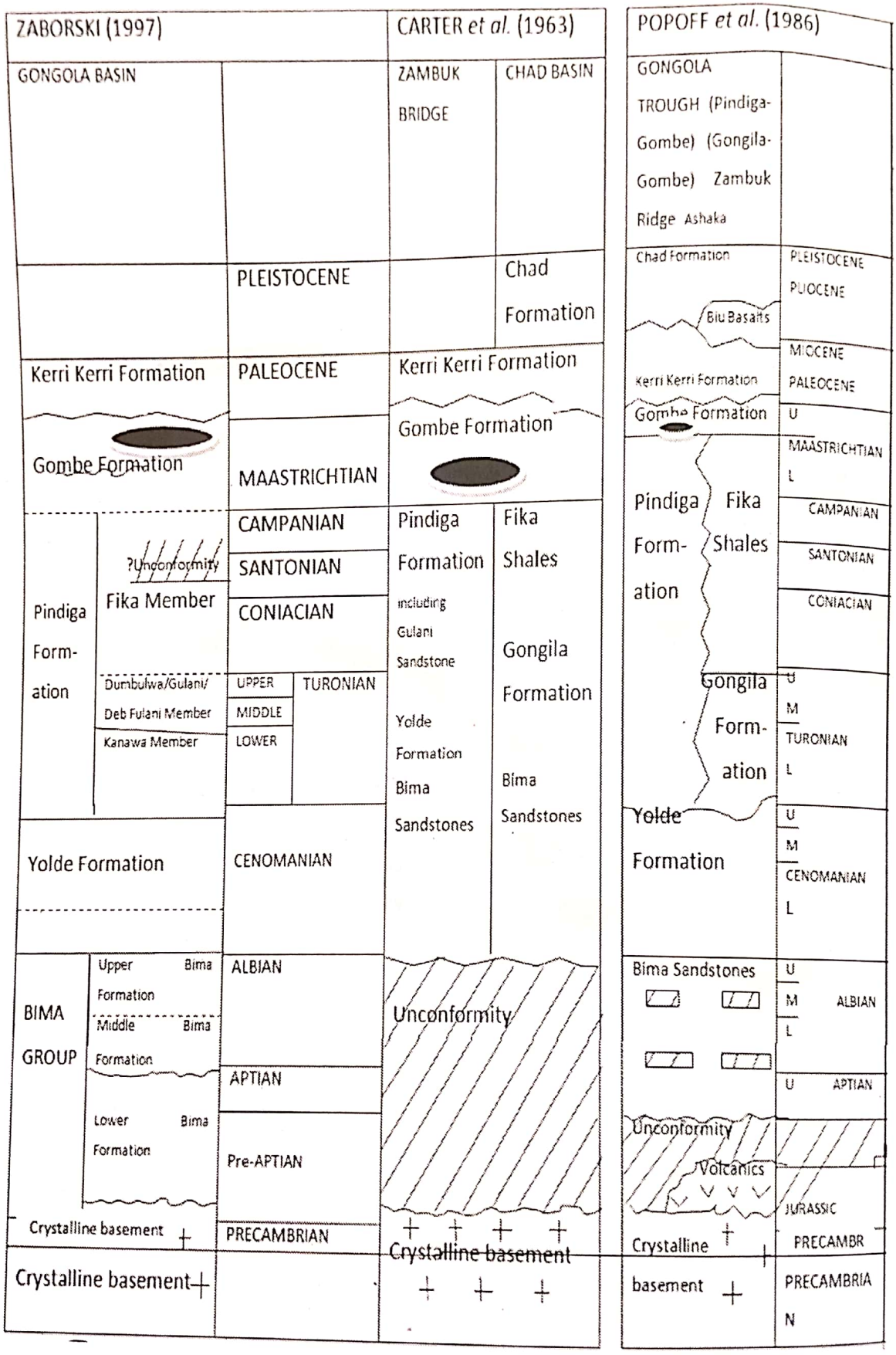


Figure 2: Lithostratigraphic successions of the Gongola sub-basin showing the Gombe Formation (modified after Zaborski et al., 1987).

2.0 Materials and Methods

The core samples used for the analyses were collected from the Maiganga coal mine at the Ashaka cement factory, Ashaka. A total of 400 samples were collected from Twenty-four (24) exploratory boreholes. Out of these, three (3) boreholes (BA–7, BA–16 and BA–17) with seventy-three (73) samples were collected and used for the study. Borehole BA–7 penetrated to a depth of 48m, while BA–16 and BA – 17 penetrated depths of 60 m and 45 m respectively. The Lithostratigraphic sequence of the boreholes is made up of shale, siltstone, sandstone and coal seams, and these serve as the samples used for the study.

Sample preparation for palynomorphs and palynofacies analyses have been extensively described by several authors in various papers and chapters in books (Batten, 1999). A brief extract of the method is given as thus. A constant weight of each sample was treated with hot hydrochloric acid (HCl) to remove carbonates prior to complete digestion in hydrofluoric acid (HF) solution in a fume cupboard. Gentle agitation of the acid was carried out to aid digestion.

The sample was then heated to boiling in hydrochloric acid (HCl) 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) for the palynomorphs recovery only but was omitted in the Palynofacies analysis. 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). Staining of the slides with safranin O was done in order to enhance the appearance of any dinoflagellate cysts under the microscope. Palynological and Palynofacies slides were prepared for each sample (horizon) and analyzed microscopically. The results of the counted

palynomorphs and Palynofacies species were plotted into distribution charts with the aid of *Stratabug software*.

3.0 Results and Discussion

Palynomorphs

The results of the palynomorphs analysis are as shown in the form of distribution charts in figures 3 to 5. Photomicrographs of some of the palynomorphs are shown in Appendix 1.

Palynomorph Assemblages and Palynostratigraphy

The palynological results presented show the abundance and diversity of the recovered palynomorphs. The pollen and spores assemblage include angiosperms, gymnosperms and pteridopytes. There are a total of 1,151 palynomorphs counts from the studied samples, out of which pollen account for 62.29 %, spores, 35.88 % and algae (*Botryococcus braunii),* 0.87 %.

Characteristic pollen and spores recovered from the studied cores include *Proteacidites sigalli, Retidiporites magdalensis, Monoporites annulatus, Cingulatisporites ornatus, Rugulatisporites caperatus, Distaverrusporites simplex, Foveotriletes margaritae, Scabratriporites annellus* and *Proteacidites longispinosus.* On the basis of the recovered pollen and spores especially the marker species such as listed above, the studied sections have been zoned into two assemblage zones as shown in the palynomorphs distribution charts (Figures 3 to 5). The two assemblage zones are (i) *Proteacidites sigalli – Echitriporites trianguliformis* zone and (ii) *Cyathidites* sp. and *Laevigatosporites-haardtii* zone. Ojo(2009), identified and listed two palyzones for the Gombe Formation based on a study carried out on surface samples from Gombe Forma. These are the Assemblage Zone I (*Spinizonocolpites-Echitriporites-Milfordia* sp. zone) and the Assemblage Zone II (*Proxapertites operculatus-Retidiporites-Echimonocolpites* zone). (Lawal and Moullade, 1987), on the other hand named the whole section of the Gombe Formation as *Spinizonocolpites baculatus* zone. While the results of this study agree with that of Ojo (2009) except for the species used to zone the section of the Formation, in which case may be as a result of the

differences in the samples analysed in the two studies, that of Lawal and Moullade (1987) is completely at variance with the biozonation in this study. Both earlier studies employed surface samples while this study employed subsurface samples hence will probably provide a more reliable results. In this study, the analyzed section of the Gombe Formation have been dated Early Maastrichtian to Late Maastrichtian based on the recovered palynoforms.

Zone I (*Proteacidites sigalli – Echitriporites trianguliformis* assemblage zone)

Stratigraphic 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 sigallii, Retidiporites magdalensis* and *Echitriporites trianguliformis*.

The upper limit of this zone coincides with the disappearance of *Retidiporites magdalensis* and *Brevicolporite guinetti* and the abundant top occurrence of *Cyathidites* sp. This zone is also associated with *Ctenolophoridites costatus, Retitricolporites irregularis, Proxapertites cursus, Psilamonocolpites marginatus, Psilatricolporites crassus, Proteacidites* sp, *Rugulatisporites caperatus*, *Proxapertites cursus* and *Auriculiidites* sp. (Figure 3).

Figure 3: Palynological distribution chart and palynomorphs zones for BA – 7 Borehole

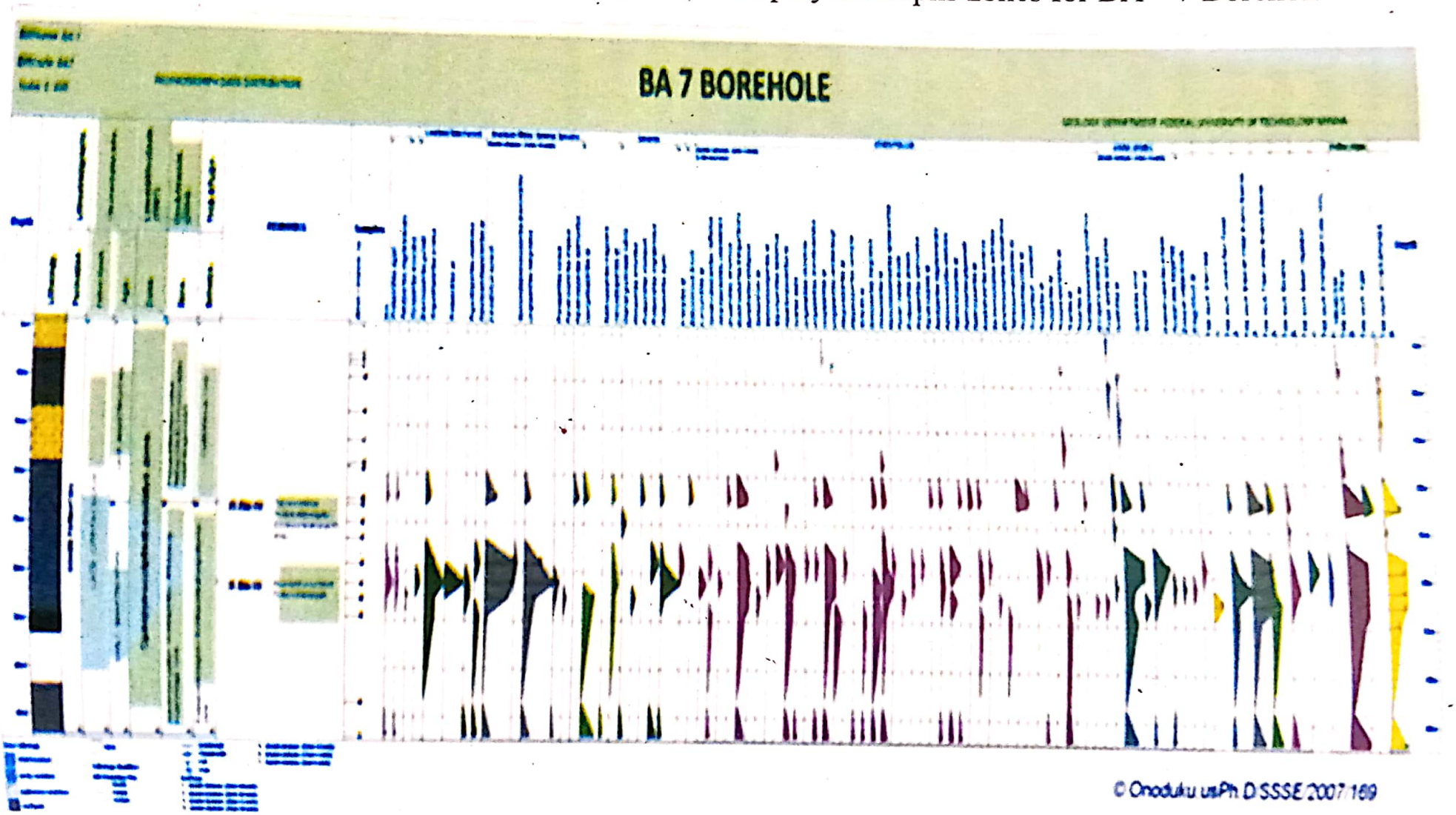
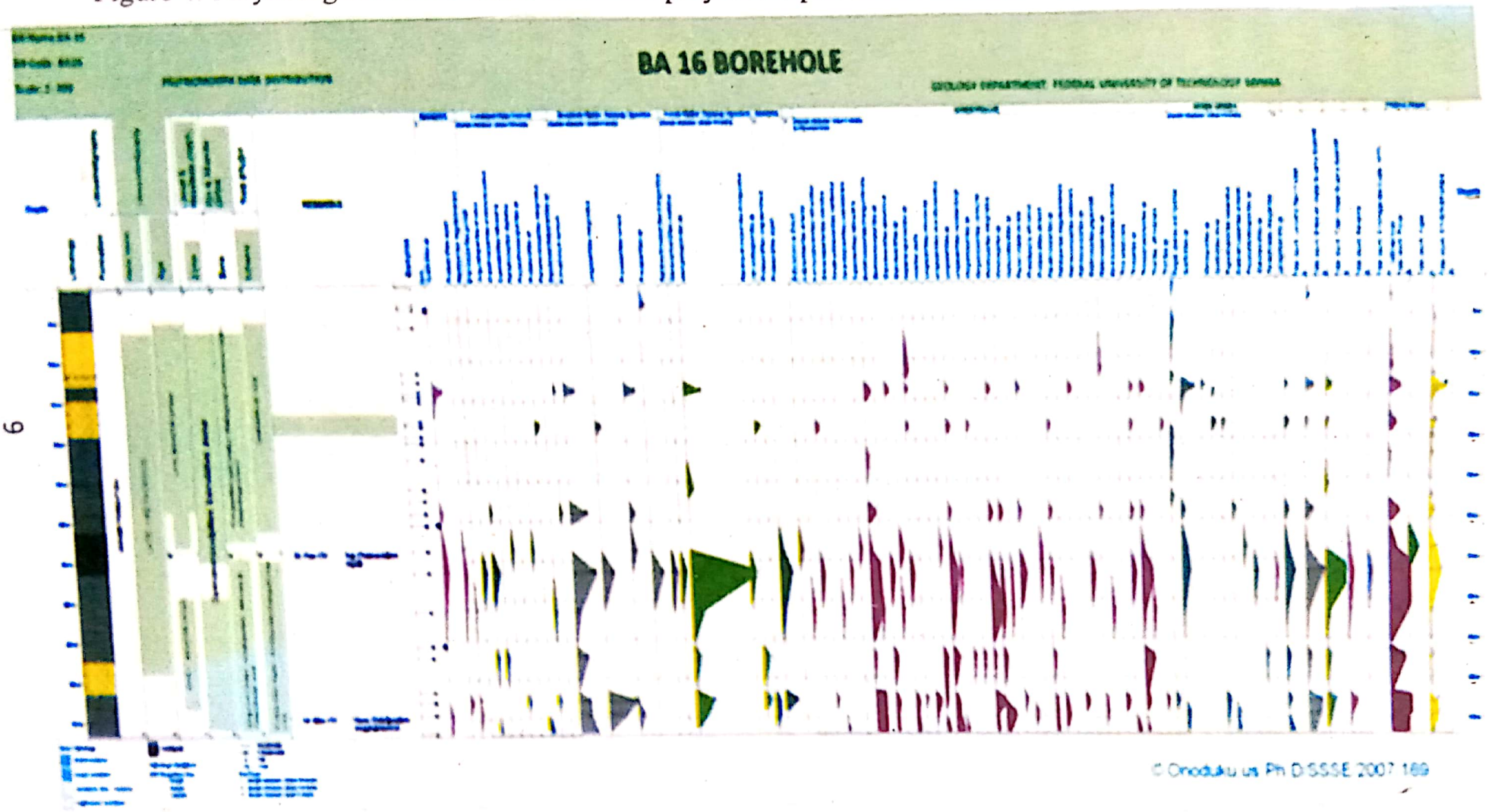


Figure 4: Palynological distribution chart and palynomorphs zones for BA – 16 Borehole



This zone corresponds to the lower part of the *Spinizonocolpites baculatus* zone of Lawal and Moullade (1987) and the *Spinizonocolpites- Echitriporites Milfordia* sp. zone of Ojo and Akande (2004). Majority of the pollen and spores that constitute this zone have been reported by the above earlier workers who dated the lower part of the Gombe Formation Early Maastrichtian and accordingly, based on the similarity of the pollen and spores found in the studied cores with those of the earlier workers, the present zone is dated Early Maastrichtian.

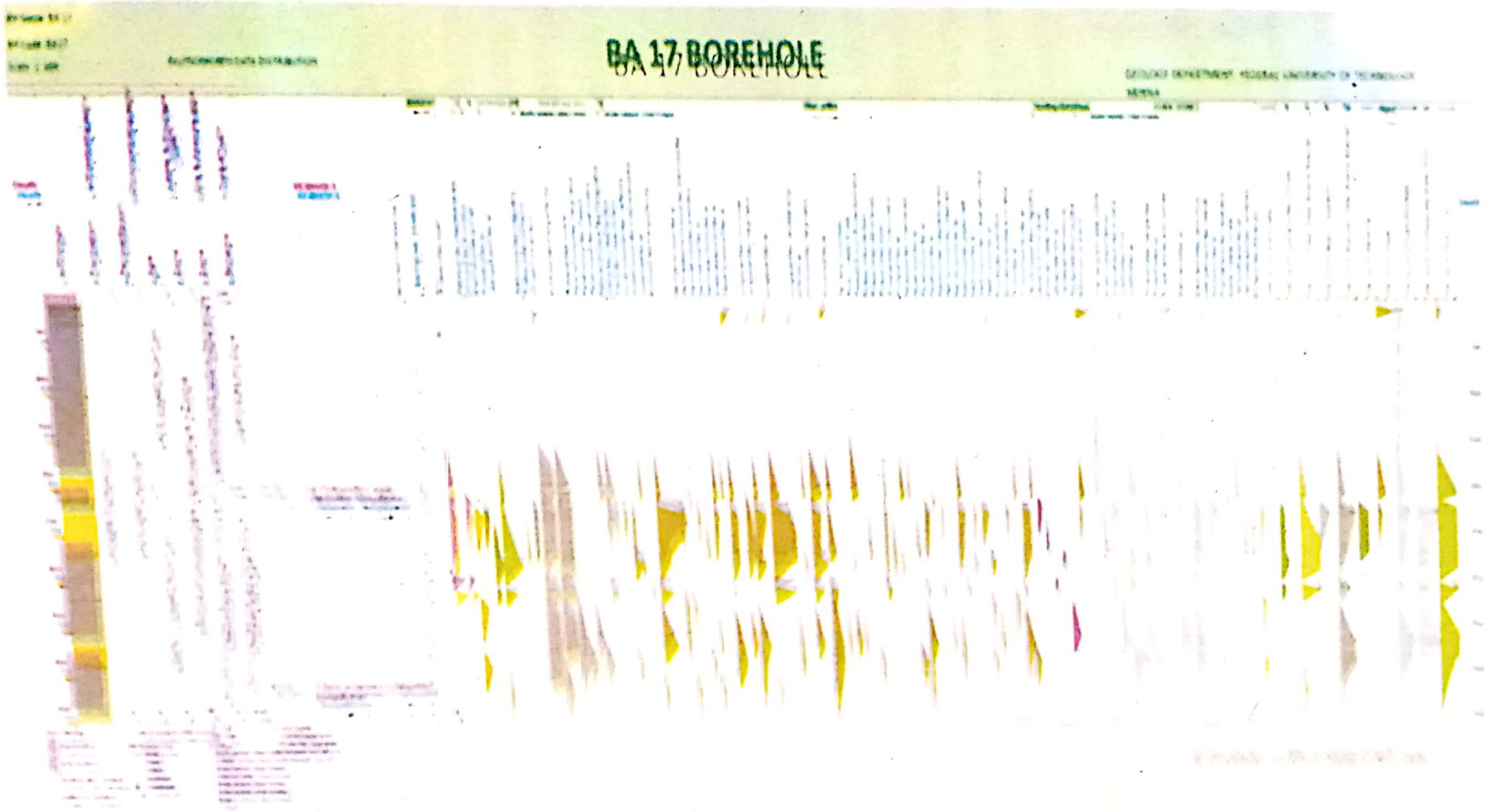
Zone II (*Cyathidites* sp. and *Laevigatosporites-haardtii* assemblage zone)

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 palynomorphs that range from the lower zone such as *Longapertites* sp, *Longapertites vandeenburgii, Tricolporopollenites* sp, *Sapotaceoidaepollenites* sp, *Acrostichum aureum, Proxapertites cursus, Laevigatosporites* sp 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 shale/mudstone facies rich in palynomorphs. This zone is equivalent to the upper *Spinizonocolpites baculatus* zone of Lawal and Moullade (1987) and the *Proxapertites operculatus - Echimonocolpites* assemblage zone of Ojo and Akande (2004). On the basis of the correlate-able palynomorphs observed, the zone have been dated Late Maastrichtian.

Figure 5: Palynological distribution chart and palynomorphs zones for BA – 17 Borehole



4.0 Palynodebris

The palynodebris recovered from the processed core samples were studied with a view to determine their types, distribution and environments of deposition within the studied sections. The palynodebris observed from the sections of the studied boreholes are grouped into 5 according to Oboh (1992), namely; Amorphous Plant Matter (PM I), Vitrinitic Brown and Black Wood (PM II), Curticle and Membraneous Debris (PM III) and Platy Tricheidal Debris (PM IV)

Amorphous Plant Matter (PM I)

This palynodebris occurs as irregularly shaped, brown masses with no cellular details. They appear like jelly material and exhibit clotted appearance which are believed to be alteration products of bacterial and thermal degradation rather than primary material. They are brownish in colour which suggest terrestrial source. The Amorphous Plant Matter is present in high amount in the all the core samples from three boreholes analysed (Figures 6, 7 and 8).

Vitrinitic Brown and Black Wood (PM II)

This palynodebris group shows some cellular structures; appear brown to black and sometimes opaque in colour and dense. They are lath-shaped with some showing equidimensional appearance. Their sizes vary from sample to sample, but generally appear like well-preserved wood. These categories of palynodebris are variously called black wood, charcoal or inertinite by several authors (Oboh, 1992). These fragments are more common in the shales and coal samples and are next to PM I in abundance.

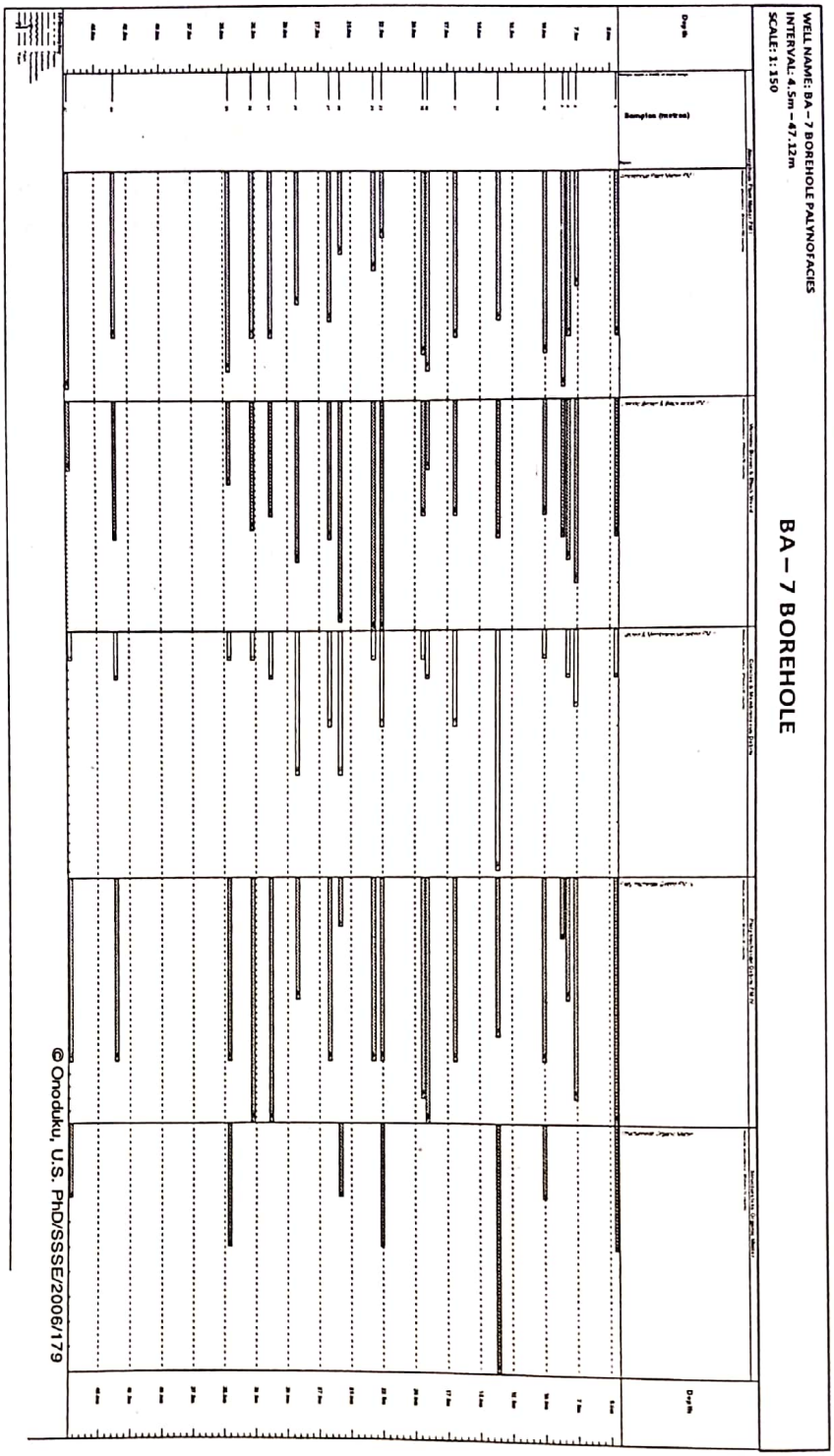
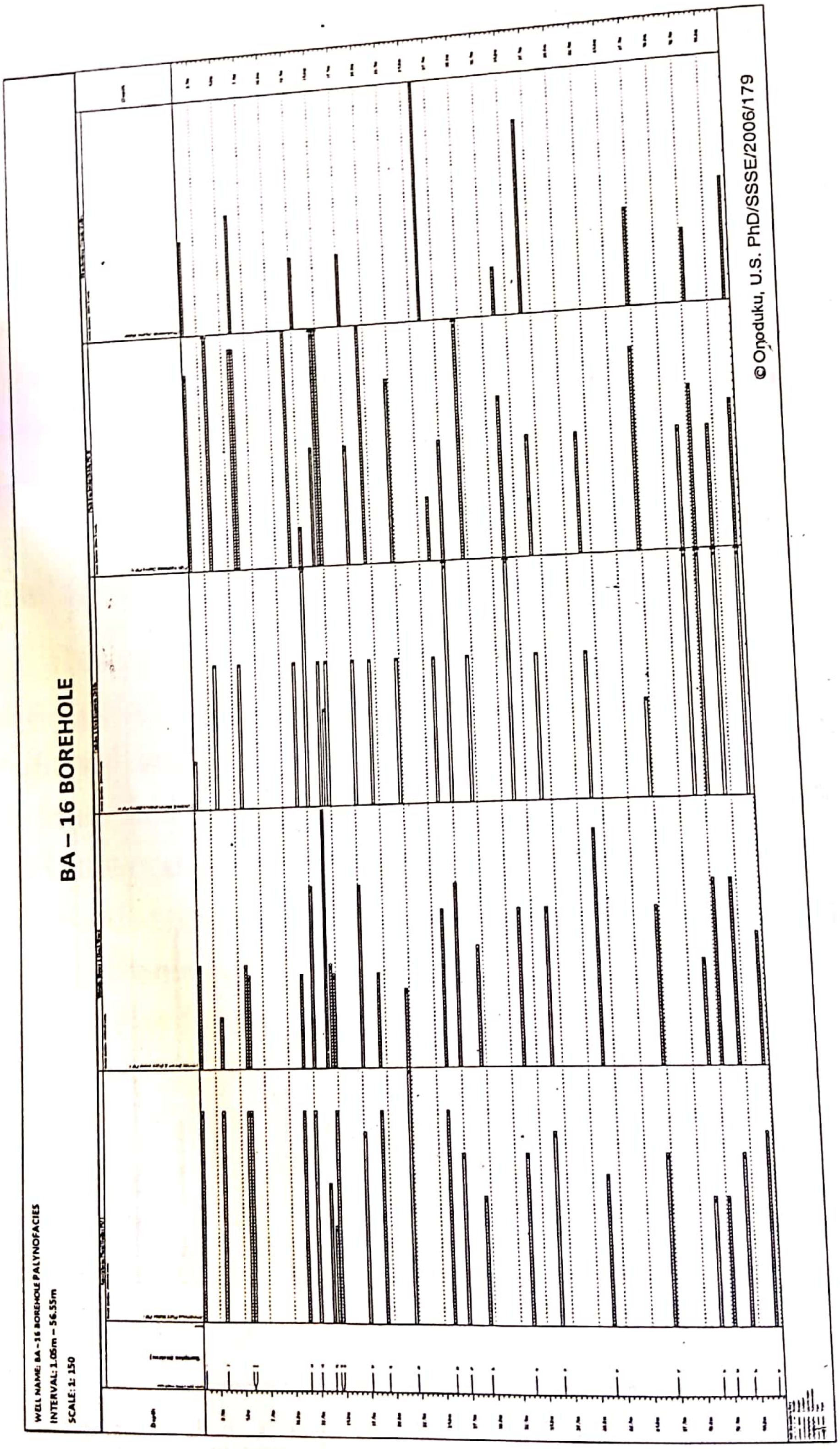


Figure 7: Plot of Palynofacies data for BA - 16



Cuticles and Membranous Debris (PM III)

This class of palynodebris appears pale yellow to light brown in colour and range in size from 20μm to over 150 μm. They are more prevalent in the shales and mudstones than the sandstones. These fragments are generally less abundant in the core samples analysed across the three boreholes. According to Oboh (1992), cuticles are thin, platy epidermal fragments from non woody organs such as leaves and roots and their buoyant nature ensures easy dispersal by water.

Platy Tricheidal Debris (PM IV)

This class of palynodebris is well preserved wood, with some black and brown stripped tricheidal debris. They are lath-shaped and vary in sizes. They are elongated, tapering cells in the xylem having woody, pitted and intact walls adapted for conduction and support in plants. These palynodebris are well distributed across the sections of the three boreholes sampled.

Environmental significance of the palynodebris

An integration of the palynodebris characteristics with lithofacies and pollen and spores features of the analysed core samples suggests two sub-environments. These are terrestrial and coastal depositional environments characterized by the common to abundant occurrence of fungal spores and poorly sorted palynomacerals I and II.

By inference therefore, the studied sections of the Gombe Formation around Maiganga coal mine can be interpreted as a product of terrestrial/coastal depositional interplay. The sandstone facies of the Gombe Formation was probably deposited in high energy environments as compared to the shale/mudstone facies which were deposited in a relatively lower energy environment.

Paleoclimatic Interpretation

The paleoclimatic setting of the studied section of the Gombe Formation is examined based on the pollen/spores data which offer clues for paleoclimatic deductions. Palmae pollen and spores such as *Acrostichum aureum, Proxapertites cursus, Retidiporites magdalensis, Longerpertites, Auriculidiites reticulatus, Echitriporites trianguliformis, E. longispinosus, Gleicheniidites senonicus* recovered from the studied section of Gombe Formation in this study indicate that the sediments belong to the Late Cretaceous Palmae Province.

5.0 Conclusion

This study was carried out on sub-surface cores from Gombe Formation and has expanded the existing knowledge of the palynology and palynofacies of the formation. The results of the analyses have shown that the Gombe Formation is a heterogeneous unit characterized by diverse palynomorphs. The recovered palynoforms which were used to zone the formation include *Echitriporites trianguliformis, Cyathidites* spp. *Monoporites annulatus, Cingulatisporites ornatus, Rugulatisporites caperatus, Distaverrusporites simplex, Proteacidites sigalii, Retidiporites magdalensis, Foveotriletes margaritae, Scabratriporites annellus* and *Proteacidites longispinosus*. On the basis of the analysed palynomorphs, the formation has been zoned into two palyzones which include Zone I (*Proteacidites sigalii – Echitriporites trianguliformis* assemblage zone) and Zone II (*Cyathidites* sp – *Laevigatosporites haardtii* assemblage zone). The formation is dated Early to Late Maastrichtian on the basis of the palynomorphs. The pollen and spores analysed belong to the Late Cretaceous Palmae Province.

Appendix 1: Photomicrographs of the palynomorphs

Plate1.

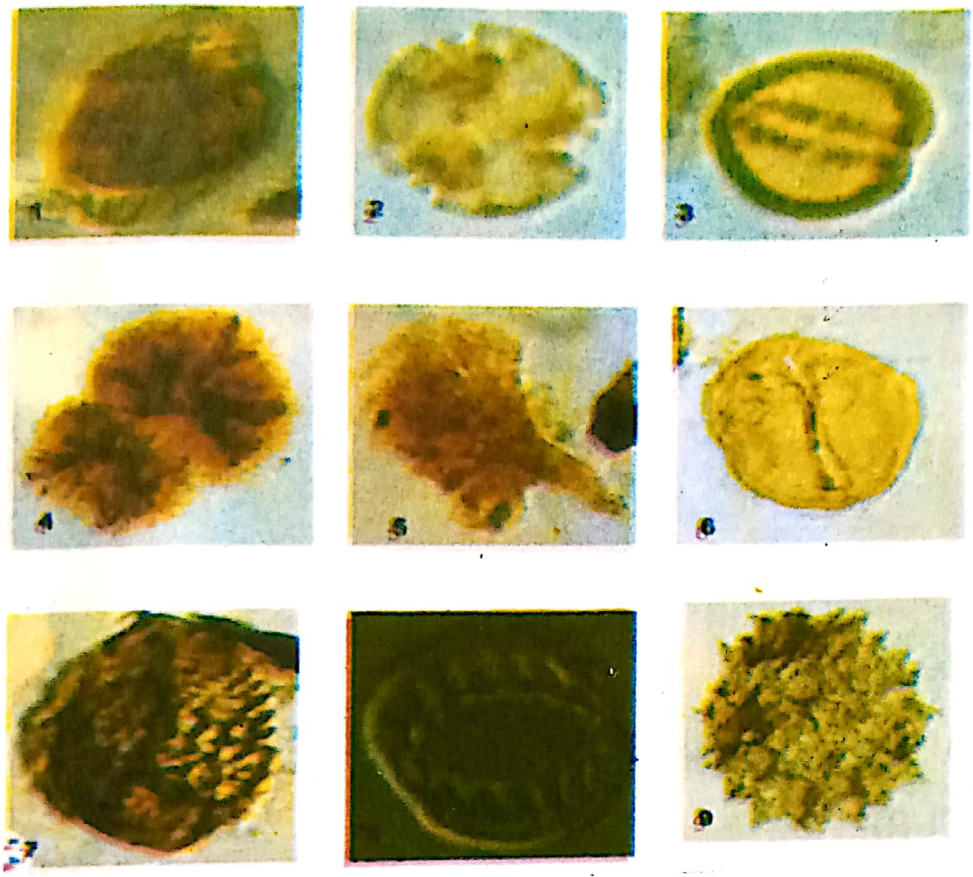


PLATE1: EXPLANATIONS

FIGURE

1. *Ephedripites ambiguous* BOLTENHAGEN & AZEMA, 1974
2. *Psilatricolporites crassus* VAN DER HAMMEN & WYMSTRA, 1964
3. *Monocolpollenites sphaeroidiites* PFLUG & THOMSON, 1953
4. *Botryococcus braunii* (A)
5. *Botryococcus braunii* (B)
6. *Monocolpites marginatus* VAN DER HAMMEN,1954
7. *Retimonocolpites* sp. PIERCE, 1961
8. *Tubistephanocolpites cylindricus* SALAMI,1983
9. *Pediastrum* sp. MEYEN, 1829

Plate 2:

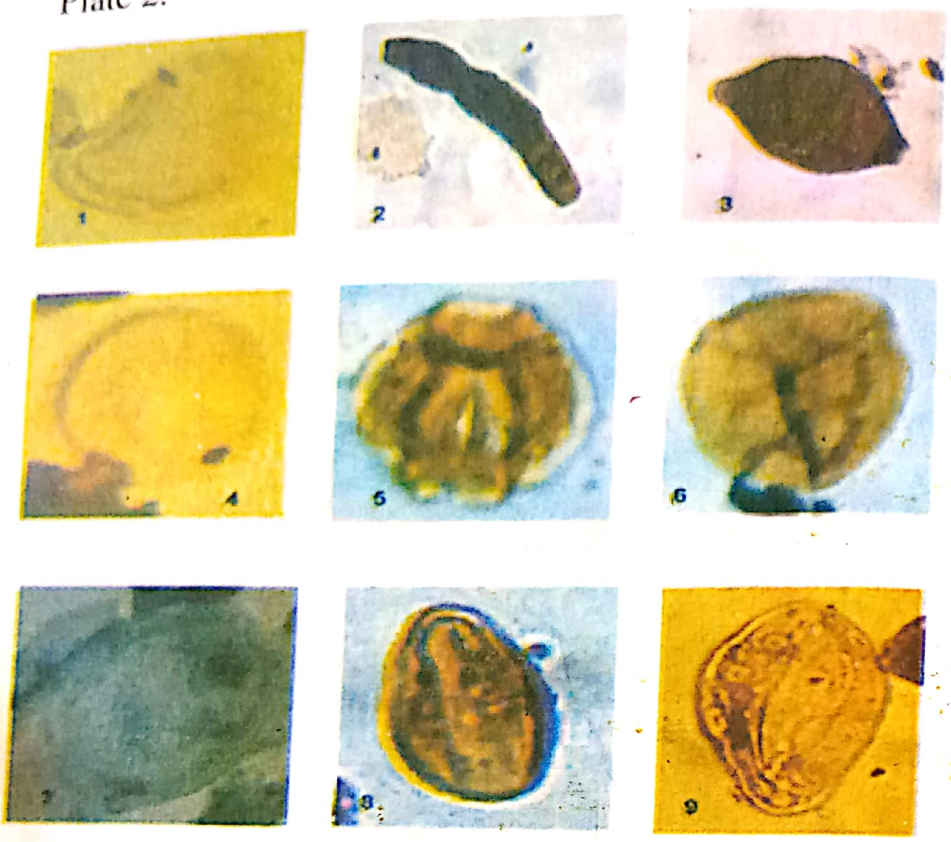


PLATE 2: EXPLANATIONS

FIGURE

1. *Laevigatosporites haardtii* (POTONIE & VENITZ) THOMSON & PFLUG, 1953
2. Fungal spore (A)
3. Fungal spore (B)
4. *Arecipites crassimuratus*
5. *Ctenolophonidiites costatus* VAN HOEKEN-KLIKENBERG, 1966
6. *Zlivisporeites blanensis* PACLTOVA, 1959
7. *Proxapertites cursus* VAN HOEKEN-KLIKENBERG, 1966
8. *Sapotaceoidaepollenites* sp.
9. *Gemmamonoporites* sp.

Plate 3:

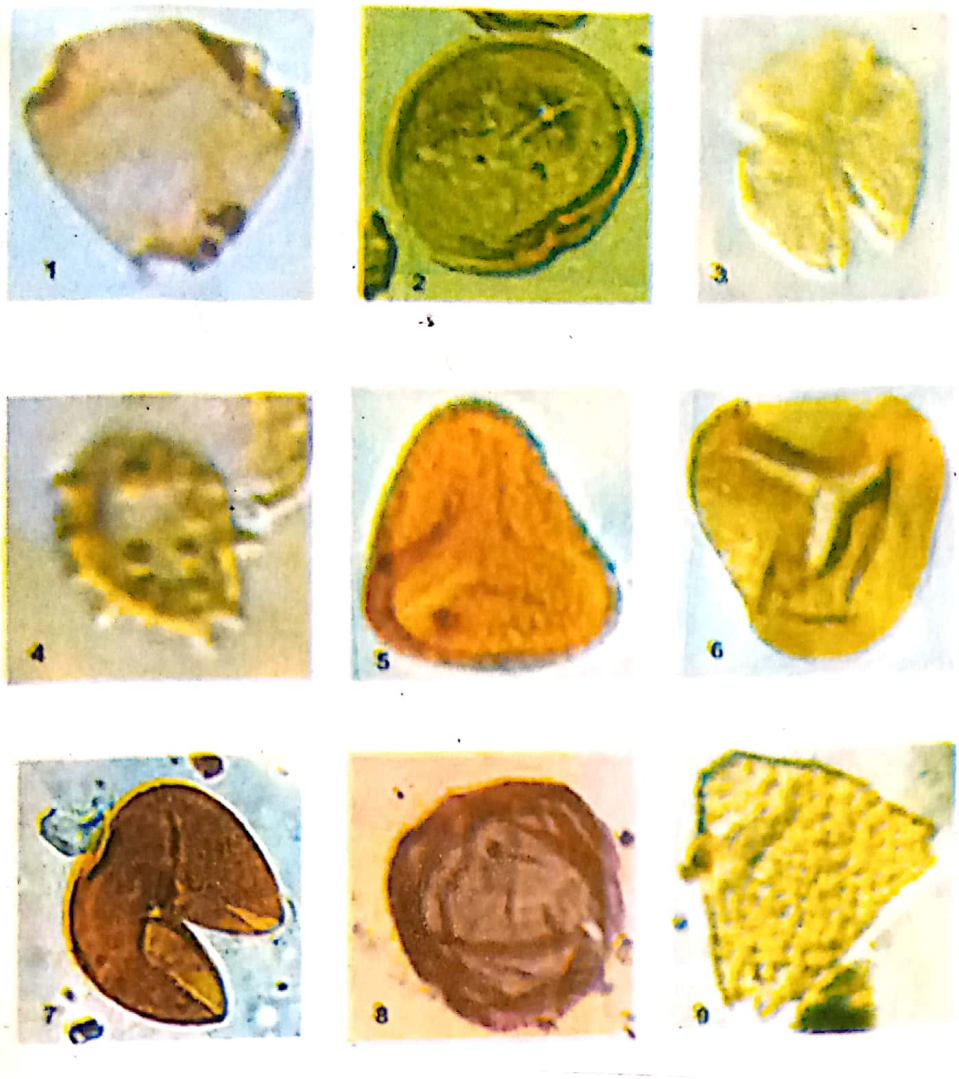


PLATE 3: EXPLANATIONS

FIGURE

1. *Cupanieidites* sp.
2. *Psilatricolporites crassus* VAN DER HAMMEN & WYMSTRA
3. *Tricolporopollenites* sp.
4. *Droseridites senonicus* COOKSON, 1950
5. *Foveotriletes margaritae* (VAN DER HAMMEN) GERMERAAD *et al.*, 1968
6. *Cyathidites* sp. COUPER, 1953
7. *Osmundacidites* sp. MARTIN & ROUSE, 1966
8. *Leoisphaeridia* sp.
9. *Proteacidites sigalii* BOLTENHAGEN, 1978

Plate 4:

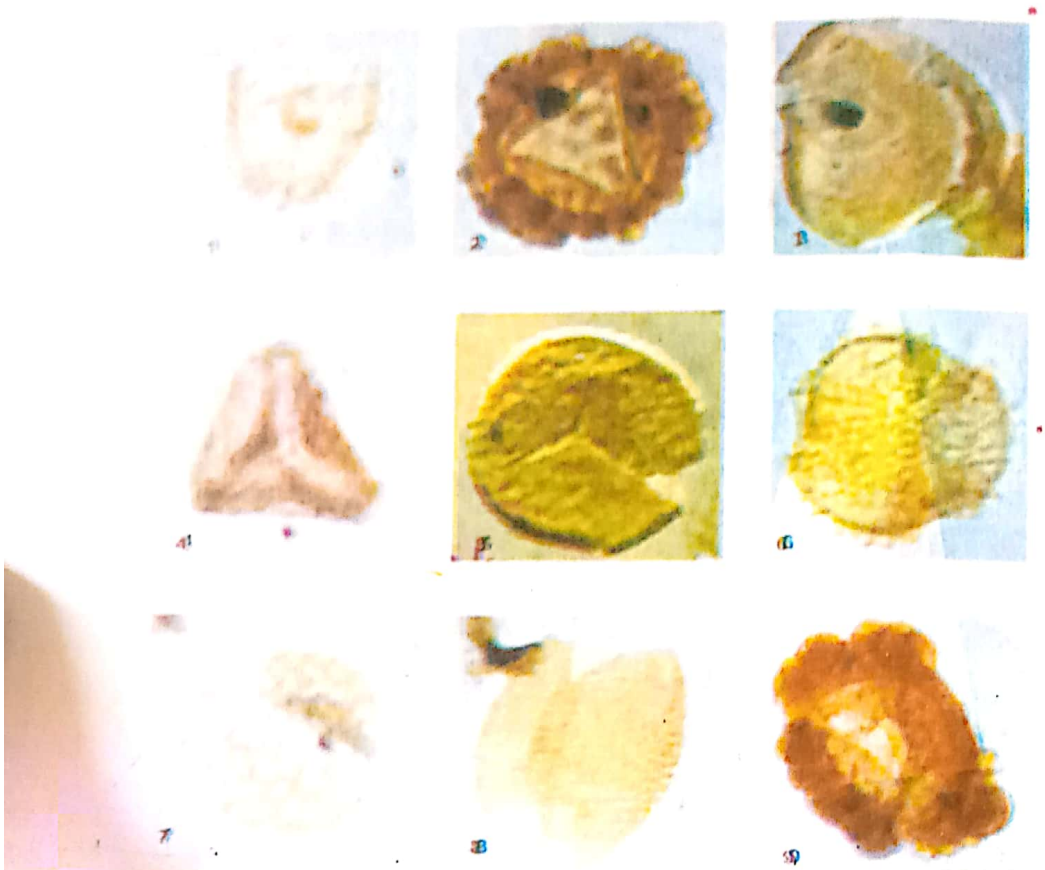


PLATE 4: EXPLANATIONS

FIGURE

1. *Nematosphaeropsis* sp.
2. *Cingulatisporites ornatus* VAN HOEKEN KLINKEN-BERG, 1964
3. *Longapertites microfoveolatus* JAN DU CHENE & ADEGOKE, 1978
4. *Glechenidites senonicus* POTONIE, 1956
5. *Rugulatisporites caperatus* VAN HOEKEN KLINKEN-BERG, 1964
6. *Retitricolporites irregularis* VAN DER HAMMEN & WYMSTRA, 1954
7. *Auriculiidites* sp.
8. *Longapertites chlonovae* BOLTENHAGEN, 1978
9. *Distaverrusporites simplex* MULLER, 1968

Plate 5:

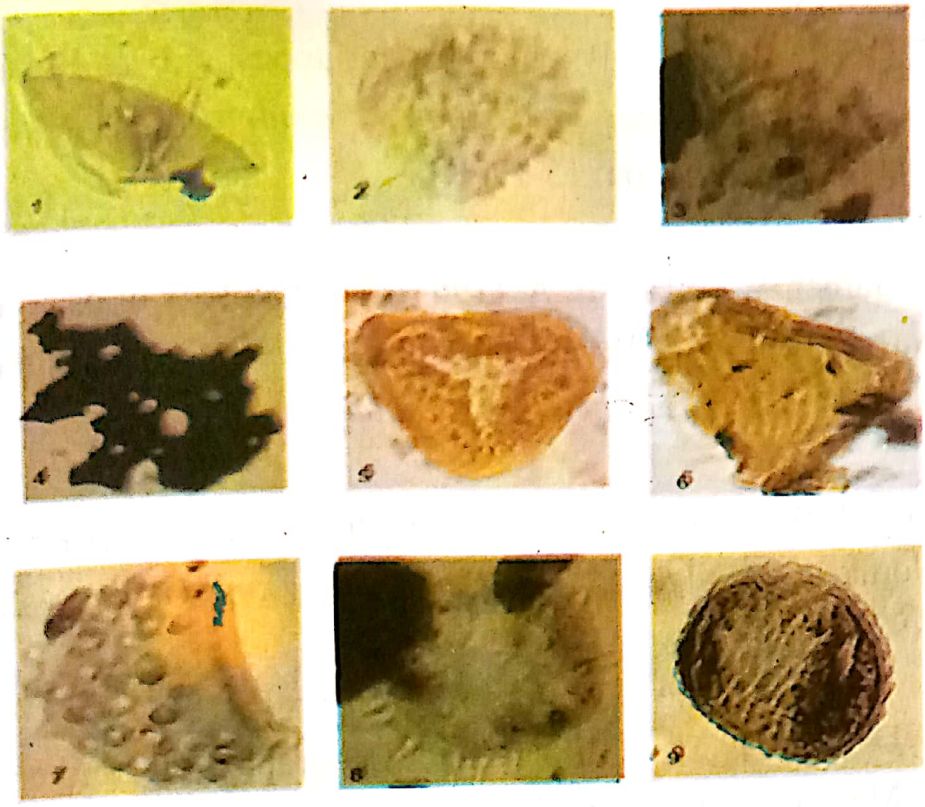


PLATE 5: EXPLANATIONS

FIGURE

1. *Monoporites annulatus* VAN DER HAMMEN, 1954
2. *Echitriporites trianguliformis* VAN HOEKEN-KLINKENBERG, 1964
3. *Auriculopollenites* sp.
4. Charred graminae cuticle
5. *Polypodiaceoisporites* sp. SAH, 1967
6. *Gnetaceaepollenites* sp.
7. *Verrucatosporites usmensis* VAN DER HAMMEN, 1956
8. *Spinizonocolpites echinatus MULLER, 1968*
9. *Verrucatosporites sp.* VAN DER HAMMEN, 1956

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