SYSTEMATIC PALYNOLOGY OF MAIGANGA COAL FACIES, NORTHERN BENUE TROUGH, NIGERIA

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Abstract

The Palynostratigraphy of the Maiganga coal mine is based on the available and recovered palynomorphs whose systematic Palynology of both existing and new palynoforms is vital in the palyno-characteristics of the Gombe Formation. Sixty-one [61] palynoforms which comprise of spores, pollen grains and algae have been identified and their systematic Palynology was described. The palynoforms are characteristic of typical Maastrichtian period which form part of the larger Cretaceous age that dominate the Gombe Formation in which the Maiganga coal deposit was formed. This study will serve as reference to future palynological studies for the study area as the described palynoforms were recovered from subsurface samples for the first time as against the previous similar studies on surface samples in the study area.

Key words: Palynostratigraphy, Maiganga, systematic Palynology, Gombe formation, Maastrichtian

1.0 INTRODUCTION

Palynology is the branch of Earth Sciences that is concerned with the study of acid-resistant microscopic organic matters recovered from sediments or sedimentary rocks (Onoduku, 2013). These organic matters can be recent or fossilized materials which have been deposited in a variety of environments that range from terrestrial to aquatic (Andrew, 2004). Palynological studies usually attempt to qualify and/or quantify the abundance and diversification of the organic matter species that characterize a given portion (depth) of a penetrated well or borehole. The quality of the palynoforms that characterize a particular range of depth of the well or borehole are used to deduce the biozonation, age, infer the paleoenvironment/paleoecology and correlation of such depth interval. The forgoing parameters of a defined depth interval of a well or borehole are useful for general mineral exploration program, oil and gas exploration, assessment of climate change as well as dating of a formation. The use of various palynoforms (pollen, spores, dinoflagellates, acritarchs, algae and other organic matters) for the above listed geoscientific purposes is usually based on their adequate recognition, identification and description, the last being the scope of this paper which fits adequately into the field of systematic Palynology. Systematic Palynology involves the microscopic study and description of palynoforms based on their various forms such as apertures, shapes, sculptures, structures, scars, number and arrangement of furrows/pores.

1.1 The Gombe Formation

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 limestone. 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.

Carter *et al.* (1963) mapped the northeastern part of the Benue Trough and stated that the Maastrichtian Gombe Sandstone rests uncomformably on the older folded rocks of the Upper Benue depression and that the Maastrichtian rocks are themselves folded. However, mapping reveals that the strong fold which affected the Upper Benue Trough is pre-Gombe, i.e. probably pre-Maastrichtian and that, as in the Abakaliki and Lower Benue Trough, the main folds were generated in Santonian times (Murat, 1972; Burke *et al.*, 1972; Whiteman, 1973). The Gombe Formation is restricted to the western part of the Gongola basin. It weathers to produce ferruginous capping. The weathering is responsible for the rugged hilly topography that characterizes most of the outcrops.

The Gombe Formation is made of 3 major lithofacies which were later proved as separate distinguishable members. At its base, it 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 o f 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 with in the Gombe Formation and this was later proved by other workers. 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 (Gombe sheet 36) 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 Fo rmation)(Figure 1).

Age	Formation	Members
Paleocene	Keri-Keri	
Maastrichtian	Gombe	Duguri member
Campanian		Arowa member

Figure 1: Lithostratigraphic subdivision of Gombe Formation (After Hamidu, 2012).

1.2 Coal seams

There are three distinct seams of coal within the Maiganga coal mine as observed during the field work and these three seams are currently being mined. The coal seams are intercalated in between an overlying sandstone and underlying shale facies. The uppermost seam 3 is about 1.2 m thick; the underlying seam 2 is about 1.5 m thick while the lowermost seam 1 is about 4.5 m thick. The coals are dark, hard, striated and ea sily crumble into fragment.

Figure 1: Maiganga Coal Seams

1.3 MORPHOLOGICAL DESCRIPTION AND TERMINOLOGIES USED IN PALYNOMORPH DESCRIPTION

The first main distinction for the morphological description and grouping of palynomorphs is usually made between spores and pollen grains (Jzuora, 1980). In general, it can be stated that with an ordinary light microscope, no differentiation can be observed in the wall or exine of spores. For pollen grains, however, a differentiation between a more or less structured outer layer (extexine) and a Structureless inner layer (endexine) can usually be seen. The main criteria for morphological grouping for spore s are based on the preserved nature of a scar and for pollen grains, on the number and arrangement of furrows and spores.For both pollen grains and spores, the sculpture of the exine is a distinct feature used for selection, which can be further subdivided based on the size of the grains. Other additional features used for morphological description of palynomorphs include their view and shape (monolete and trilete), structure of pollen grains, sculpture and apertures.The terminologies used in the descriptio n of palynomorphs are as briefly stated below just for the guidance and refresh of the readers' memory in Palynology. These terminologies include

(i) View and shape – This refers to the manner of arrangement of the spores in the sporangium which dictate the array of the tetrad marks. These marks could be trilete scar for radially symmetric spores and monolete for bilaterally symmetric spores. Also, a group of 4 pollen grains resulting from the division of one pollen mother cell is called a tetrad while an indi vidual grain being arranged in a tetrahedron. The point of contact between a spore and other adjacent three within a sporangium is called the proximal pole and the area opposite is called the distal pole.

(ii) Structure of pollen grains – Pollen grains are structurally made of an outer coat called the exine and an inner layer called intine. The exine usually forms the preserved fossil while the intine usually disintegrates and disappears with the plant's exit. Under the light microscope, two layers of the exine are distinguishable into an inner layer called endexine and an outer layer called extexine. The extexine is further subdivided into an outermost tegillum or tectum and inner pillar-like elements called columellae or granulae. The term structure defines all the characteristics arising from the form and arrangement of the exine elements inside the tegillum or tectum.

(iii) Sculpture – This is defined as the ornamentation that is formed on or in the outer wall of a palynomorph. When it protrudes outwards of the grain, it is called positive-sculpture like psilate, scabrate, verrucate, areolate, gemmate, baculate, clarate, regulate, striate, perforate, foveolate, fossulate and reticulate.

(iv) Apertures – These refer to scars, furrows, pores, as they characterize palynomorp hs. They provide growth point(s) foe the gametes. Aperture can be simple or compound. Palynomorphs without apertures are said to be inaperturate. Elongated apertures are called colpi (sing. Colpus) or furrows or sulcus while circular ones are called Pori (sing. Porus) or pores. They can be either situated in the extexine and/or in the endexine.

2.0 MATERIALS AND METHODS

The major materials employed in this study comprised of ditch cuttings, palynomorph charts and palynomorph albums. Others include a palynological microscope (Zeiss 230, bifocal and transmitted light source) attached with camera, standard and individual past authors' palynological albums and various literatures on systematic Palynology by various authors. The methodology used in the study involved the systematic microscopic study of the palynoslides prepared. In doing so, each palynoslides was thoroughly viewed under transmitted palynological microscope, searching for, marking any palynomorph seen, describing it and taking the photomicrograph of the specie. Marker or diagnostic species were specially described in detail. The depth of the studied wells at which the palynoforms described were encountered was equally recorded to correlate with the age of the formation from which they are deposited.

3.0 RESULTS AND DISCUSSION

The results of the systematic study and description of the palynoforms found in the palynoslides are as explained in 3.1 and shown on the photomicrograph.

3.1 Systematic Palynology

The systematic Palynology adopted in this work generall y follows the patterns of Potonie' (1956, 1958, 1960), Dettmann (1963) and Atta-Peters and Salami (2004). Other relevant previous works by Salami (1983), Van Hoeken -Klinkenberg (1964), Ojo (2009), Obianuju (2008), Aboul Ela (1978) and Onoduku (2013) were a lso consulted especially for synonyms and general descriptions of forms. Finally, the work of Ames and Spackman, 1985 on the catalog of fossil spores and pollen, was widely consulted for species names, general description, authors and references. All speci es magnification is X 1000.In this work, the analyzed palynomorphs have generally been grouped into three, namely Pollen, Spores, and Fresh Water Algae. For easy and less cumbersome systematic, the palynomorphs have further been grouped and described under palyno-designated headings such as sporites and pollenites divisions (Aboul Ela, 1978), Pteridopytes spores, Gymnosperm pollen, Angiosperm pollen and Dinoflagellates. Pteridopytes spores are discussed under sporites while gymnosperms and angiosperms pollen are discussed under pollenites.

Division: Sporites Potonic', 1956

Family: Pteridopytes spores

Subdivision: TRILETES

Genus: Cyathidites (Couper, 1953).

Cyathidites minor Couper, 1953
BA – 7, 32.7 m
Fig. 25

Description: Trilete spore, amb triangular with straight to slightly concave sides and rounded apices. Exine psilate and thick

Age: Maastrichtian

Genus: Rugulatisporites (Pflug and Thomson, 1953).

Rugulatisporites caperatus Van Hoeken-Klinken-berg, 1964
BA – 7, 35 m
Fig. 35

Description: Trilete microspore, amb sub-triangular, triangular or spherical, sides convex, radial corners round triangular or sub -triangular forms, trilete mark thin, arms moderate, slightly raised but without Margo, exine moderate, rugulate and cavaliculate, both proximal and distal surfaces are sculptured.

Age: Maastrichtian

Genus: Foveotriletes (Van der Hammen, 1954, ex Protonie, 1956).

Foveotriletes margaritae (Van der Hammen) Germeraad *et al.*, (1968)
BA – 7, 32 m
Fig. 23

Description: The species has foveolate distal surface, thin wall and short less pronounced trilete mark

Age: Maastrichtian

Genus: Osmunda (Martin and Rouse, 1966).

Osmundacidites sp. Martin and Rouse, 1966
BA – 16, 40 m
Fig. 19

Description: Trilete spores, sub-spherical in outline, folded and crumpled. Faint Laesurae, thin Margo subtending the commissure. The ornamentation consists of slender bacula which are slightly clavate. The bacula are straight and relatively uniform in size, shape and spacing.

Age: Maastrichtian

Genus: Gleicheniidites (Potonie, 1956)

Gleicheniidites senonicus Potonie, 1956

BA – 16, 37m

Fig. 30

Description: Trilete microspore, trilete mark, thin, amb triangular to sub -triangular, sides moderately concave, corners round, tricrassate but crassitudes are compressed as to appear cica tricose.

Age: Maastrichtian

Genus: Cingulatisporites (Van Hocken-Klinken-berg, 1964).

Cingulatisporites ornatus Van Hocken-Klinken-berg, 1964

BA – 16, 37 m

Fig. 59

Description: Trilete microspore, amb triangular-round, sides convex, central body surrounded by a distinct ornamented cingulum, trilete mark thin, armed long and extended to the margins of the central body, not bordered by Margo, proximal surface convex, smooth but covered by low vernicae, cingulum split into several clavate structures

Age: Maastrichtian

Subdivision: MONOLETE (Potonie, 1956).

Genus: Laevigatosporites (Protonie, 1956)

Laevigatosporites haardtii Protonie and Venitz

BA – 17, 3 m

Fig. 11

Description: Monolete spore, posses limited sculptures and usually appears as tiny particles

Age: Maastrichtian

Subdivision: CINGULATISPORATES

Genus: Zlivisporites (Pacltova, 1959)

Zlivisporites blanensis (Pacltova, 1959)

BA – 17, 27 m

Fig. 15

Description: Specimen has cingulated sculptures which appear to represent residual perisporal membranes.

Age: Maastrichtian

Subdivision: VERRUCATI (Muller, 1968).

Genus: Distaverrusporites (Muller, 1968)

Distaverrusporites simplex (Muller, 1968)

BA – 16, 29 m

Fig. 28

Description: Trilete microspore, amb triangular, sides convex, trilete mark thin, arms long and extend to the equatorial margin, not bordered by any Margo, exine thick.

Age: Maastrichtian

Division: Pollenites Potonie, 1956

Class: Gymnospermae

Genus: Ephedripites (Boltenhagen and Azema, 1974)

Ephedripites ambigus (Boltenhagen and Azema, 1974)

BA – 7, 32 m

Fig. 4

Description: The Ephedripites is regarded as a taxonomic synonym of Equisotosporites (Singh, 1964, 1971), multicostate oval in outline, twice as long as broad, narrow ridges, covering the colpi.

Age: Maastrichtian

Class: Monocolpates (Iversen and Troels-Smith, 1950).

Genus: Auriculiidites (Elsik, 1964, Elsik and Thanikaimoni, 1970).
Auriculiidites sp.
BA – 7, 32 m
Fig. 60

Description: Oval monosulcate pollen grain with auriculate structures at the extremities of the grain. Sulcus long, extending to diameter of the grain, exine thin, and microreticulate. The microreticulate ornamentation and the overall smaller size differentiate this sp ecies from A. reticulatus.

Age: Maastrichtian

Genus: Spinizonocolpites (Muller, 1968).

Spinizonocolpites echinatus (Muller, 1968)
BA – 16, 42 m
Fig. 55

Description: *S. echinatus* has smooth to finely reticulate ornamentation, closely spaced processes and expanded or bulbous bases.

Age: Maastrichtian

Genus: Longapertites (Van Hoeken-Klinkenberg, 1964).

Longapertites microfoveolatus (Jan du Chene and Adegoke, 1978)
BA – 16, 47 m
Fig. 52

Description: Palm pollen, fine foveolate sculpture.
Age: Maastrichtian
Genus: Longapertites (Van Hoeken-Klinkenberg, 1964)
Longapertites chlonovae (Boltenhagen, 1978)
BA – 16, 53 m
Fig. 34
Age: Maastrichtian

Genus: Monocolpites (Van der Hammen, Pierce, 1961).

Retimonocolpites sp. (Pierce, 1961)
BA – 7, 22 m
Fig. 8

Description: Intectate reticulate, Monocolpates pollen grain, endocolpi only. The lumina of the reticulum vary in size, appearing smaller on the two extremes of the pollen grain.

Class: Porosa (Potonie, 1970).

Sub-class: Triporines (Potonie, 1956)
Genus: Proteacidites (Cookson, 1950)
Proteacidites sigalii Boltenhagen, 1978
BA – 17, 20 m
Fig. 24

Description: Pollen sub-isopolar, oblate, angular apertures, triporate. Amb angular, sides nearly straight, apertures sub-circular, exine slightly thicker in the equatorial inter-aperture regions, sexine about half as thick as nexine, ornamented with reticulum.

Age: Maastrichtian

Sub-class: Triporines (Potonie, 1960).

Genus: Echitriporites (Van Hoeken-Klinkenberg, 1964)
Echitriporites triangulliformis (Van Hoeken-Klinkenberg, 1964)
BA – 17, 21 m
Fig. 39

Description: It is characterized by fine echinate or spinose form. Triporate, triangular in polar view, pores circular, thick wall, Structureless, surface psilate, rather densely and even covered with spines, conical shaped with fairly sharp points.

Age: Maastrichtian

Class: Tricolpates (Iversen and Troels-Smith, 1950).

Genus: Retitricolpites (Van der Hammen, 1956a)
Retitricolpites irregularis (Van der Hammen, 1956b)
BA – 7, 47 m
Fig. 48

Description: Tricolpate pollen grain, probably iso-polar, radially symmetrical, short colpi, exine thick and coarsely reticulate.

Age: Maastrichtian

Class: Psilatricolpates (Van der Hammen and Wymstra, 1964)

Genus: Psilatricolpites (Van der Hammen and Wymstra, 1964)
Psilatricolporites Crassus (Van der Hammen and Wymstra, 1964)
BA – 17, 38 m
Fig. 20

Description: Psilatectate pollen grain with clearly visible columellae, Tricolpate, indistinct and short Constricticolpate.

Age: Maastrichtian

Class: Proxapcrturates (Van der Hammen, 1956).

Genus: Proxapertites (Van der Hammen, 1956b)
Proxapertites cursus (Van Hoeken-Klinkerberg, 1966)
BA – 17, 37 m
Fig. 17

Description: Proxaperturates pollen grains, reticulate, under the muri of the reticulum are columellae, but most of the lumina are without columellae, semi-tectate

Age: Maastrichtian

Class: Stephanocolpates

Genus: Tubistephanocolpites (Salami, 1983).
Tubistephanocolpites cylindricus (Salami, 1983)
BA – 7, 33 m
Fig. 5

Description: Stephanocolpates pollen, it is circular to sub-circular in outline, encircled by meridionally arranged colpi with pores. Exine is smooth.

Age: Maastrichtian

Class: Droseraceae

Genus: Droseridites (Cookson, 1950 ex. potonie, 1956).
Droseridites senonicus (Cookson, 1950)
BA – 7, 23 m
Fig. 22

Description: The species is characterized by inaperturate and spinose pollen grains that are united in loose tetrahedral tetrads. The grains are prolate, striate and Tricolpate. The c olpi are slender and long, the striae are very fine, densely packed and situated parallel to the polar axis.

Age: Maastrichtian

Class: Monoporates

Genus: Monoporites (Cookson, 1950)

Monoporites annulatus (Van der Hammen, 1954)

BA – 17, 23 m

Fig. 61

Description: The species consists of a spherical, often thin-walled and rather large grain, with a single pore. They are characteristics of grasses.

Age: Maastrichtian

Genus: Monocolpopollenites (Pflug and Thomson, 1953).

Monocolpopollenites sphaeroidites (Pflug and Thomson, 1953)

BA – 7, 29 m

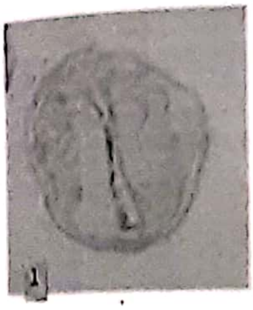
Fig. 51

Description: Monocolpates copus, spherical in shape.

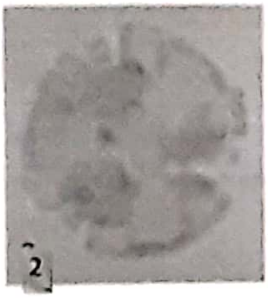
Age: Maastrichtian

PHOTOMICROGRAPHS OF PALYNOMORPHS

ALL MAGNIFICATION IS X 1000



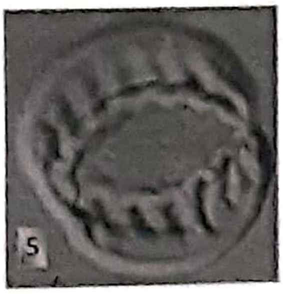
Monocolpites marginatus



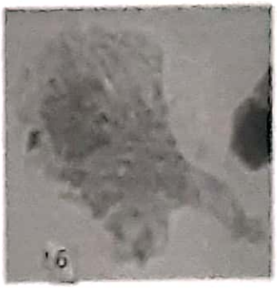
Psilatricolporites Crassus

Botryococcus braunii (A)

Ephedripites ambiguous

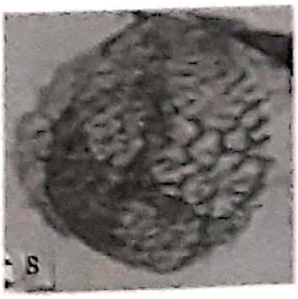


Tubistephanocolpites cylindricus



Botryococcus braunii (B)

Monocolpopollenites



Retimonocolpites sp.

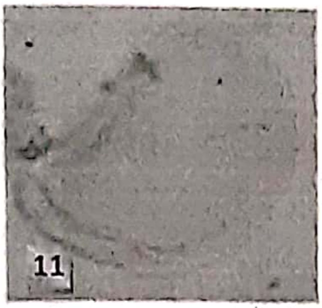
Pediastrum sp

7

8

9

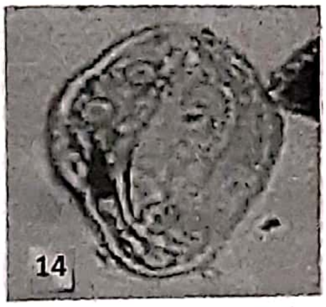
Sapotaceoidaepollenites sp.



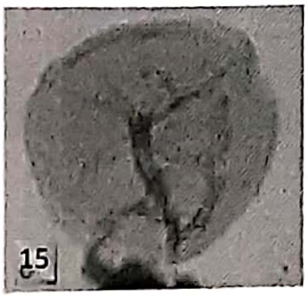
Laevigatosporites haardtii

Ctenolophonidites costatus

Arecipites crassimuratus

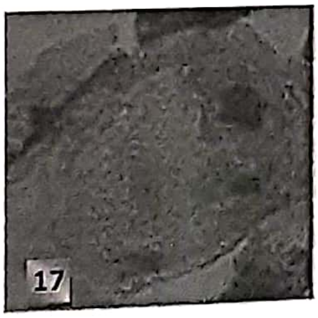


Germmamonoporites

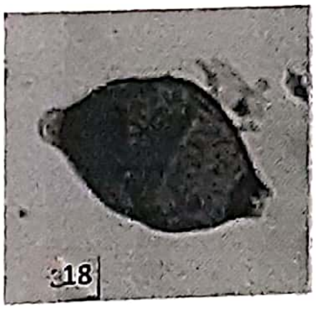


Zlivisporites

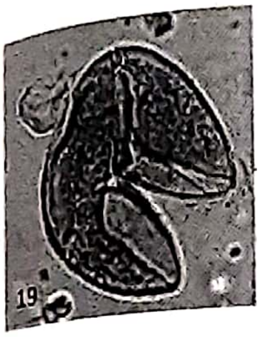
Fungal spore (A)



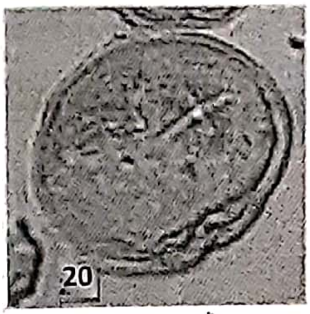
Proxapertites cursus



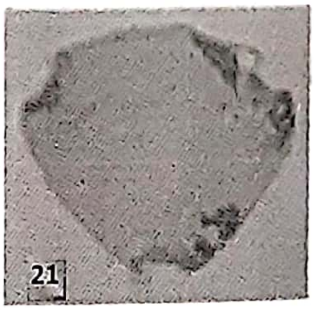
Fungal spore (B)



Osmundacidites sp.

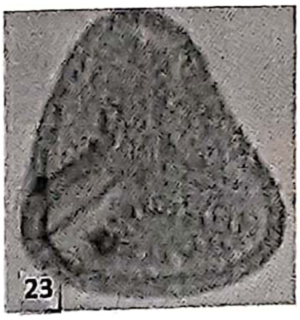


Psilatricolporites crassus

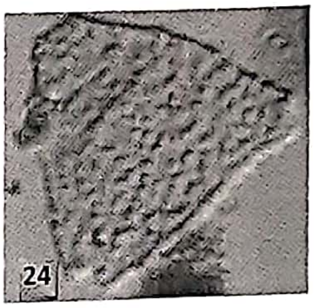


Cupanieidites sp.

Droseridites Senonicus



Foveotriletes margaritae



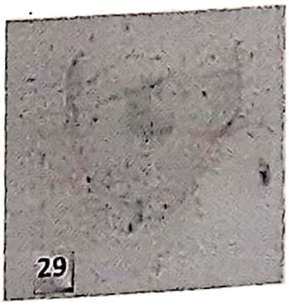
Proteacidites sigalii

Cyathidites sp.

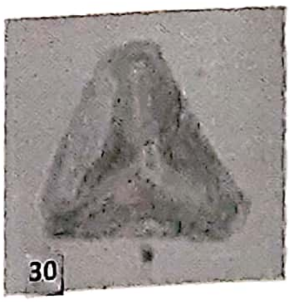
Tricolporopollenites sp.

Leoisphaeridia sp.

Distaverrusporites simplex

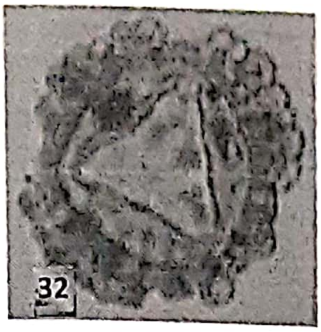


Nematosphaeropsis sp.

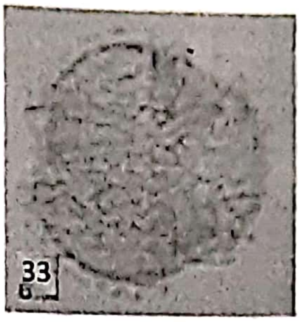


GlechenditesSenonicus

Longapertites

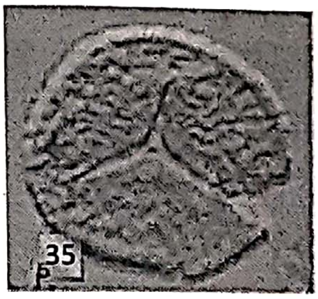


Cingulatisporites Ornatus

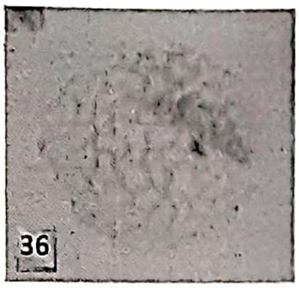


Retitricolporites

Longapertites chlonovae

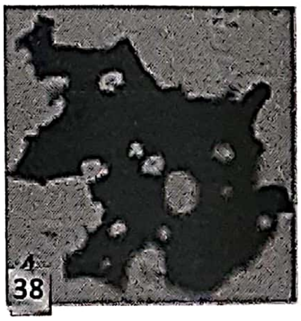


Rugulatisporites caperatus

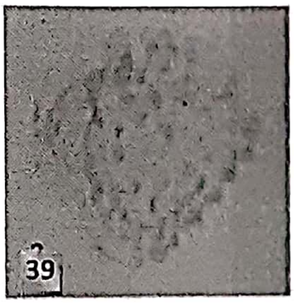


Auriculiidites sp.

Polypodiaceoisporites sp.

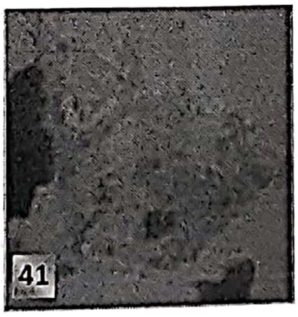


Charred Graminae Cuticle

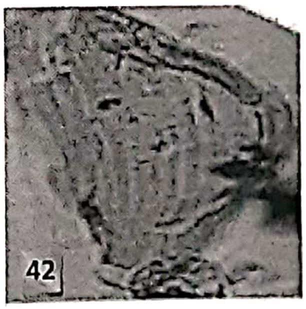


Echitriporites trianguliformis

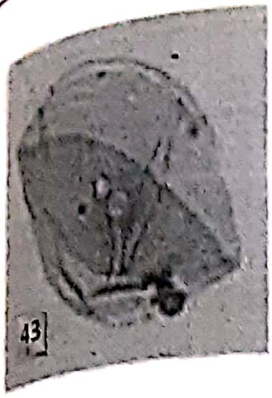
Spinizonocolpites echinatus



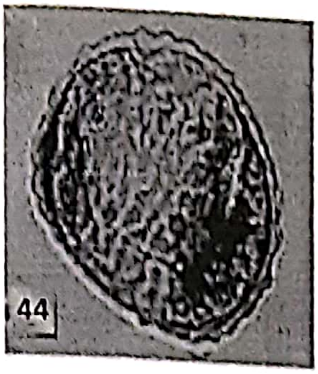
Auriculopollenites



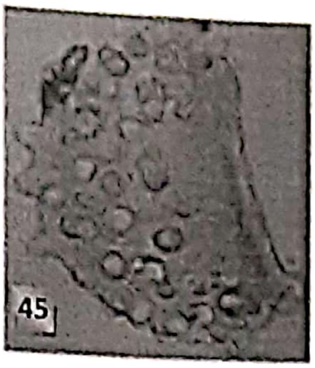
Gnetaceaepollenites sp.



Monoporites annulatus

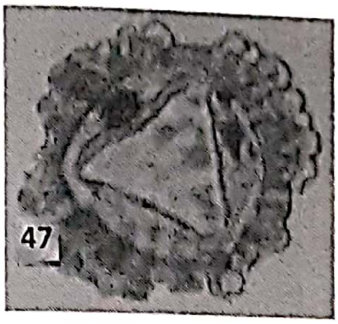


Verrucatosporites sp.

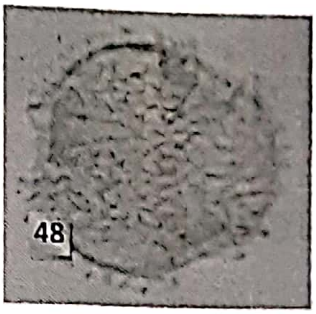


Verrucatosporites usmensis

Laevigatosporites haardti sp.

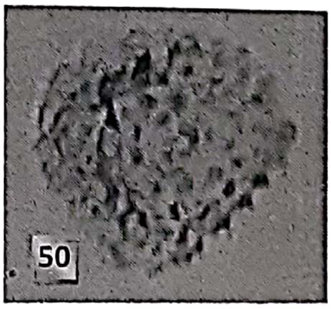


Cingulatisporites ornatus

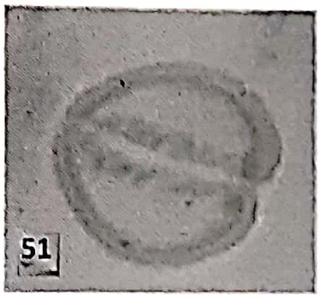


Retitricolporites irregularis

Longapertites chlonovae



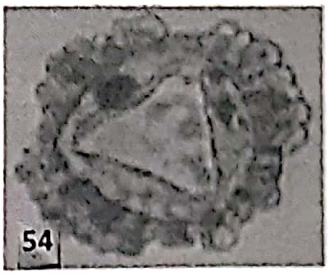
Echitriporites trianguliformis



Monocolpopollenites sphaeroidites sp

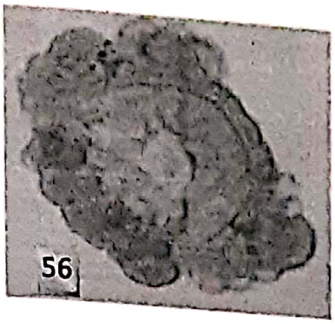
Longapertites microfoveolatus

Rugulatisporites caperatus

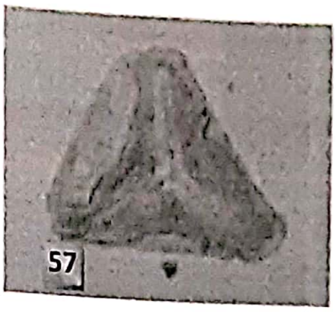


Droseridites senonicus sp.

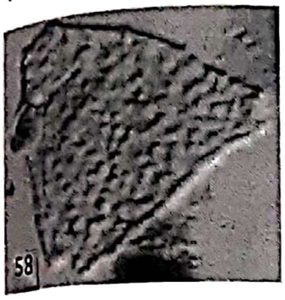
Spinizonocolpites echinatus



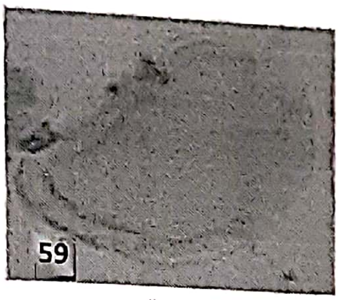
Distaverrusporites simplex



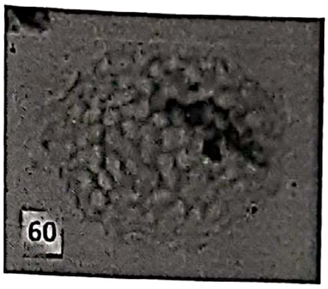
Gleicheniidites senonicus



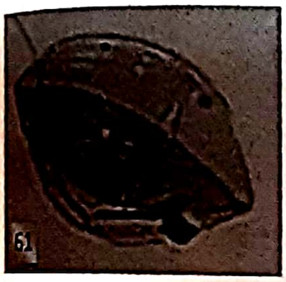
Proteacidites Sigalii



Cingulatisporites ornatus sp.



Auriculiidites spp.



Monoporitesannulatus

4.0 CONCLUSION

The paper has aptly dwelt on the descriptive systematic Palynology of the various palynoforms recovered from the Maiganga coal mine situated within the Gombe Formation. The observed and described forms include various Spores and Pollen grains as well as algal spores, totaling 61 species.

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