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# Palynological and Palaeoenvironmental Study of the Middle-Upper Maastrichtian Mamu Coal Facies in Anambra Basin, Nigeria

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**Abstract:** The Middle-Upper Maastrichtian Mamu Formation in the Anambra Basin is characterized by fossiliferous dark gray, indurated, fissile shale, overlain by intercalation of sand and shale facies sequence with coal inter-beds inferring deposition under shallow marine conditions. The sequence is also characterized by rapid facies change within short stratigraphic interval. Detailed palynostratigraphic study of a reference *Well*-1008 and coal samples from different horizons in eight cored *Wells*-1002,1267,1235,1239, 1219, 1213 and 1356 were analyzed in order to determine the palynological zones of the reference *Well* and geological age of the coal seams in the Mamu Formation. The reference *Well*-1008 indicates two palynological zones, while one palynological zone was established for the other eight *Wells* belonging to *Spinizonocolpites baculatus Assemblage Zone*. Two palynological zones were established for the *Well*-1008 - Zone 1: *Longapertites marginatus Acme Zone* characterized by the maximum development of *Longapertites marginatus*; associated with other forms such as *Retimonocolpites sp.2, Periretisyncolpites sp., Retidiporites magdalenensis, Monocolpites marginatus,Cingulatisporites ornatus, Constructipollenites ineffectus, Aquilapollenites sp*. and *Triporites sp*. The marker forms are inferred to have been deposited as a result of marine transgression marked by dark shales which were deposited during the Middle Maastrichtian. The interval is further marked by preponderance high palynomorph abundance and diversity which could have resulted due to conducive environmental conditions and appreciable shift in marine shoreline onto the continent. The palynological Zone 2, belongs to *Spinizonocolpites baculatus Assemblage Zone*, characterized by co-occurrence of *Nigeripollis gemmatus sp*, *Echitriporites trianguliformis*, *Periretisyncolpites sp*.,*Rugulatisporites caperatus*, *Cingulatisporites ornatus*, *Constructipollenites ineffectus*, *Zlivisporites blanensis* and *Distaverrusporites simplex*. All the coal seam beds belong to the Zone 2 of *Spinizonocolpites baculatus* assemblage zone, dated Late Maastrichtian age. It is suggested that the coal deposits were formed as a result of interplay between the pockets of marine water and fluvial processes during the regressive phase in the Late Maastrichtian time. This is further characterized by relatively low abundance of palynomorph population and diversity associated with low sea level and basin ward shift of marine shoreline.

**Key words:** Acme zone · Transgression · Lacustrine · Marginal marine and Assemblage zone.

## INTRODUCTION

Coal has been a key source of energy and a major contributor to the economic growth in most industrialized and developing countries like Nigeria. It is widespread geographically and found throughout much of the Post-Devonian geologic column.

The Anambra Basin which corresponds to the western complimentary syncline to the emergent Abakaliki Anticlinorium in the lower Benue Trough southeastern Nigeria (Figure 1) has been a major geological area for coal exploration since 1909. Major exploitation of Nigerian coal began in 1915, with an annual production of over 900 000 tonnes in 1958, but has declined as a result of the increased use of oil and gas. The coals in the Anambra Basin outcrop mainly in Enugu area where four mines: Iva Valley, Onyeama, Okpara and Ribadu were worked by the Nigerian Coal Corporation. Other mines that were recently opened included those of Okaba and Orukpa within the Mamu Formation.

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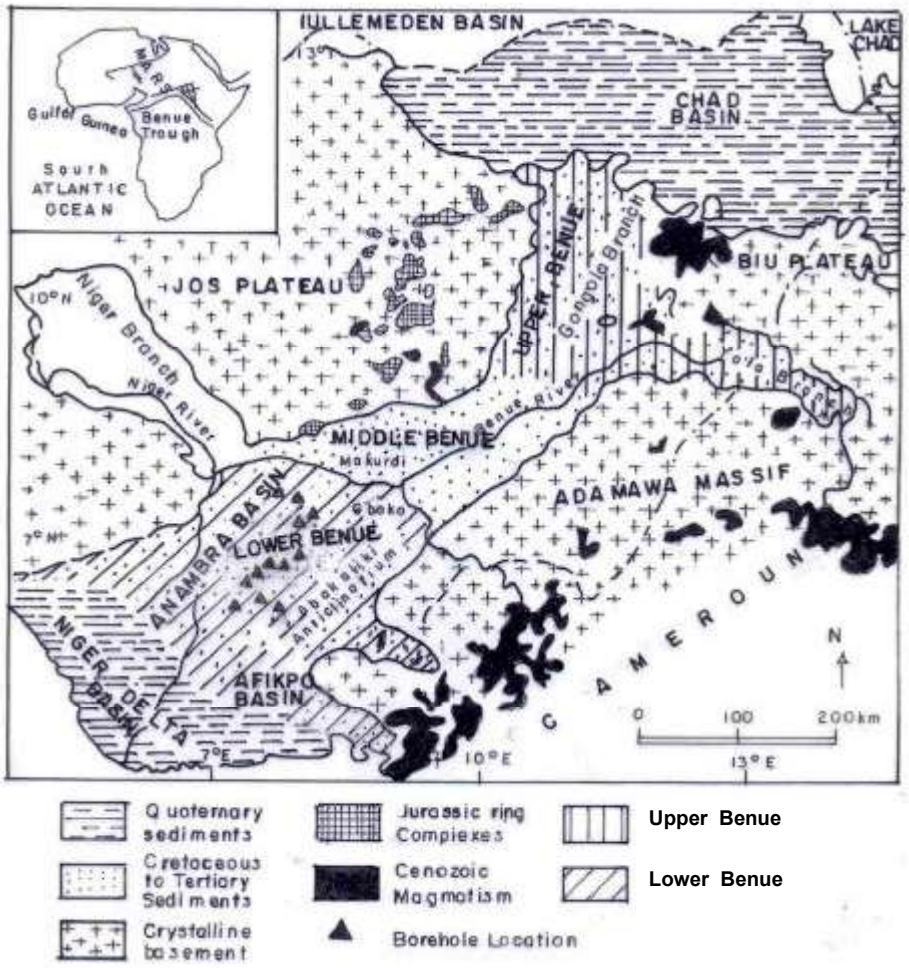



Fig. 1: Geological Map of Nigeria showing the lower Benue Trough and location of studied *Wells* (modified from Coulon *et al*. [11])

The Maastrichtian Mamu Formation in the Anambra Basin (Figure 1) consists of rhythmic sequences of sandstones, shales, siltstones, mudstones, sandy shales with interbedded coal seams inferring deposition under shallow marine conditions. The coal in this basin is sub-bituminous and occurs principally at two levels; the Lower Coal Measures (Mamu Formation) and the Upper Coal Measures (Nsukka Formation). The coal-bearing Mamu Formation occurs as a narrow strip trending north-south from the Calabar Flank, swinging west around the Ankpa plateau and terminating at Idah near the River Niger [1]. The lignite deposits occur in the Oligocene-Miocene Ogwashi-Asaba Formation [2]. Coal and lignite resources have an estimated reserve of 1.5 billion tons and 300 million tons respectively [3].

The Mamu Formation has been described by many authors either on the basis of their sedimentological and biostratigraphic characteristics [4-9]. Mamu coal was dated Maastrichtian age by Van Hoekeen-Klinkenberg [10] but was not refined to epoch level. This paper attempts the refinement and found out that a number of the coal beds were deposited between Mid- Late Maastrichtian time.

**Geologic Setting and Stratigraphy:** The Anambra Basin is a NE-SW trending syncline that is part of the Central African Rift System which developed in response to the stretching and subsidence of major crustal blocks during a Lower Cretaceous break-up phase of the Gondwana super-continent (Figure 1). The movements were re-activated by further plate activity in Lower Tertiary soon after the intermittent Upper Cretaceous rifting. The Anambra Basin contains about 6km thick Cretaceous / Tertiary sediments and is the structural link between the Cretaceous Benue Trough and the Tertiary Niger Delta [13]. The Anambra Basin is a part of the lower

Table 1: Cretaceous-Tertiary stratigraphy in SE Nigeria (modified from Reyment [2]; Akande *et al*. [12])

| Basin | Period | Stratigraphy | Sea-level Change | | | | | |
|---|---|---|---|---|---|---|---|---|
| Niger delta | Tertiary | Pliocene to Paleocene | NigerDelta Units | | | | | Regression |
| Anambra basin | | Eocene | Ameki Group | Nsugbe Formation<br>Nanka Formation | | | | |
| | | | | Ameki Formation | | | | Transgression |
| | | Paleocene | Imo Shales | | | | | |
| | | Danian | Nsukka Formation | | | | | Regression |
| | U. Cretaceous | Maastrichtian | Ajali Sandstone | | | | | |
| | | | Mamu | | | | | |
| | | Campanian | Nkporo Shales | EnuguShales | Afikpo | Owelli | Otobi | Transgression |
| Abakaliki-Benue | | Coniacian-SAntonian | Awgu Shales | | | | | Regression |
| | | Turonian | Eze-Aku Shales | | | | | Transgression<br>Regression<br>Transgression |
| | | Cenomanian | Odukpani Formation | | | | | Regression |
| | L. Cretaceous | Albian | Asu River Group | | | | | Transgression |
| | | L. Palaeozoic | Basement | | | | | |

Benue Trough containing post-deformational Campanian - Maastrichtian to Eocene sedimentary strata. It extends northward to the lower Benue River and also forms a boundary with the Tertiary Niger Delta to the south (Figure 1). The structural setting and general geology of the Anambra Basin have been documented by various workers [5, 14-17]. Sedimentation in the Anambra Basin commenced with the Campano – Maastrichtian marine and paralic shales of the Enugu and Nkporo Formations, overlain by the coal measures of the Mamu Formation. The fluviodeltaic sandstones of the Ajali and Owelli Formations lie on the Mamu Formation and constitute its equivalents in most places (Table 1). The marine shales of the Imo and Nsukka Formations were deposited in the Paleocene, overlain by the tidal Nanka Sandstones of Eocene age. Downdip, towards the Niger Delta, the Akata Shale and Agbada Formation constitute the Paleogene equivalents of the Anambra Basin (Table 1).

The stratigraphy of Mamu Formation is characterized by fossiliferous dark gray, indurated, fissile shale, overlain by intercalation of sand and shale facies sequence with coal inter-beds. The stratigraphy of the reference *Well*-1008 (Figure 3) is similar to that of the typical Mamu Formation characterized by intercalation of sand and shale, commonly associated with coal seam. The stratigraphy of well- 1008 ranges from depth 201 m at the top to depth 235 m at the bottom where the analysis commenced. The lithostratigraphic description of *Well*-1008 is characterized at the base by dark, well indurated fissile shale (233-235 m) at the point where our analysis commenced. This is overlain by a fining – upward (graded) sequence of sandstone that varies in size from medium grain at the bottom to fine grain size at the top (230-233 m). Interval 221-230 m is characterized by intercalation of sand and shale beds; the shales are dark grey and indurated while the sandstone facies are fine grained, indurated and laminated.

The first coal bed appeared at interval 220-221 m. This is overlain by fairly thick, dark grey, indurated, fissile shale (211-220 m).This shale interval is intercalated by heterolith sand-shale facies between intervals 213-214 m. The second coal bed occurred at depth interval 210-211m. The stratigraphic interval that overlies this coal bed is characterized by relatively moderately thick shale (206-210 m) and fine grained sandstones associated with shale laminae (203-205 m). The last appeared coal seam in this well is at depth 203m, exhibiting the same properties like other underlying coal seams. Directly overlying this coal bed is a very thin shale (202-203 m) overlain by thin fine grained sandstone bed associated with light gray shale laminae.

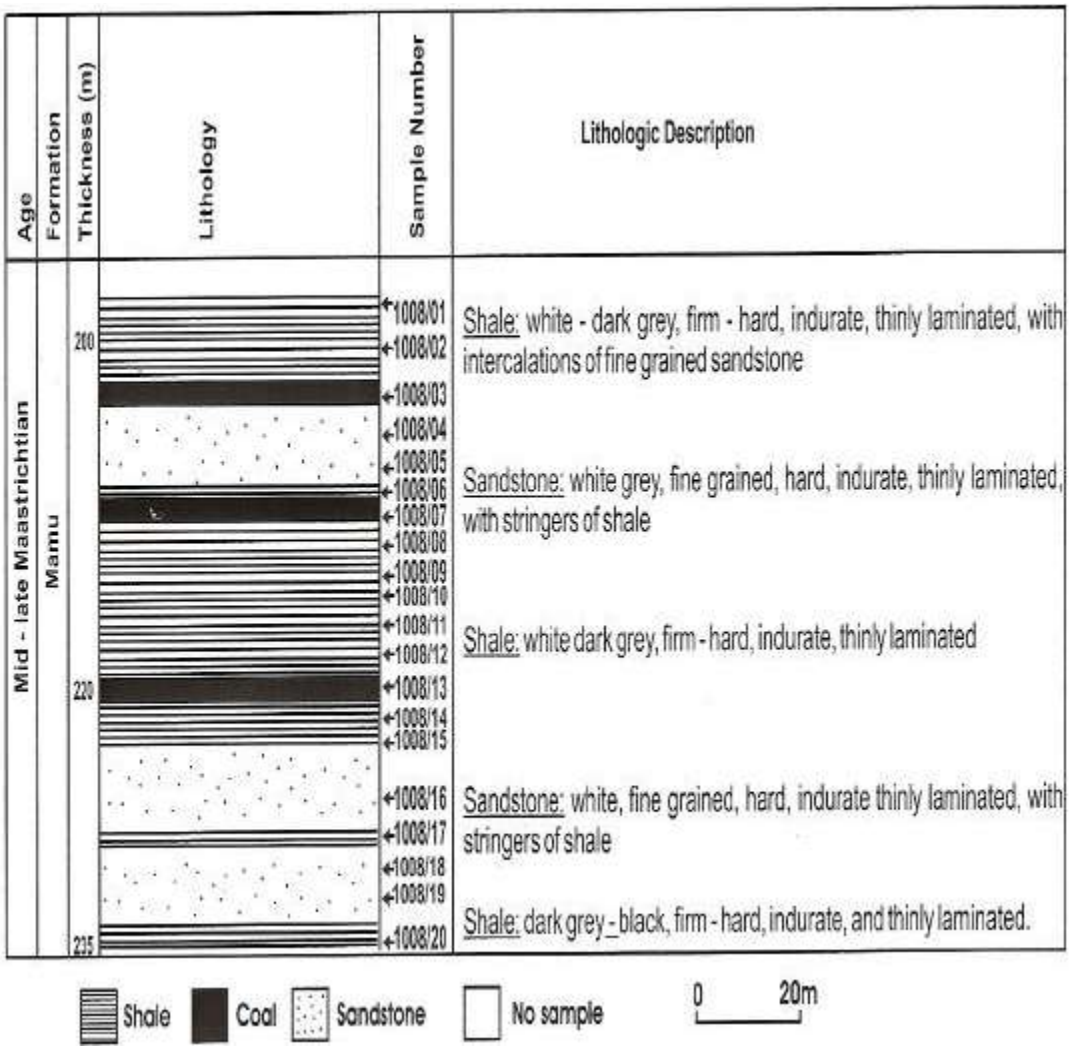



Fig. 3: Lithologic log of BH 1008

## MATERIALS AND METHOD

Sixteen core samples from nine drilled *Wells* (1008, 1002, 1001, 1267, 1235, 1239, 1219, 1213 and 1356) were used for the preparation of the palynological slides used for miospore content determination. The samples were taken at different points of occurrence in different wells. The coal samples were not considered alone but also with bounded strata. A well with three appearances of coal beds is considered as a reference *Well*-1008 to determine the palynological contents and geological ages of the coals. Reference well-1008 (Figure 3) has eight samples prepared in all, with three of them being coal beds at different stratigraphic horizons (203 m, 210-211 m and 220-221 m). There was no specific sampling interval because of our interest in sampling the coal beds; otherwise, they might be omitted if regular sampling interval was followed. The sample preparation was carried out following the international standard. The coal, shale and sandstone samples were crushed with the mortar and pestle because they are well indurated, thus, this will enhance maximum recovery of pollen and spores. The crushed samples with exception of the coal samples were initially treated with dilute hydrochloric acid (10%) in order to eliminate carbonate substance present in them. They were later soaked in 40% hydrofluoric acid for silica and silicates digestion.

The samples were not oxidized in order to avoid corrosion; but were sieved with $10_{um}$ mesh in order to maximize concentration of miospore grains and to achieve clean slides for easy identification and photography. The recovered residues were mounted on glass slides with Depex (DPX).

The amount of palynomorph recovered is moderate to barren. Total count of grains present were noted and presented in the checklist for absolute representation of different important pollen and spores grains recovered.

## RESULTS AND DISCUSSION

The palynological distribution chart of reference *Well*-1008 against the litho-log section of interval 201-235 m is presented in Figure 4. Absolute number of frequency of occurrence of each pollen and spore was noted and used. The palynomorph recovery was moderate to poor and rarely barren. Pollen and spores recovered were compared with the work of Van Hoeken-Klinkenberg [10,18], Jardine and Magloire [19], Lawal [20], Lawal and Moullade [21], Edet and Nyong [22] and in the compilation work of Salard-Cheboldaeff [23].

The composition of the coal beds were also plotted to show different forms present and frequency of occurrence of such important grains (Fig.3). The palynostratigraphy of the well is given in Figure 3. Two palynological zones are suggested based on the occurrence of marker fossils (Fig.4). The erected zone 1 is here given *Longapertites marginatus* Acme Zone. The stratigraphic interval ranges from 235-228 m. This interval lies below the first occurrence of coal bed located at 229-221 m. The established Zone 1: *marginatus Longapertites* Acme Zone is characterized by high fossiliferous horizons, relatively high frequency of palynomorph abundance and diversity (Fig. 3). The zone is further characterized by maximum development of *Longapertites marginatus*, relatively moderate occurrence of other important forms such as *Zlivisporites blanensis, Monosulcites sp, Retimonocolpites sp 2* [20], *Longapertites sp* and *Periretisyncolptes sp.* Other signifigant pollen and spores present in this interval are *Retidiporites magdalenensis, Monocolpites marginatus, Cingulatisporites ornatus, Constructipollenites ineffectus, Proxapertites cursus, Longapertites vaneendenburgi, Periretisyncolpites giganteus, Triporites* sp and *Aquilapollenites minimus*.

The Zone 2 is established after the work of Lawal and Moullade [21] referred to as *Spinizonocolpites baculatus* Assemblage Zone. Other associated marker forms that characterize this zone include forms such as *E chitriporites trianguliformis,* continuous occurrence of Longapertites marginatus, Retimonocolpites sp, Zlivisporites *blanensis, Distaverrusporites simplex, Contructipollenites ineffectus, Cingulatisporites ornatus and Periretisyncolpites sp*. The coal beds within this zone contain poor recovery of pollen and spore grains. Diagnostic forms present in them *include Echitriporites trianguliformis, Zlivisporites blanensis, Longapertites marginatus and Inaperturopollenites sp*. Other forms present are *Monosulcites sp, Retidiporites magdalenensis Distaverrusporites simplex, Cingulatisporites ornatus and Periretisyncolpites sp.*

Most of these forms present are similar to those described by Lawal, [20], Lawal and Moullade [21] and in Salard-Cheboldaeff, [23]; also correspond in part to *Proteacidites dehaani Zone* established by Germeraad *et al,* [24] for Tropical zones.

The other coal beds in *Well-1267* is characterized by the presence of *Periretisyncolpites giganteus, Constructipollenites ineffectus, Monocolpites marginatus, Monosulcites sp, Monocolpites sp, Ephedripites sp and Leiotriletes sp.* Coal beds in *Well-1001* shows the occurrence of *Retimonocolpites sp,*

| FORMATION | DEPTH (m) | LEIOTRILETES SP | TRIPORITES SP | ARAUCARIACITES SP | INAPERTUROPOLLENITES SP | LONGAPERTITES MARGINATUS | MONOCOLPITES MARGINATUS | ZLIVISPORITES BLANENSIS | MONOCOLPITES SP | MONOSULCITES SP | ECHITRIPORITES TRIANGULIFORMIS | RETIMONOCOLPITES SP | RETIMONOCOLPITES SP 2 | RETIDIPORITES MAGDALENENSIS | DISTAVERRUSPORITES SIMPLEX | PERISYNCOLPITES SP | CINGULATISPORITES ORNATUS | CONSTRUCTIPOLLENITES INEFFECTUS | EPHEDRIPITES REGULARIS | RETIMONOCOLPITES SP 2 | LONGAPERTITES SP | TRICOLPOROPOLLENITES SP | PROXAPERTITES SP | TRIPORITES CF VERSEN | LONGAPERTITES VANEENDENBURGI | PERIRETISYNCOLPITES GIGANTEUS | TRICOLPITES SP | TRICOLPITES SP | AQUILAPOLLENITES SP | TRICOLPITES SP | ISABELIDINIUM SP | RETIDIOSPHAERA SP | CINGULA CELLATE CYST | SENEGALINIUM SP | FUNGAL SPORE | PALYNOMORPH BURDENDE | PALYNOMORPH DIVERSITY | TOTAL BISEFORE | TOTAL DINOFLAGELLATE | ALGAE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MAMU | 201-205 | 1 | 1 | 2 | 2 | 1 | 1 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | 2 | 11 | 6 | 8 | 0 | 2 |
| | 205 | | | | 1 | 1 | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | 1 | | 4 | 4 | 3 | 1 | 0 |
| | 206-210 | 5 | | 1 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | 8 | 4 | 7 | 0 | 1 |
| | 210-211 | 1 | | | 4 | 1 | 2 | 3 | | 2 | 1 | 3 | 1 | 1 | 1 | 1 | 1 | | | | | | | | | | | | | | | | 4 | | 6 | 21 | 14 | 21 | 4 | 6 |
| | 214-220 | 9 | | | 1 | | 4 | 2 | | | | 2 | 1 | | 2 | | | 2 | 1 | | | | | | | | | | | | | | | | | 21 | 11 | 21 | 0 | 0 |
| | 220-221 | | | | | | | | | | | | BARREN | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 229-230 | 9 | | | 9 | 19 | 2 | 5 | 2 | 5 | | | 3 | | | 4 | 1 | 2 | | 8 | 8 | 2 | 2 | 1 | 1 | 3 | 1 | 2 | 1 | 1 | | 2 | 1 | 1 | 9 | 115 | 88 | 102 | 4 | 9 |
| | 230-235 | 3 | | | 4 | 1 | 1 | 1 | | | | 4 | 1 | | | | | | | 1 | | | | | 1 | 3 | | | 1 | | | | | | 28 | 12 | 28 | 0 | 0 |

Fig. 4: Palynological distribution chart of *Well-1008*

| Depth (m) | ZONATION (After Lawal & Moullade, 1986) | New Zone (modified after Lawal & Moullade, 1986) | Characteristics | Age | Paleoenvironment |
|---|---|---|---|---|---|
| 201-202 | *Spinizonocolpites Baculatus* Assemblage Zone | *Spinizonocolpites Baculatus* Assemblage Zone | Characterized by continuous occurrence of *Longapertites marginatus*, associated with *Perisyncolpites spp. Retidiporites magdalenensis, Cingulatisporites ornatus, Zlivisporites blanensis, Longapertites vancendenburgi, Monocolpites marginatus and Constructipollenites ineffectus* | Late Maastrichtian | Lacustrine |
| 203-204 | | | | | |
| 208-210 | | | | | |
| 210-211 | | | | | |
| 214-220 | | | | | |
| 220-221 | | | | | |
| 228-230 | | *Longapertites marginatus* Acme Zone | Characterized by maximum development of *Longapertites marginatus* | Mid-Maasrichtian | Marginal marine |
| 233-236 | | | | | |

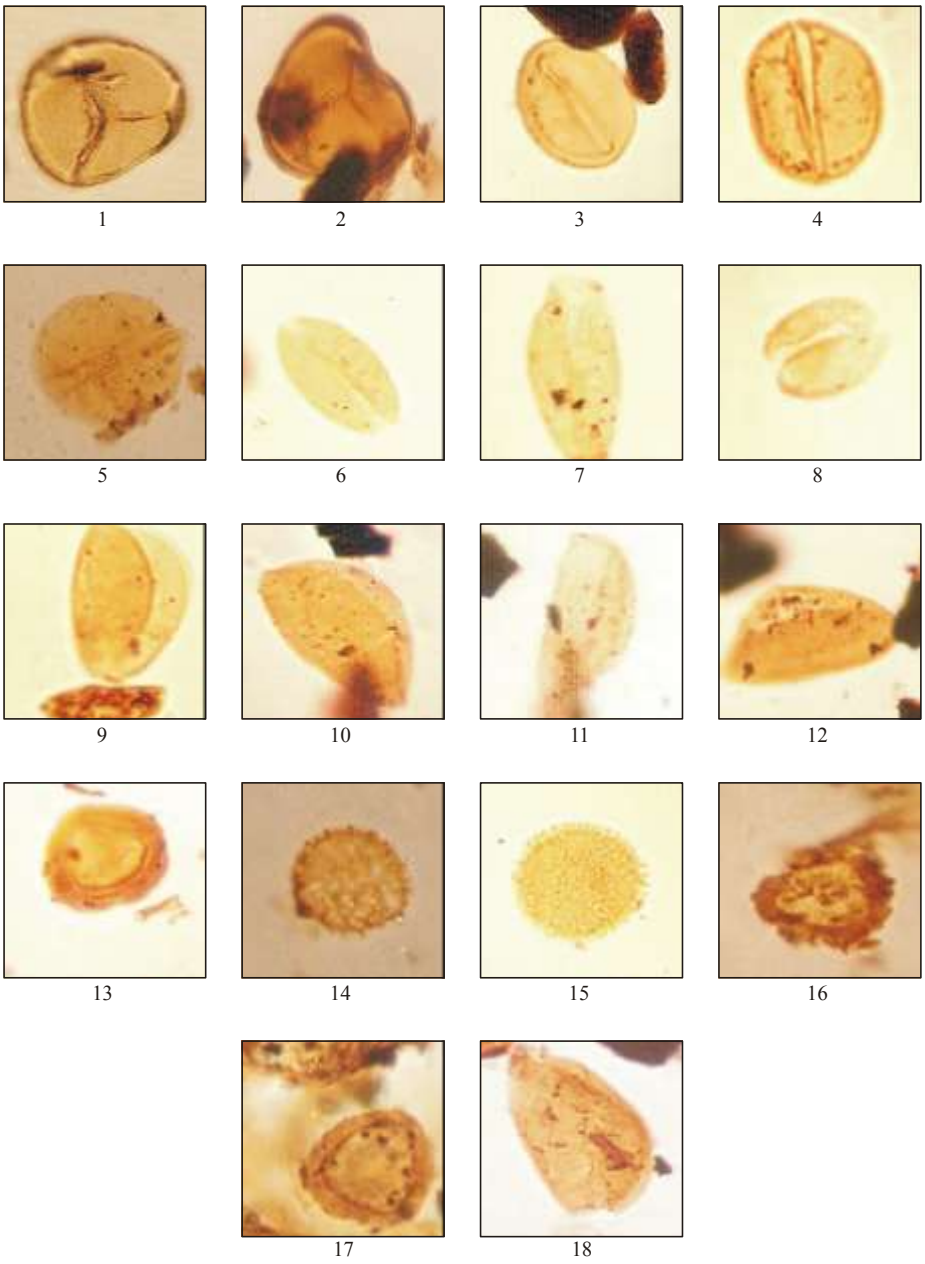
Fig. 5: Palynostratigraphic zonation of Well 1008

*Monocolpites sp, Proxapertites cursus, Retidiporites magdalenensis and Buttinia andreevii.* Coal beds in the *Wells 1267 and 1001* share similar miospore composition that suggest Late Maastrichtian age. However, the coal bed in *Well-1002* is marked by *Zlivisporites blanensis, Longapertites marginatus,* increase in *Monosulcites sp;* others present are *Monocolpites marginatus, Rugulatisporites cuperatus, Foveotriletes margaritae and Inaperturopollenites sp.* The relative increase in the recovered fossils suggest a Late Maastrichtian age especially because of the strikingly presence of *Rugulatisporites caperatus*.

In *Well-1213*, the miospores present is not that different from the fossil assemblage of the ones above, it is defined by the presence of two coal beds. The lower coal bed is barren while the upper coal bed is characterized by the occurrence of *Proxapertites operculatus, Retidiporites magdalenensis, Foveotriletes margaritae, Gemmamoncolpites sp, Distaverrusporites simplex, Longapertites marginatus, Leiotriletes sp* and *Retimonocolpites sp.* This particular coal seam is dated Late Maastrichtian on the basis of co-occurrence of strikingly important forms such as *Distaverrusporites simplex, Gemmamonocolpites sp and Proxapertites sp*. However, the coal bed present in *Well-1239* has very few recovery of *Proteacidites sp 4, Monosulcites sp, Constuctipollenites ineffectus,* suggest Late Maastrichtian age. This assemblage is similar to those of Lawal and Moullade, [21] and Germaraad, *et al* [24]. The other three *Wells- 1356, 1235 and 1219* shows occurrence of *Leiotriletes sp, Zlivisporites blanensis and Araucariacites sp; Inaperturopollenites sp, Monosulcites sp, Monocolpites sp, Leiotriletes sp* and *Monocolpites marginatus;* a barren level respectively. The age of the three wells cannot be placed, but they are tentatively dated Maastrichtian age. There is no further evidence to refine this Maastrichtian age into epoch.

The preponderance increase in *Longapertites marginatus* with maximum development was reported by Van Hoeken-Klinkenberg [10] in the Nigerian coal deposits from Southeastern Nigeria. It was described to indicate a transition from Cretaceous into Tertiary period. Though the samples studied by Van Hoeken-Klinkenberg [10] are borehole ditch cutting samples, unlike cored samples used by us which are more reliable. Thus, attention might not be given to the systematic increase and decrease in *Longapertites marginatus* which could be due to favourable environmental factors during Middle - Maastrichtian time. This conducive condition led to the boom of the form probably as a result of marine incursion (transgression). During the regressive phase of the marine water, the retained water in the continent in conjunction with fluvial processes led to the formation of coal seam in the Late-Maastrichtian. Therefore, there might not be observation of systematic increase and decrease in *Longapertites marginatus* as observed in our research.

In the work of Lawal and Moullade, [21], it was also reported that there was a tremendous increase or maximum development of *Longapertites marginatus*. This observation was made on the studied samples which suggests a *Longapertites marginatus Acme Zone* on the basis of stratigraphic position relative to the surrounding




Pate I
(All magnification at ×800)

1Leiotriletes sp(Potonie and Gellectich) Krutzsch, 1959
2Leiotriletes sp
3-5Monocolpites marginatus Van der Hammen, 1954
6-8Monosulcites spLawal and Moullade, 1986
9-10Longapertites marginatusVan Hoeken-Klinkenberg, 1964
11Longapertites marginatus
12&18 Longapertites vaneendenburgiGermeraad *et al*, 1968.
13&17 Cingulatisporites ornatus
14-15Constructipollenites ineffectusVan Hoeken-Klinkenberg, 1964
16 Distaverrusporites simplexMuller, 1968

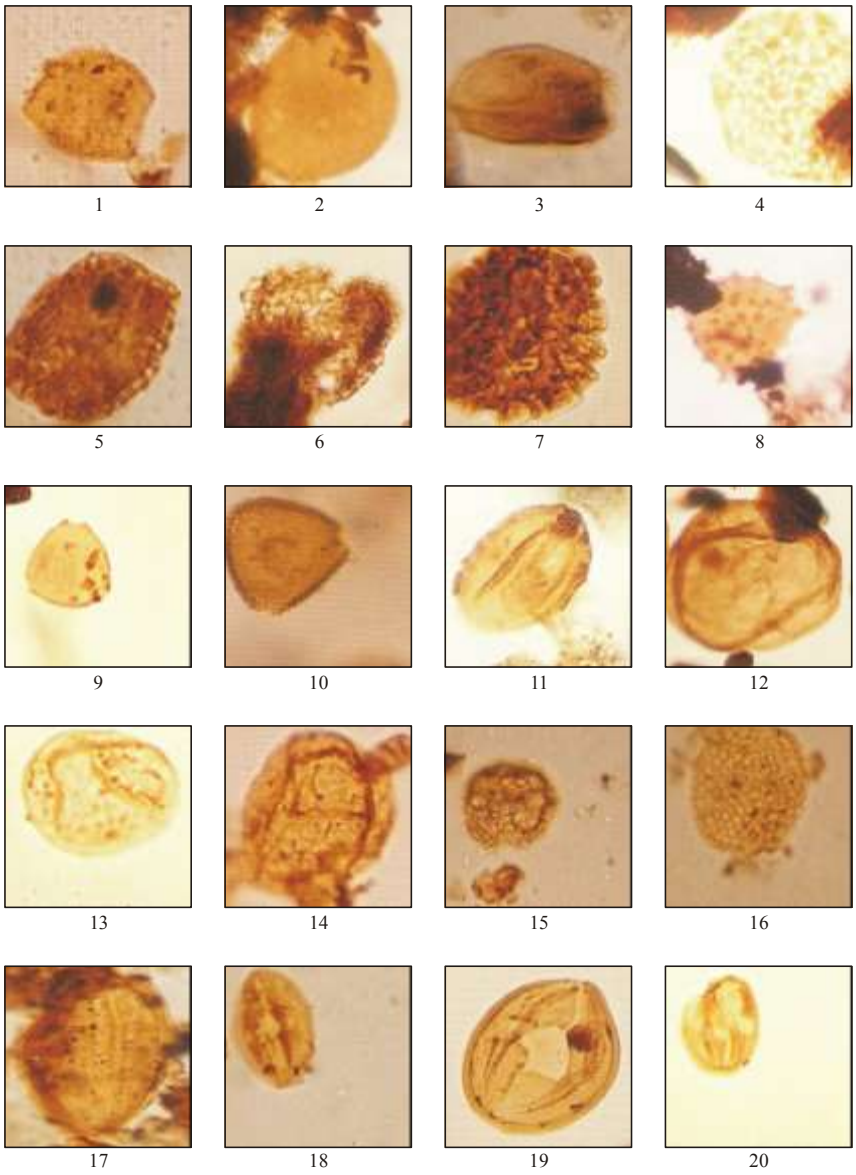



Plate 2
(All magnification at ×800)

1-3Retidiporites magdalenensisVan der Hammenand Garcia, 1966
4Periretisyncolpites giganteusLawal and Moullade, 1986
5-8Periretisyncolpites spLawal and Moullade, 1986
9Echitriporites trianguliformisVan Hoeken-Klinkenberg, 1964
10Triorites sp
11Triporites sp
12Tricolpites sp
13Inaperturopollenites spLawal and Moullade, 1986
14Araucariacites spCookson, 1947
15-16Zlivisporites blanensisPacltova, 1961
17Retimonocolpites sp. 2Lawal and Moullade, 1986
18Ephedripites regularisBrenner, 1963
19-20Tricolporopollenites spJardine and Magloire, 1965

depths. The zone is also defined by the presence of *Stephanocolpites* or Stephanocolporate forms such as *Ctenolophonidites costatus* and *Stephanocolpites* sp. which establishes the begining of Late Maastrichtian. Therefore, the establishment of this zone is only observable in the marine shale facies present in the reference Well-1008. It occurs below the first coal seam at the base of the well at depth 220-221 m. Thus, all coal beds analyzed are younger than Middle- Maastrictian age. The overlying interval (221-201 m) of *Spinizonocolpites baculatus Assemblage Zone* erected after Lawal and Moullade [21] is characterized by lesser palynomorph abundance and diversity. However, other floral assemblages present and associated with the marker are *Echitriporites trianguliformis, Distaverrusporites simplex, Gemmamonocolpites sp and Milfordia sp 3*. Others are *Monocolpites marginatus, retimonocolpites sp 2, Zlivisporites blanensis Rugulatisporites cuperatus, Cingulatisporites ornatus, Periretisyncolpites spp., Constructipollenites ineffectus* and *Proxapertites cursus* (Plates 1-2). All these forms are similar to assemblages described for this zone by Lawal [20], Lawal and Moullade [21]; similar in part to some forms described by Van Hoeken-Klinkenberg [10,18] and Edet and Nyong, [22].

The presence of *Periretisyncolpites sp, Echitriporites trianguliformis* and *Retimonocolpites sp* are described by Salard-Cheboldaeff [23] to belong to the Late Maastrichtian. In further comparison with other earlier workers, the assemblage flora of zone II recovered in the reference well and those of other coal beds in eight wells are similar to those of Late-Maastrichtian sediments described by Van der Hammen [25], Van ]der Hammen and Wijmstra [26], Jardine and Magloire [19], Germaraad *et al.* [24], Jan du Chene [27], Jan du Chene *et al.* [28] and Salard Cheboldaeff [29,30].

## CONCLUSION

It is indeed pertinent to affirm that the marine incursion in the early part of the Mamu Formation occurred during the Middle Maastrichtian age on the basis of both sedimentological and palynological inferences. The marine shales are dark gray in colour and showed strong effervescence on acid test, signifying the presence of calcite precipitates. The palynological evidence is based on the high abundance and diversity of miospores as a result of marine incursion onto the continent due to increase in sea level (transgression).This event allows pollen and spores deposited in the hinterland to be washed and carried by water, marked by landward shift of the shoreline. The palynological event during the period is characterized by maximum development of *Longapertites marginatus* associated with *Retimonocolpites sp.2, Periretisyncolpites spp., Retidiporites magdalenensis, Monocolpites marginatus, Cingulatisporites ornatus, Constructipollenites ineffectus, Aquilapollenites sp and Triporites sp.* The *Longapertites marginatus* maximum development could be as a result of the presence of favourable environmental conditions.

However, the regressive phase that succeeds the transgression is within the Spinizonocolpites baculatus zone, characterized by the co-occurrence of *Gemmamonocolpites sp, Echitriporites trianguliformis, Periretisyncolpites spp, Rugulatisporites cuperatus, Cingulatisporites ornatus, Constructipollenites ineffectus, Zlivisporite blanensis* and *Distaverrusporites simplex*. The interval is further characterized by low frequencies and abundance of palynomorphs due to dry climate associated with drop in sea level. The coal measures are suggested to have formed as a result of saline water and fluvial processes during this phase. The environment of deposition of zone 1 is marginal marine while the environment of deposition of the zone 2 interval is brackish in nature.

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