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PALYNOLOGY AND BIOSTRATIGRAPHY OF THE MAASTRICHTIAN COAL MEASURES IN THE ANAMBRA BASIN, SOUTHEASTERN NIGERIA.

E. JUDE OGALA

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ABSTRACT

A total of sixty-eight (68) core samples retrieved from eleven wells penetrating the Mamu Formation in the Anambra Basin, Southeastern Nigeria were studied for their palynomorph content in order to determine the age and paleoenvironment of deposition of the Mamu Formation. The wells are characterized by intercalation of laminated fine grained sand and light-dark grey fissile shale with interbeds of coal seams. The lower part with dark grey shale is characterized by the maximum development of *Longapertites marginatus Acme Zone*, dated Middle Maastrichtian. The upper part defined by intercalation of sand and shale with coal seam layers interbedding belong to *Spinizonocolpites baculatus Assemblage Zone*. This zone is characterized by the occurrence of *Spinizonocolpites baculatus, S.echinatus, Gemmazonocolpites sp, Constructipollenites ineffectus, Syncolporites marginatus, Periretisyncolpites gigantus, Zlivisporites blanensis, Retidiporites magdalenensis, Distaverrusporites simplex, Foveotriletes margaritae, L.vaneendenburgi, Proxapertites cursus, Proteacidites sp, Buttina andreevi, Periretisyncolpites sp and Monocolpites marginatus.* All these forms characterize Upper Maastrichtian age on the basis of the recognized diagnostic forms in the wells. The palynomorph abundance and diversity peaks and fossil assemblage of Mamu Formation show similarity with South American forms characterized by colder and warmer climate. These are directly related to eustatic change in sea level resulting to transgression and regression phases. The marine incursion resulted in Mid-Maastrichtian leading to the deposition of basal shale sequence of Mamu Formation while the coal seams were deposited during the regressive phases in the Late Maastrichtian.

KEY WORDS: Biostratigraphy, Maastrichtian Coal Measures, Palynomorph, Mamu Formation, Anambra Basin

INTRODUCTION

The Mamu Formation occurs extensively in the Anambra Basin in southeastern Nigeria (Fig. 1). The Mamu Formation (Reyment, 1965) originally referred to as the Lower Coal Measures (Simpson, 1954), consists of sandstones, shales, mudstones, sandy shale with inter-bedded coal seams. The formation outcrops along the Awgu-Enugu Escarpment and is exposed in coal mines at Udi, Enugu, Orukpa, Ezimo, Okaba and Ogboyoga. The sandstones are white, fine-grained and well sorted. These sandstones are usually well bedded. The shales are light-dark grey and frequently alternate with the sandstone to form a characteristically stripped rock. The coal seams range from a few centimeters to about 4 meters in thickness. The Mamu Formation overlies the Enugu Shales while the Ajali Formation (False-bedded sandstone) overlying the Mamu Formation comprises mainly consolidated poorly sorted and cross-bedded sandstone. The Nsukka Formation (Upper Coal Measures) which overlies the Ajali Formation has similar lithology to that of Mamu Formation.

A generally parallic depositional environment ranging from estuarine channels, barrier bar, marsh and tidal flats have been interpreted for the Mamu Formation (Reyment, 1965; Agagu et al., 1985). Petters (1978) described the Mamu Formation as a regressive deltaic offlap sequence of sandstone, siltstone, mudstone, shales and sandy shales with interbedded coal seams.

The aim of the present study is to describe the lithofacies and investigate the miospore content in order to determine the age and paleoenvironment of deposition of the Mamu Formation.

GEOLOGICAL SETTING

The evolution of the Southern Nigerian sedimentary basin began in the Early Cretaceous with the formation of the Benue – Abakaliki Trough as a failed arm of a rift triple junction associated with the separation of the African and South American continents and subsequent opening of the South Atlantic (Murat, 1972). The Benue Trough originated from Early Cretaceous rifting of the central West African basement uplift (Murat, 1972, Benkhelil, 1989). It forms a regional structure which is exposed from the northern frame of the Niger Delta and runs northeastwards for about 1500 km to underneath Lake Chad where it terminates (Fig. 1). Regionally, the Benue Trough is part of an Early Cretaceous rift complex known as the West and Central African Rift System.

E. Jude Ogala, Department of Geology, Delta State University, Abraka, Delta State, Nigeria.

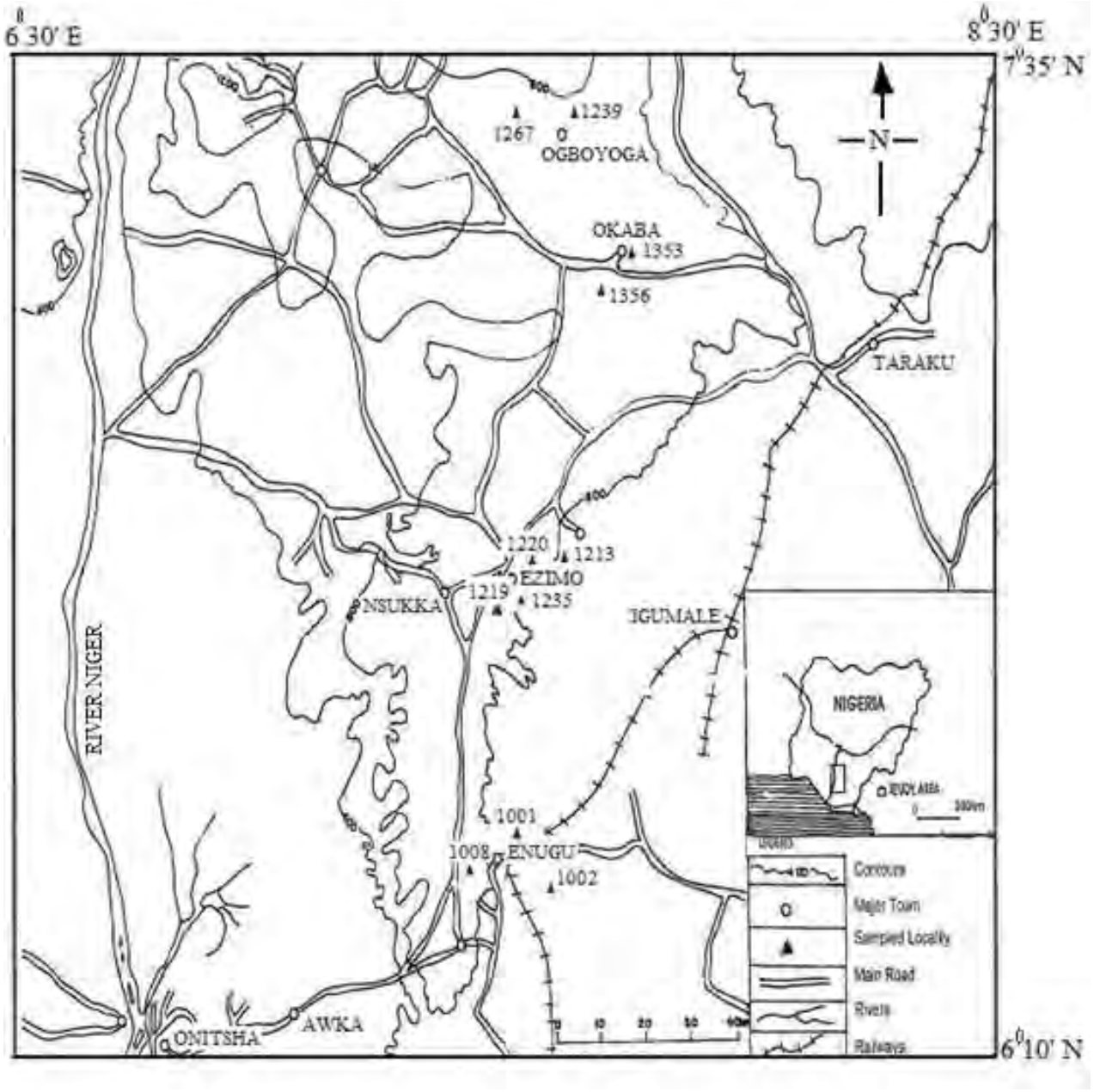

Figure 1: Map of the study area showing borehole locations.

The origin of the Anambra Basin and its lithic fill is tied to the genesis and the tectonics of the Benue Trough. The Anambra Basin is located in the southwestern end of the Benue Trough of Nigeria (Fig. 1). The basin is bounded on the west by the Precambrian basement complex rocks of western Nigeria and on the east by the Abakaliki Anticlinorium. It extends northward to the lower Benue River and also forms a boundary with the Tertiary Niger Delta to the south (Fig.1).The platform areas bordering the Benue Trough to the west (Anambra Platform) and to the east (Afikpo Platform) became downwarped due to the Santonian tectonism to form the Anambra Basin and the Afikpo Syncline respectively (Murat, 1972; Petters, 1978; Benkhelil, 1989). The Anambra Basin contains about 6 km thick Cretaceous/Tertiary sediments and is the structural link

The geologic strata of the Anambra Basin were deposited in a syncline initiated by the major folding episode in the Benue Trough during Late Cretaceous times. During the Late Santonian – Danian, the Anambra Basin became filled up and vegetation grew along with sedimentation resulting in the deposition deltaic foresets and flood plains (Wright et al., 1985; Nwajide and Reijers, 1996). Sedimentation in the Anambra Basin commenced with the Campano – Maastrichtian marine and paralic shales of the Enugu and Nkporo Formations. These basal units are overlain successively by the coal measures of the Mamu Formation (Lower Coal Measures), the Ajali Sandstone (Middle Coal Measures), and the Nsukka Formation (Upper Coal Measures). The Tertiary succession

consists of the marine shales of the Imo Formation deposited in the Paleocene, overlain by the Ameki Formation (lateral equivalents the tidal Nanka Sandstones) of Eocene age (Fig. 2).

PERIOD/AGE		FORMATION	BASIN
Tertiary	Eocene	Bende/Ameki Formation	Niger Delta Basin
	Palaeocene	Imo Shale Group	
Cretaceous	Maastrichian - Palaeocene	Nsukka Formation	Anambra Basin
	Maastrichian	Ajali Formation Mamu Formation	
	Campanian - Maastrichian	Enugu/Nkporo /Owelli Formation	
	Santonian		

Major Unconformity

Figure 2: Stratigraphic sequence of the Anambra Basin.

Sample materials and analytical method

The samples were selected at regular interval of 10 m. The sample preparation was carried out following the international standard technique of maceration. Sixty-eight (68) core samples retrieved from 11 boreholes penetrating the Maastrichtian Mamu Formation in the Anambra Basin was used for this study (Fig. 3). The samples collected from the Upper Cretaceous units in the Anambra Basin include sandstones, siltstones, shales, silty shales with interbedded coal seams (Fig. 3).

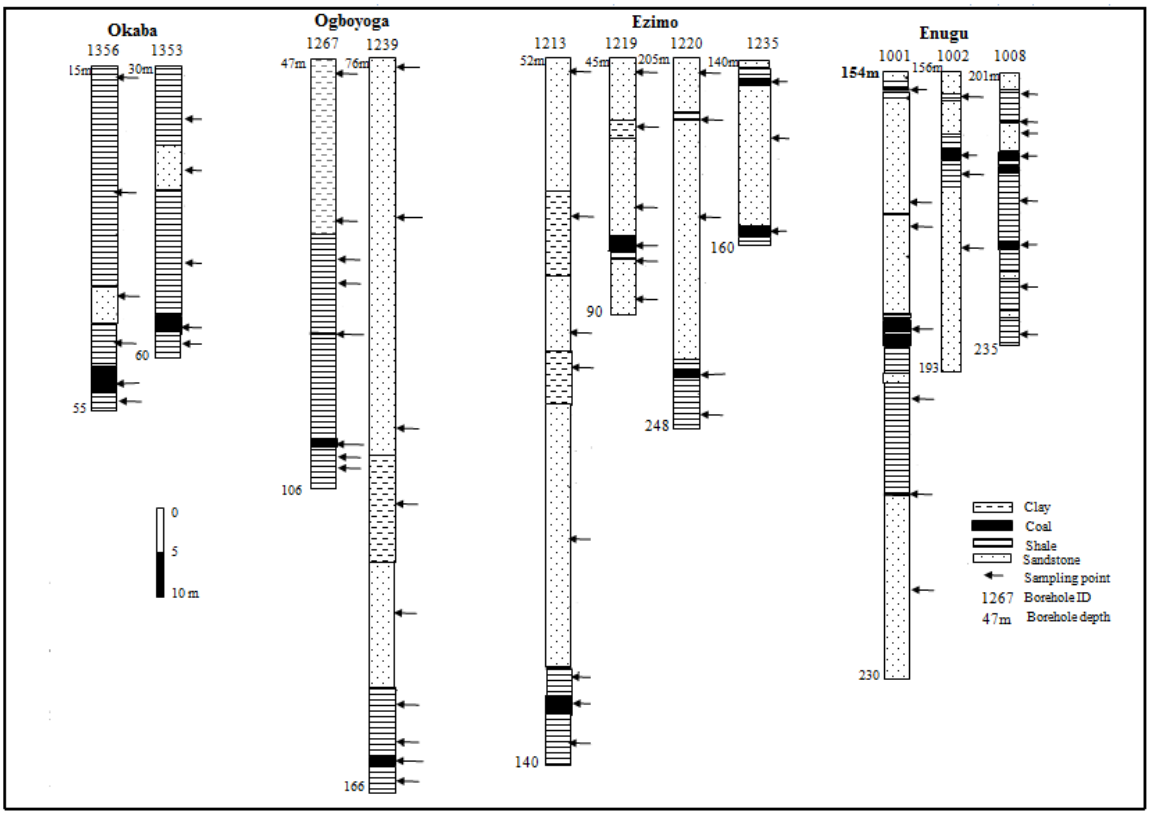

Figure 3: Lithologic logs of sampled boreholes.

The sandstones are white to light grey, fine to very fine grained, thinly laminated, and poor to well sorted in texture. The shales are light to dark grey in colour, moderately hard and fissile. The coal, shale and sandstone samples were crushed with the mortar and pestle because they are well indurated. Carbonate minerals were dissolved using dilute HCl acid and silicate minerals removed using HF acid. The organic residue was washed with cold nitric HNO_3 acid followed by a wash with KOH. The residues were sieved through a 10 µm mesh screen to remove small particles that would be unidentifiable in transmitted light microscopy. The recovered residues were mounted on glass slides and covered with cover-slips with the aid of Depex (DPX) mountant. Samples were examined at a minimum of 800X.

Palynostratigraphy

The sixty-eight (68) samples analyzed from different wells yielded rich to barren microflora. Pollen and spores recovered were compared with the work of Van Hoeken-Klinkenberg (1964, 1966), Jardine and Magloire (1965), Lawal (1982), Lawal and Moullade (1986), Edet and Nyong (1994) and Salard-Cheboldaeff (1991).

The stratigraphic depth ranges of the boreholes are shown in Figure 3 while a correlation panel of the studied boreholes showing facies variation is presented in Figure 4. Diagnostic microflora of BH-1001 was plotted against depth and lithostratigraphy (Fig. 5a).

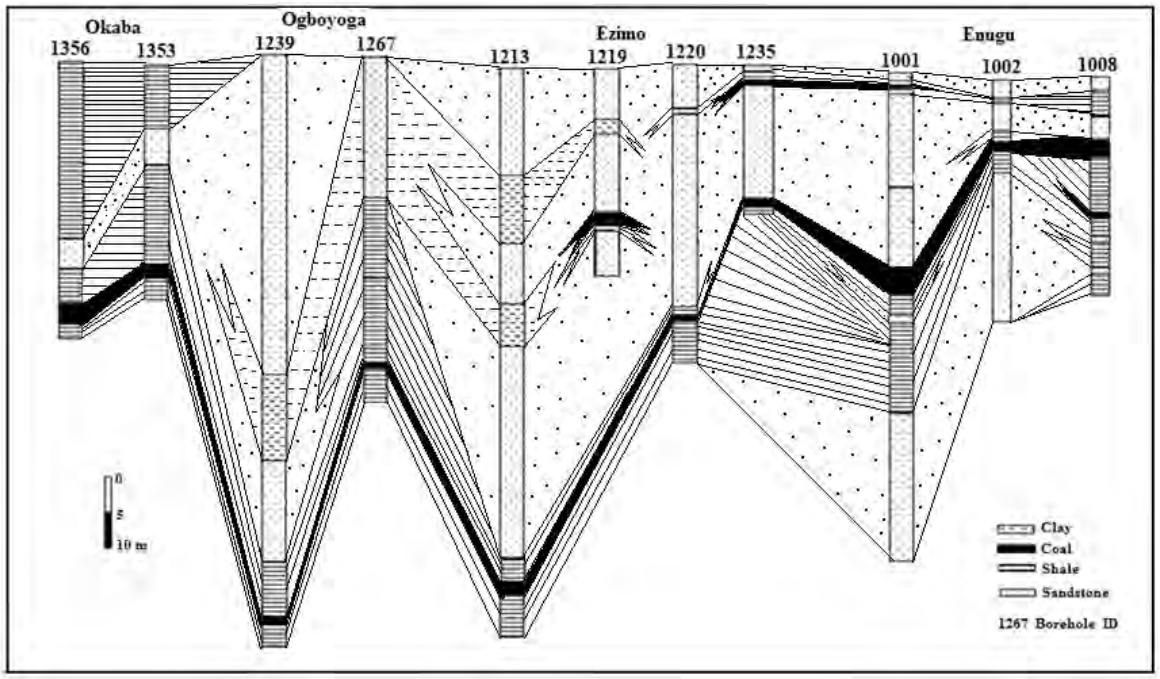

Figure 4: Correlation panel of the studied boreholes showing facies variation

FORMATION	DEPTH (m)	LEIOTRILETES SP	RETIMONOCOLPITES SP	ZLIVISPORITES BLANENSIS	MONOSULCITES	GEMMAZONOCOLPITES SP	PERIRETISYNCOLPITES SP	MONOSULCITES SP	CONSTRUCTIPOLLENITES	MONOCOLPITES	INAPERTUROPOLLENITES	LONGAPERTITES	TRICOLPOROPOLLENITES	LONGAPERTITES SP 3	MONOCOLPITES SP	AURICULIDITES SP	DISTAVERRUSPORITES SP	CYATHIDITES SP	PROXAPERTITES CURSUS	RETIDIPORITES	BUTTINIA ANDREEVI
MAMU	154-157	7	2	2	2	1	1	5	3	1	2	2	1	1							
	157	4	1										1		1						
	163-172	1			1			1				2				1					
	172					1		1									2				
	173-184	1	1					1			1						1	3	1		
	184-186																		1	1	1
	193-197		1							1					1						

Figure 5a: Palynological distribution chart of BH-1001.

The miospore recovered is very poor except the topmost interval (154-157 m) that shows relatively moderate frequency of pollen and spores. An informal zone of *Gemmazonocolpites sp* assemblage zone (Fig. 5b)

FORMATION	Depth (m)	Zonation	Characteristics	Age	Paleoenvironment
MAMU	154-157 157 163-172 172 173-184 184-186 193-197	*Gemmazonocolpites sp Assemblage Zone*	*Basal occurrence of Gemmazonocolpites sp, Distaverrusporite sp, Monocolpites marginatus and Retimonocolpites sp*	Late-Maastrichtian	Marginal marine

Figure 5b: Palynological zonation of BH-1001.

is established on the basis of the occurrence of *Gemmazonocolpites sp*. However, the palynomorph assemblage present is similar to the *Spinizonocolpites baculatus* assemblage zone of Lawal and Moullade (1986) also similar to the pollen recovered in the work of Edet and Nyong (1992) on the Nkporo shale. The entire interval studied belongs to a single palynological zone – *Gemmazonocolpites sp* assemblage zone equivalent to *Spinizonocolpites baculatus* assemblage zone of Lawal and Moullade (1986). It is characterized in this well by the occurrence of *Gemmazonocolpites sp* (Lawal and Moullade 1986), *Distaverrusporites simplex*, *Constructipollenites ineffectus*, *Longapertites marginatus, proxapertites cursus*, *Buttinia andreevii* and *Retidiporites magdalenensis*. Other important forms present are *Periretisyncolpites sp*, *Monosulcites sp*; *Zlivisporites blanensis*, *Monocolpites marginatus* and *Leiotriletes sp* (Plates 1, 2, 3, and 4). The striking marker form that characterizes this well is *Gemmazonocolpites sp*, present at intervals 172 m and 154-157 m, also reported by Lawal and Moullade (1986) in the Pindiga Formation. All other flora assemblages present are similar to those reported by Lawal (1982) for the Late Maastrichtian sediments but dated Maastrichtian by Van Hoeken –Klinkenberg (1964 and 1966), Jardine and Magloire (1965) and Edet and Nyong (1994). Thus, the Well-1001 belonging to Mamu Formation is here dated Late Maastrichtian.

BH-1002 has a thickness of about 37 m (Fig. 3). Pollen and spores recovery and diversity are moderate and well preserved (Fig. 6a). Palynomorphs with stratigraphic continuous occurrence are *Monosulcites sp*, *Retidiporites magdalenensis*, *Periretisyncolpites sp*, *Inaperturopollenites sp*, *Longapertites marginatus*, *Zlivisporites blanensis*, *Monoporites sp* and *Leiotriletes sp*. Other forms present are *Tetradites sp, Buttinia andreevii, Foveotriletes margaritae, Rugulatisporites caperatus, Retimonocolpites sp, Longapertites vaneendenburgi, Cingulatisporites ornatus,* and *Proxapertites cursus*. The miospore assemblages present in this well are similar to those observed in Well-1239. The zonation of BH-1002 is based on the established zones of Lawal and Moullade (1986). It was also compared with the work of Oloto (1987) on the sediments recovered from Gbekebo-1 well on the flank of the Niger Delta and the work of Edet and Nyong (1994) on the Nkporo Shale located on the Calabar Flank, Nigeria. Therefore one broad zone is suggested for BH-1002 – *Longapertites marginatus* Acme Zone (Fig. 6b). Few other forms are also similar to pollen grains observed by Salard-Cheboldaeff (1979) in Cameroon sediments. The assemblages of *Longapertites sp*, *Periretisyncolpites spp.*, *Retimonocolpites sp* were described from Abeokuta Formation, southwestern Nigeria, and in the Coal Measures of southeastern Nigeria; they belong to the Middle Maastrichtian sediments (Salard-Chebolfaeff, 1991). Similar palynoflora were described to have been found in the Iullemmenden Basin in the northwestern Nigeria (Boudoresque, 1980).The sediments of BH-1002 (193-156 m) of Mamu Formation is here dated Middle Maastrichtian on the basis of co-occurrence of *Longapertites spp*, *Periretisyncolpites* spp, *Retimonocolpites sp*, *Constructipollenites ineffectus* and *Foveotriletes margaritae*.

The stratigraphic interval of BH-1008 is 34 m in thickness (Fig. 3). The palynostratigraphy of the well is presented in Figure 7a. Two palynological zones are suggested based on the occurrence of marker fossils (Fig. 7b).

FORMATION	DEPTH (m)	CYTHIDITES SP	ZLIVISPORITES BLANENSIS	LOGAPERTITES MARGINATUS	MONOPORITES SP	MONOCOLPITES MARGINATUS	LEIOTRILETES SP	INAPERTUROPOLLENITES SP	PERIRETISYNCOLPITES SP	RETIDIPORITES MAGDALENENSIS	MONOSULCITES SP	RETIMONOCOLPITES SP	PROXAPERTITES SP	RETIMONOCOLPITES SP 2	LOGAPERTITES VANEENDENBURGI	AURICULIDITES SP 4	MONOCOLPITES SP	CINGULATISPORITES ORNATUS	MONOCOLPITES MARGINATUS	RUGULATISPORITES CUPERATUS	RETIMONOCOLPITES SP	FOVEOTRILETES MARGARITAE	TETRADITES SP	MONOSULCITES MAGNOSAGENATUS	CONSTRUCTIPOLLENITES INEFFECTUS	TRICOLPOROPOLLENITES SP	BUTTINIA ANDREEVI	PHELODINIUMBELONIENAE	ANDALUSIELLA SP	DINOFLAGELLATE CYST	SENEGALENIUM SP 2	BATIACASPHAERA SP	PALYNOMORPH ABUNDANCE	PALYNOMORPH DIVERSITY	TOTAL MOSPORE	TOTAL DINOFLAGELLATE	ALGAE
MAMU	156-159	1	2	1	1	1	5	2	1	2	1	3	1	1		1												1	1	2			27	15	24	3	0
	165-166				1		3	5	2	1	10				1	1	1	1													1	1		29	13	26	3	0
	166-167		4	2	1		5	7		1	6						2		2	1	1	1	1	1									36	15	36	0	0
	178-193	1	1	3		1	9	3	2		3	1					1		1		1				1	4	1	2			1	1	36	17	30	6	0

Figure 6a: Palynological distribution chart of BH-1002

FORMATION	Depth (m)	Zonation	Characteristics	Age	Paleoenvironment
MAMU	156-159 165-166 166-167 178-193	*Longapertites marginatus Acme Zone*	*Based on increased occurrence of Longapertites marginatus, Rugulatisporites caperatus, Foveotriletes margaritae, Retidiporites magdalenensis, Monoporites sp and Tetrad pollen.*	Middle Maastrichtian	Marginal marine

Figure 6b: Palynological zonation of BH-1002.

FORMATION	DEPTH (m)	LEIOTRILETES SP	TRIPORITES SP	ARAUCARICITES SP	INAPERTUROPOLLENITES SP	LONGAPERTITES MARGINATUS	MONOCOLPITES MARGINATUS	ZLIVISPORITES BLANENSIS	MONOCOLPITES SP	MONOSULCITES SP	ECHITRIPORITES TRIANGULIFORMIS	RETIMONOCOLPITES SP	RETIDIPORITES MAGDALENENSIS	DISTAVERRUSPORITES SIMPLEX	PERISYNCOLPITES SP	CINGULATISPORITES ORNATUS	CONSTRUCTIPOLLENITES INEFFECTUS	EPHEDRIPITES REGULARIS	RETIMONOCOLPITES SP 2	LONGAPERTITES SP	TRICOLPOROPOLLENITES SP	PROXAPERTITES SP	TRIPORITES CF IVERSENI	LONGAPERTITES VANEENDENBURGI	PERIRETISYNCOLPITES GIGANTEUS	TRIORITES AFRICAENSIS	SPINIZONOCOLPITES BACULATUS	TRICOLPITES SP	AQUILAPOLLENITES SP	TRIORITES SP	ISABELIDINIUM SP	BATIACASPHAERA SP	DINOFLAGELLATE CYST	SENEGALINIUM SP	FUNGAL SPORE	PALYNOMORPH ABUNDANCE	PALYNOMORPH DIVERSITY	TOTAL MIOSPORE	TOTAL DINOFLAGELLATE	ALGAE
MAMU	201-202	1	1	2	2		1	1																		1								2	11	8	9	0	2
	203				1				1																	1				1					4	4	3	1	0
	206-210	5		1	1																					1							1	8	4	7	0	1
	210-211	1			4		2	3		2	1	3	1	1	1	1															4			6	31	14	21	4	6
	214-220	3			1		4	2				2	1		2		2	1																	21	11	21	0	0
	220-221												BARREN																											
	228-230	9			9	19	2	5	2	5			3		4	1	2		8	6	2	2	1	1	3	1		2	1	1		2	1	1	9	115	33	102	4	9
	233-235	9			4	1	1	1				4	1						1					1	3				1						28	12	28	0	0

Figure 7a: Palynological distribution chart of BH-1008.

DEPTH(m)	FORMATION	ZONATION (After Lawal&Moullade, 1986)	New Zone (Modified after Lawal &Moullade, 1986)	CHARACTERISTICS	AGE	PALEO-ENVIRONMENT
201-202 203 208-210 210-211 214-220 220-221 228-230	MAMU	*Spinizonocolpites baculatus* Assemblage Zone	*Spinizonocolpites baculatus* Assemblage Zone	Characterized by continuous occurrence of spinizonocolpites baculatus, associated with Periretisyncolpites sp, Retidiporites magdalenensis, Cingulatisporites ornatus, Zlivisporites blanensis, Monocolpites marginatus and Constructipollenites ineffectus	Late Maastrichtian	Marginal marine
233-236			*Longapertites marginatus* Acme Zone	Characterized by maximum development of Longapertites marginatus.	Mid-Maasrichtian	

Figure 7b: Palynological zonation of BH-1008.

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 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* (Lawal, 1982), *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 (1986) referred to as *Spinizonocolpites baculatus* Assemblage Zone. Other associated forms present within this stratigraphic interval include *Echitriporites trianguliformis,* continuous occurrence of *Spinizonocolpites baculatus*, *Retimonocolpites sp*, *Zlivisporites blanensis, Distaverrusporites simplex, Contructipollenites ineffectus, Cingulatisporites ornatus and Periretisyncolpites sp*. Most of these forms present are similar to those described by Lawal, (1982), Lawal and Moullade (1986), and in Salard-Cheboldaeff, (1991); also correspond in part to *Proteacidites dehaani* zone established by Germeraad *et al*, (1968) for Tropical zones.

The palynostratigraphic interval of Well-1219 is 45 m thick (Fig. 3). The interval studied is almost barren of microfloral except the topmost unit 45-54 m (9 m thick). The barren intervals are predominantly sandstone and a single interval of coal characterized by very high concentration of opaque minerals which is suggested to indicate high grade thermal effect on the coal seam. The topmost fossiliferous interval is composed of diagnostic forms such as *Spinizonocolpites baculatus*, *Retimonocolpites sp* 2 and rare occurrence of *Longapertites marginatus.* Other associated forms include *Retimonocolpites sp,Monosulcites sp, Zlivisporites blanensis and Leiotrilete sp.* The stratigraphic interval is tentatively dated Late Maastrichtian (Fig. 8) on the basis of the occurrence of *Spinizonocolpites baculatus Retimonocolpites sp* 2 and paucity of *Longapertites marginatus.* This is correlated with the observation of Lawal and Moullade (1986).

FORMATION	Depth (m)	Zonation (After Lawal and Moullade, 1986)	Characteristics	Age	Paleoenvironment
MAMU	45-54	Spinizonocolpites baculatus zone	Based on the occurrence of Retimonocolpites sp, Monocolpites sp, Spinizonocolpites baculatus and Zlivisporites sp.	Maastrichtian	Marginal marine
	54-56				
	61-64				
	68-80				
	80-82				
	88-90				

Figure 8: Palynological zonation of BH-1219

The sequence of BH-1235 (20 m thick) varies from coal at the bottom through clay and sandstone units to coal seam at the top (Fig. 3). Palynomorphs recovery is very poor. Pollen and spores grains recovered include *Monocolpites marginatus, Monosulcites sp, Monocolpites sp, Leiotriletes sp, Inaperturopollenites sp,* and *Tricolporopollenites sp* (Fig. 9a). There is no striking marker species among the forms present. But the appearance of Monocolpites marginatus is indicative of Maastrichtian age (Lawal and Moullade, 1986). Therefore, the interval (20 m thick) analyzed for this well is here dated Maastrichtian age (Fig. 9b).

FORMATION	DEPTH (m)	INAPERTUROPOLLENITES SP	MONOSULCITES SP	MONOCOLPITES SP	TRICOLPOROPOLLENITES SP	MONOCOLPITES MARGINATUS	LEIOTRILETES SP	FUNGAL SPORE	POLYNOMORHP ABUNDANCE	PALYNOMORPH DIVERSITY	TOTAL MIOSPORE	TOTAL DINOFLAGELLATE	ALGAE
MAMU	140-141	1	1	1	1			2	6	5	4	0	2
	141-144			BARREN									
	159-160			1		1	3		6	4	6	0	0

Figure 9a: Palynological distribution chart of BH-1235.

MAMU FORMATION	Depth (m)	Zonation After Lawal & Moullade (1986)	Characteristics	Age	Paleoenvironment
	140-141	? Spinizonocolpites baculatus zone	Based on the occurrence of Monocolpites marginatus, Leiotriletes sp, Inapertropollenites sp, Monosulcites sp and Tricolporopollenites sp.	Maastrichtian	Fluvial
	141-144				
	159-160				

Figure 9b: Palynological zonation of BH-1235.

The stratigraphic intervals analyzed for palynological information in BH-1220 (43 m thick) is barren except the topmost interval that contains few miospores (Fig. 3). The interval (244-248 m) is composed of forms such as *Constructipollenites ineffectus*, *Distaverrusporites sp*, *Inaperturopollenites sp* and *Leiotriletes sp* (Fig. 10a). The two diagnostic species, *Constructipollenites ineffectus* and *Distaverrusporites sp* are marker forms (Fig. 10b) for Maastrichtian sediments (Van Hoeken-Klinkenberg, 1964, 1966; Lawal and Moullade, 1986; Edet and Nyong, 1994).

FORMATION	DEPTH (m)	CONSTRUCTIPOLLENITES NEFFECTUS	DISTAVERRUSPORITES SP	INAPERTUROPOLLENITES SP	LEIOTRILETES SP	FUNGAL SPORE	PALYNOMORPH ABUNDANCE	PALYNOMORPH DIVERSITY	TOTAL MIOSPORE	TOTAL DINOFLAGELLATE	ALGAE
MAMU	205-206				BARREN						
	212-213				BARREN						
	213-227				BARREN						
	229-240				BARREN						
	244-248	1	1	1	2	2	7	5	5	0	2

Figure 10a: Palynological distribution chart of BH-1220

FORMATION	Depth (m)	Zonation (After Lawal and Moullade, 1986)	Characteristics	Age	Paleoenvironment
MAMU	205-206	Spinizonocolpites baculatus zone	Based on the presence of constructipollenites ineffectus, Distaverrusporites sp and Inapperturopollenites sp	Maastrichtian	Marginal marine
	212-213				
	213-227				
	229-240				
	244-248				

Figure 10b: Palynological zonation of BH-1220

BH-1213 has a stratigraphic interval range between 140-52 m (Fig. 3). It is composed of intercalation of sand and shale with coal interbed at interval 134-132 m located at the lower part, while the upper part is composed mainly of whitish to light brown fine grained, laminated sandstone, with intercalated whitish to light brown claystone. Palynomorph recovery has a linear relationship with the facies type present in the well. Thus, the lower part that is characterized by dark grey shale and thin coal bed also contain substantial quantity of pollen and spores while the upper part is defined by barren sandy facies (Fig. 11a). The entire well section belongs to the *Spinizonocolpites baculatus* Assemblage Zone II established after Lawal and Moullade (1986) dated Late Maastrichtian. The interval is characterized at the base where the analysis commenced by the appearance of marker fossils such as *Spinizonocolpites bacculatus*, *Rugulatisporites cuperatus*, *Longapertites marginatus*, *Distaverrusporites simplex*, *Retidiporites magdalenensis*, *Zlivisporites blanensis* and *Monocolpites marginatus*. The basis of dating the base of the interval is based on the occurrence of strikingly important grains such as *Constructipollenites, Spinizonocolpites bacculatus* and a few continuous appearance *Longapertites marginatus* (Fig. 11b). The middle part of the stratigraphic section is characterized by the assemblages of *Gemmamonocolpites sp*, *Foveotriletes margaritae*, *Proxapertites cursus*, *Monocolpites marginatus*, *Buttinia andreevii*, *Constructipollenites* ineffectus, *Periretisyncolpites giganteus*, *Periretisyncolpites sp*, and relatively high frequency of *Monosulcites sp*. The assemblages of these forms are similar to those described for Late Maastrichtian sediments by Lawal and Moullade (1986).

BH-1356 has short stratigraphic section (Fig. 3). It has a depth interval of 40 m thick. It is characterized by intercalation of sand and shale; but the near basal part has an interbed of coal seam of about 3 m thick. The shale facies are dark grey, indurate and fissile; while the sandstone units are dark to light grey, fine grained, laminated and well sorted (Fig. 3). The interval 55-15 m is characterized by paucity of miospores. The basal interval analysed is barren of pollen and spores, while the overlying coal bed has poor recovery of palynomorphs, but defined by the appearance of *Tricolpites gigantoreticulatus*, *Zlivisporites blanensis*, and trilete spores. At 40 m horizon, there is a slight increase in appearance of pollen and spores in the sandstone bed. The diagnostic marker forms present are *Constructipollenites ineffectus*, *Rugulatisporites caperatus*, *Retidiporites magdalenensis*, *Periretisyncolpites sp*, *Proxapertites cursus*, *Periretisyncolpites giganteus*, *Monocolpites marginatus*, and *Cingulatisporites ornatus*. Other species present are *Zlivisporites blanensis*, *Distavurrusporites simplex*, *Aquilapollenites alveolatus*, *Milfordia sp*.3, and *Foveotriletes margaritae* (Fig. 12a). The forms present in this stratigraphic level are Late Maastrichtian in age because they are similar to the palynomorph assemblage described by Lawal and Moullade (1986), and Salard- Cheboldaeff (1991). However, the zone marker- *Spinizonocolpites echinatus* of (*Spinizonocolpites baculatus / echinatus* Assemblage Zone) is present at interval 36-15 m (Fig. 12b)

.

FORMATION	MAMU							
Depth (m)	52-68	68-78	86-92	104-110	126	126-129	132-134	134-135
LEIOTRILETES SP	BARREN	BARREN	BARREN	BARREN	7		BARREN	
RETIMONOCOLPITES SP	BARREN	BARREN	BARREN	BARREN	2		BARREN	
LOGAPERTITES MARGINATUS	BARREN	BARREN	BARREN	BARREN	3	1	BARREN	2
DISTAVERRUSPORITES SP	BARREN	BARREN	BARREN	BARREN	2		BARREN	1
GEMMAMONOCOLPITES SP	BARREN	BARREN	BARREN	BARREN	1		BARREN	
FOVEOTRILETES MARGARITAE	BARREN	BARREN	BARREN	BARREN	1	1	BARREN	
RETIDIPORITES MAGDALENENSIS	BARREN	BARREN	BARREN	BARREN	2		BARREN	2
PROXAPERTITES OPERCULATUS	BARREN	BARREN		BARREN	1		BARREN	
EPHEDRIPITES MULTICOSTATUS						1		
MONOCOLPITES MARGINATUS						8		
LEIOTRILETES SP						10		
RETIMONOCOLPITES SP						2		
MONOSULCITES SP						9		4
TRICOLPOROPOLLENITES SP SCL 215						2		
BUTTINIA ANDREEVI						3		
CONSRTUTIPOLLENITES INEFFECTUS						1		
INAPERTUROPOLLENITES SP						3		2
PERIRETISYNCOLPITES GIGANTEUS						2		
MONOSULCITES MAGNOSAGENATUS						1		
CYATHIDITES SP						1		
CICATRICOSISPORITES VENUSTUS						1		
PERIRETISYNCOLPITES SP						1		
PROXAPERTITES CURSUS						1		
MONOCOLPITES MARGINATUS								4
TETRADITES SP								2
ZLIVISPORITES BLANENSIS								1
TRICOLPIPITES SP 1								1
SPINIZONOCOLPITES BACULATUS								2
TRICOLPOROPOLLENITES SP SCL 215								2
TRICOLPITES SP								2
RUGULATISPORITES CUPERATUS								1
MONOCOLPITES								2
ILEXPOLLENITES CHMARIE								1
PHELODINIUMBELONUENAE								2
FUNGAL SPORE								1
PALYNOMORPH ABUNDANCE					19	48		40
PALYNOMORPH DIVERSITY					8	17		20
TOTAL MIOSPORE					19	48		36
TOTAL DINOFLAGELLATE					0	0		3
ALGAE					0	0		1

Figure 11a: Palynological distribution chart of BH-1213

	Depth (m)	Zonation	Characteristics	Age	Paleoenvironment
MAMU FORMATION	52-68	*Longapertites marginatus Acme Zone*	*Well development of Longapertites marginatus*	Middle – Maastrichtian	Brackish
	68-78				
	86-92				
	104-110				
	126				
	126-129	*Buttinia andreevi Assemblage Zone*	*Characterized by Buttinia andreevi, Foveotriletes magaritae, Periretisyncolpites spp, Proxapertites cursus, Monosulcites magnosagentus and Tricolporopollenites sp*	Early – Maastrichtian	Marginal marine
	132-134				
	134-135				

Figure 11b: Palynological zonation of BH-1213.

FORMATION	Depth (m)	LEIOTRILETES SP	MONOSULCITES SP	CONTRUCTIPOLLENITES	RUGULATISPORITES CUPERATUS	RETIMONOCOLPITES SP	MILFORDIA SP	RETIDIPORITES MAGDALENENSIS	TRICOLPITES SP	LONGAPERTITES SP 3	PERIRETISYNCOLPITES SP	LOGAPERTITES SP	PROXAPERTITES CURSUS	PERIRETISYNCOLPITES	INAPERTUROPOLLENITES SP	VERRUCATOTRILETES BULLATUS	PERIRETISYNCOLPITES GIGANTEUS	SPINIZONOCOLPITES ECHINATES	MONOCOLPITES MARGINATUS	RETIMONOCOLPITES SP 3	RETIMONOCOLPITES SP 1	LOGAPERTITES MARGINATUS	RETIMONOCOLPITES SP 2	CF CUPANIDITES SP	CYATHIDITES SP	MAURITIDITES CRASSIBACULATUS	CINGULATISPORITES ORNATUS	ZLIVISPORITES BLANENSIS	TRICOLPOROPOLLENITES SP	DISTAVURRUSPORITES SP	AQUILAPOLLENITES ALVEOLATUS	MILFORDIA SP 3	ARAUCARICITES SP	TRICOLPITES	FOVEOTRILETES MARGARITAE	EPHEDRIPITES SP	TETRADITES SP	DINOFLAGELLATE CYST	PALYNOMORPH ABUNDANCE	PALYNOMORPH DIVERSITY	TOTAL MOSPORE	TOTAL DINOFLAGELLATE	ALGAE
MAMU	15-25	5	3	1	1	4	1	4	1	1	1	1	1	1	1	1	2	1																							32	19	32	0	0
	25-36	7	3			1		1			1			2	3		1	1	7	1	1	3	4	1	1	1														38	17	38	0	0
	36-38		1			1					1								1			2																6	6	6	0	0
	40	13	4	1	3	3		1			2		2		2		3		10						1		4	4	3	1	1	1	1	1		1	1	1	2	65	23	63	2	0
	50-53	2																										1						1				4	3	4	0	0
	53-55												BARREN																									BARREN				

Figure 12a: Palynological distribution chart of BH-1356.

FM	Depth (m)	Zonation	Characteristics	Age	Paleoenvironment
MAMU FORMATION	15-25	*Spinizonocolpites baculatus Assemblage zone*	Characterized by the appearance of *Spinizonoclpites echinatus, Mauritiidites crassibaculatus and Periretisyncolpites spp.*	Mid-Maastrichtian	Marginal marine
	25-36				
	36-38	Longapertites marginatus Acme Zone	On the basis of stratigraphic position and occurrence of *Longapertites marginatus*	Mid-Maastrichtian	Brackish
	40	*Cingulatisporites ornatus Assemblage zone*	Basal occurrence of *Cingulatisporites ornatus, Aquilatisporites alveolatus, Foveolatus margaritae, Periretisyncolpites giganteus and Retidiporites magdalenensis*	Early-Maastrichtian	Marginal marine
	50-53				
	53-55				

Figure 12b: Palynological zonation of BH-1356.

Other important miospores present in this interval (36-15 m) are *Monocolpites marginatus*, *Longapertites marginatus*, *Periretisyncolpites giganteus*, *Proxapertites cursus*, *Periretisyncolpites sp*, *Retidiporites magdalenensis*, *Consructipollenites ineffectus*, *Rugulatisporites caperatus*, *Leiotriletes sp*, and *Monosulcites sp* (Plates 1, 2, 3 and 4).

Verrucatotriletes bullatus was first described by Van Hoeken-Klinkenberg (1964) during his palynological investigation of some Upper Cretaceous sediments in Nigeria. In particular, the V. bullatus was first seen in the Maastrichtian, Lower Coal Measures of a borehole in Enugu. This same species was only encountered once in BH-1356 amongst the eleven wells analyzed. However, its strong association with marker species such as Constructipollenites ineffectus, Spinizonocolpites echinatus, Periretisyncolpites spp, Rugulatisporites caperatus and Milfordia sp are all indicative of Late-Maastrichtian age. Almost all the important assemblage species mentioned by Salard (1990) for characterizing Upper-Maastrichtian sediments were observed in BH-1356. However, BH-1356 gives a clear picture of a chronostratigraphic sequence that ranges from Early-Maastrichtian at the base, through fairly developed Middle-Maastrichtian characterized by Acme development of Longapertites marginatus at the mid-section of the well to an Upper-Maastrichtian assemblage zone at the upper part of the well.

BH-1353 is 30 m thick (Fig. 3). It is composed of intercalation of sand and shale. The sand facies is light grey in colour, fine grained and thinly laminated, while the shale sequence is dark grey in colour, moderately hard and fissile in nature. They are interbedded at the bottom by a coal seam between intervals 57-55 m. Palynomorph assemblages recovered in this well are characteristic of Maastrichtian sediments described by Van Hoeken- Klinkenberg (1966), Lawal, (1982), Lawal and Moullade, (1986), Salard-Cheboldaeff, (1991), Edet and Nyong (1994). The diagnostic forms present are *Periretisyncolpites sp*, *P. giganteus*, *Retimonocolpites sp*, *Longapertites marginatus*, *Monocolpites marginatus*, *Constructipollenites ineffectus*, *Tetradites sp*, *Monosulcites sp*, *Leiotriletes sp*, *Inaperturopollenites sp* and *Rugulatisporites caperatus* (Fig. 13a). The microfloral content of this stratigraphic section is compared to other established studied Wells (1239 and 1002). They were found to correlate both on the basis of lithofacies and palynofacies contents. Therefore, the Well-1353 is conveniently dated Early Maastrichtian age (Fig. 13b). Well-1239 is 90 m thick, characterized by intercalation of sand and shale with coal seam at the near base (Fig. 3). The base of the Well is marked by the appearance of diagnostic miospores such as *Retidiporites magdalenensis, Constructipollenites ineffectus, Distaverrusporites simplex, Triporate pollen, Verrucatosporites sp, Longapertites vaneendenburgi, Tetradites sp, and Monocolpites marginatus.* Other forms present at the (166-163 m) are *Proteacidites sp*, smooth trilete spore, *Zlivisporites blanensis* and relative occurrence of *Monosulcites* (Fig. 14a). This assemblage of pollen and spores is similar to those reported by Van Hoeken-Klinkenberg, (1964, 1966) for the Upper Cretaceous pollen recovered in the Mamu Coal Measures. The overlying strata (163-76 m) contain similar lesser diversity but with few new pollen and spores appearance such as *Syncolporites marginatus*, *Periretisyncolpites giganteus* and *Priteacidites sp* 4. The new forms and those described for the basal bed have been described in sediments of Upper Maastrichtian sediments (Van der Hammen, 1954; Van der Hammen and Wijmstra, 1964). In the works of Jardine and Magloire (1965), and Germeraad *et al* (1968), a number of these forms were reported in Maastrichtian sediments. The forms are well emphasized in the research work of Jan du Chene (1977); Jan du Chene *et al* (1978a, 1978b); Salami (1990); Lawal (1982); Lawal and Moullade (1986); and Edet and Nyong (1994). These assemblages are particularly similar to *Spinizonocolpites baculatus* Assemblage Zone VI of Lawal and Moullade (1986) dated Upper Maastrichtian (Fig. 14b).

FORMATION	Depth (m)	LEIOTRILETES SP	MONOSULCITES SP	INAPERTUROPOLLENTES SP	PERIRETISYNCOLPITES SP	TETRADITES SP	MONOSULCITES MAGNOSAGENATUS	RETIMONOCOLPITES SP	RUGULATISPORITES SP	LONGAPERTITES MARGINATUS	PERIRETISYNCOLPITES GIGANTEUS	TRICOLPITES SP	MONOCOLPITES MARGINATUS	CONSTRUCTIPOLLENITES INEFFECTUS	BACUTRIPORITES URIVENSIS	DINOFLAGELLATE CYST	ANDALUSIELLA MAUTHEI	ANDALUSIELLA LAEVIGATA	ANDALUSIELLA SP	ANDALUSIELLA POLYMORPHA	PHELODINIUM BELONUENAE	PHELODINIUM SP	SPINIFERITES SP	FUNGAL SPORE	PALYNOMORPH ABUNDANCE	PALYNOMORPH DIVERSITY	TOTALMOSPORE	TOTAL DINOFLAGELLATE	ALGAE
MAMU	30-34			NO SAMPLE																									
	43-39			BARREN																									
	53-55	2	3	2	1	1	1	1	1	1	1					2	1	1	2	1	1			1	23	17	14	8	1
	57-60	6	4	1							2	1	1	1	1	1		1		1		1	2		26	16	20	6	

Figure 13a: Palynological distribution chart of BH-1353.

MAMU FORMATION	Depth (m)	Zonation	Characteristics	Age	Paleoenvironment
	30-34	*Andalusiella sp Assemblage zone*	Based on the continuous occurrence of *Andalusiella sp* and other *peridinoids*	Early Maastrichtian	Lacustrine to Marine
	39-43				
	53-55				
	57-60				

Figure 13b: Palynological zonation of BH-1353.

FORMATION	DEPTH (M)	PROTEACIDITES SP	GLEICHENIDITES SP	CYATHIDITES SP	LEIOTRILETES SP	TRICOLPOROPOLLENITES SP	CONSTRUCTIPOLLENITES INEFFECTUS	ZLIVISPORITES BLANENSIS	MONOSULCITES SP	SYNCOLPORITES SP	PERIRETISYNCOLPITES GIGANTUS	FOVEOTRILETES MARGARITAE	INAPERTUROPOLLENITES SP	MONOCOLPITES MARGINATUS	TRICOLPITES GIGANTORETICULATUS	MONOCOLPITES SP 4	RETIDIPORITES MAGDALENENSIS	MONOCOLPITES SP	PROTEACIDITES SP 4	TETRADITES SP	LOGARPERTITES VANEENDENBURG	TRIORITES SP	VERRUCOSISPORITES SP	TRICOLPITES SP	TRIPORITES SP	DISTAVERRUSPORITES SIMPLEX	DINOFLAGELLATE CYST	FUNGAL SPORE	PALYNOMORPH ABUNDANCE	PALYNOMORPH DIVERSITY	TOTAL MIOSPORE	TOTAL DINOFLAGELLATE	ALGAE
MAMU	76-107					BARREN																											
	107-119	1																											1	1	1	0	0
	119-127	1																											1	1	1	0	0
	127-139		1																										1	1	1	0	0
	142-143					BARREN																											
	154-156			2	17	1	3	1	2	1	1																	3	31	9	27	4	0
	156-160			1	24	1		1	2			1	1	6	2	1	1	1										1	48	14	47	0	1
	162-163				1		1		1				1						1										5	4	5	0	0
	163-166	2	1	2	6	3	5	2	7			2	3	2			2	1		1	1	1	2	1	1	2	1		50	24	49	1	0

Figure 14a: Palynological distribution chart of BH-1239.

	Depth (m)	Zonation (After Lawal and Moullade, 1986)	Characteristics	Age	Paleoenvironment
MAMU FORMATION	76-107 107-119 119-127 127-139 142-143 154-156 156-160 162-163 163-166	Spinizonocolpites baculatus Assemblage Zone	*Based on the frequency of Constructipollenites ineffectus, Periretisyncolpites spp, and Zlivisporites blanensis*	Late-Maastrichtian	Marginal marine

Figure 14b: Palynological zonation of BH-1239.

The Well-1267 distribution chart and palynological zonation are presented in Figures 15a and 15b respectively. Palynomorph abundance and diversity are relatively moderate. The well is 59 m thick (Fig. 3). The assemblages of flora recovered contain some diagnostic age forms. The base of the Well where analysis commenced (106-104 m) to about the top of the stratigraphic interval considered for this well at interval (76-75m) is moderately rich in floral recovery. Forms that appeared at the base in this well include *Syncolporites marginatus*, *Spinizonocolpites sp*, *Triorites sp*, *Constructipollenites ineffectus*, *Periretisyncolpites giganteus*, *Monocolpites sp*, *Monocolpites marginatus*, and *Ephedripites sp*. The appearance of these grains conforms to the *Spinizonocolpites baculatus* Assemblage Zone VI of Lawal and Moullade (1986). The middle part of the well is quite relatively diverse and abundant in microflora. Some forms show a fairly continuous occurrence such as *Constructipollenites ineffectus*, *Cingulatisporites ornatus*, *Monosulcites sp*, *Monocolpites marginatus*, *Leiotriletes sp*, *Proxapertites cursus*, *Buttinia andereevii*, *Periretisyncolpites sp*, and *Inaperturopollenites sp* (101-75m) in Figure 15a. Few forms show a relatively maximum development such as *Inaperturopollenites* and *Leiotriletes sp*. Pollen and spores with sporadic occurrence include *Pereretisyncolpites giganteus* and *Monocolpites sp*. Other important pollen and spores that occur in this stratigraphic interval (100-75 m) are *Tricolpites sp*, *Longapertites marginatus*, *Milfordia sp2*, *Retitricolpites sp.* This interval is also marked by the appearance of ferns such as *Zlivisporites blanensis*, *Foveotriletes margaritae*, *Verrucatosporites sp*; they are characterized by a relatively high frequency of pollen and spore abundance and diversity. This surface can be referred to as maximum flooding surface (MFS) where there was a maximum incursion of marine shoreline onto the land, referred to as transgression. The occurrence of dinoflagellate cysts such as *Batiacasphaera sp, Senegalinium sp, Andalusiella* polymorpha suggests that the sediments were deposited in a marine setting, except the coal seam that was deposited in a brackish environment. This period further signifies that the marine transgression led to the deposition of the lithofacies present at the basal part of Mamu Formation during the Middle Maastrichtian time (Ogala *et al*., 2009). It is also noticed that this period was followed by regressive phase when the marine water recedes, leading to the interplay of fluvial processes and pockets of marine water left behind forming deposition of coal seams in the brackish environment.

4.2 Depositional Palaeoenvironment

Eleven boreholes were analyzed for palynological content. The sporomorphs contained vary in frequency from depth to depth and from borehole to borehole. Some boreholes contain diagnostic age forms that depict their environment of deposition while deductions were also made based on the stratigraphic position and lithological content of the intervals.

BH-1356 ranges in depth from 15-55 m (Fig. 3). The upper (21 m thick) and lower (15 m thick) parts vary from coastal to marginal marine environments. The intervals are characterized by sporomorphs and rare dinoflagellate cysts at the lower interval (40-55 m). The environmentally diagnostic pollen and spore grains that define the intervals are *Proxapertites cursus*, *Leiotriletes* sp and *Spinozonocolpites* sp. However, at depth 40 m, two forms of dinoflagellate cysts were recovered (Fig. 12a). Thus, the main group of sporomorphs found is *Nypa* pollen (*Spinizonocolpites echinatus*), Palmae pollen such as *Retitriporites* and *Proxapertites cursus*. They are all indicative of brackish environment (Fredricksen, 1985). The *Nypa* pollen type *(Spinizonocolpites*) that characterize the basis of the zone and age dating of the sediments seems to be very important in determining the paleoenvironment of the sediment within the interval under consideration. *Nypa* is a branched, creeping, prostrate palm of brackish to salt water environment. Muller (1968) described it to have a low pollen productivity which might be responsible for rare recovery of *Spinizonocolpites echinatus* in this well. Also, it has been found that the interval 36-38 m is coaly in nature; contain no *Nypa* pollen which may support the assertion of Fredricksen (1985) that *Nypa* pollen are sparse in coal or marine rocks. Therefore, they are not constituent of peat- forming swamps. *Proxapertites* (Van der Hammen, 1954) was considered to have a probable affinity with *Astrocaryum* (palmae). However, Muller (1968) showed that on both morphological and biogeographic grounds, *Proxapertites* hardly has affinity with this genus; rather *Proxapertites* has close morphological similarity with *Nypa*. It can be concluded that it is probably related to *Nypa*. Muller (1968) and Germaraad et al., (1968) showed that *Proxapertites* has Pantropical distribution similar to that of *Nypa* pollen. Therefore, Muller (1968) suggested their concentration in deltaic to shallow marine sediments. It is on this premise that the presence of *Proxapertites* in samples analyzed could suggest marginal marine (Fig. 12b). The coal interval (36-38 m) is composed of *Monosulcites sp*, *Retimonocolpites sp*, *Periretisyncolpites sp*, *Monocolpites marginatus* and *Longapertites margintus*. Presently, it cannot be determined which of the recovered sporomorph are anephilous and zoophilous pollen. But the formation of the coal could be interplay of the salt marine water and fresh waters in a lacustrine to brackish environments (Ogala et al., 2009).

BH-1001 (Fig. 3) does not contain environmentally diagnostic forms such as the *Nypa*. But *Proxapertites cursus* grains are found at two different intervals 173-184 m and 184-186 m (Fig. 5a). Its presence at these levels could suggest a brackish environment in a deltaic setting. Thus, the entire interval 154-197 m of BH-1001 is

depositional environment (Fig. 5b).

BH-1267 ranges in interval from 47-106 m (Fig. 3). The interval has a thin coal bed at 100-101 m. The stratigraphic interval contains few environmentally significant marker forms such as *Triorites sp* (15a) *which* is indicative of brackish environment (Fredricksen, 1985).

Other forms present such as *Milfordia* pollen at interval 99-100 m could indicate a tidal marsh environment (Fredricksen, 1985). Other environmentally important marker forms are *Triporites* and *Proxapertites* group and monocotyledonous group which are found at various depth of the borehole. The presence of Maastrichtian markers such as *Cingulatisporites ornatus, Buttinia andreevi, Retidiporites magdalenensis, Monocolpites marginatus, Longapertites vaneendenburgi, Proxapertites cursus, Auriculiidites sp* and *dinoflagellates cysts* such as *Batiacasphaera sp, Senegalinium sp and Andalusiella* polymorpha are indicative of brackish to shallow marine environments. Therefore, interval (47-106 m) is assigned a brackish to shoreline environment (Fig. 15b

FORMATION	Depth (m)	TRIPORITES SP	EPHEDRIPITES MULTICOSTATUS	PROTEACIDITES SP 5	INAPERTUROPOLLENITES SP	MONOCOLPOPOLLENITES SP	TRICOLPOROPOLLENITES SP SCL	CYATHIDITES SP	INAPERTUROPOLLENITES SP 3	RETIDIPORITES MAGDALENENSIS	TRIORITES AFRICAENSIS	TRICOPITES SP	VERRUCATOSPORITES SP	ARAUCARICITES SP	LEIOTRILETES SP	LOGAPERTITES VANEENDENBURGI	MONOCOLPITES MARGINATUS	BUTTINIA ANDREEVI	MONOSULCITES SP	TRICOLPOROPOLLENITES SP	MONOCOLPITES SP	GLEICHENIDITES SENONICUS	PROXAPERTITES CURSUS	BACUTRIPORITES SP	PERIRETISYNCOLPITES SP	MONOPORITES SP	RETITRICOLPITES SP	CINGULATISPORITES ORNATUS	PERIRETISYNCOLPITES GIGANTEUS	FOVEOTRILETES MARGARITAE	CONSTRUCTIPOLLENITES	AURICULIDITES SP	MILFORDIA SP 2	LOGAPERTITES MARGINATUS	ZLIVISPORITES BLANENSIS	SYNCOLPORITES SBTILIS	TRICOLPOROPOLLENITES SCL 428	TRIPORITES CF INVERSENI	RETITRICOLPITES SP 1	SYNCOLPORITES MARGINATUS	TRICOLPITES SP1	TRICOLPOROPOLLENITES SP S141	TRIORITES SP	BATIACASPHAERA SP	SPINIDINIUMSP	SENEGALINIUMSP	ANDALUSIELLA POLYMORPHA	FUNGAL SPORE	PALYNOMORPH ABUNDANCE	PALYNOMORPH DIVERSITY	TOTAL MIOSPORE	TOTAL DINOFLAGELLATE	ALGAE
MAMU	47-61	1	1																																												2	2	2	0	0
	61-75			1																																												1	1	1	0	0
	75-76		1		5	6	8	4	1	1	1	2	2	3	1	1	1	1	2																									3	1	1	1	28	81	24	48	5	28
	86-87								6						1		3	1	1	1																												5	18	7	13	0	5
	91-99				10	1		3							23		2		5	2	5	4	1	1	1	1	1	1																			3	64	17	60	1	3
	99-100				2					1					3		4		2		3	1	1		1			2	4	2	1	1	3	1	2												35	19	35	0	0
	100-101														1				2										1		2					1	1										9	7	9	0	0
	104-106		1												1		1		1	1	1	1								1		2						1	1	1							18	16	18	0	0

Figure 15a: Palynological distribution chart of BH-1267.

FM	Depth (m)	Zonation (After Lawal and Moullade, 1986)	Characteristics	Age	Paleoenvironment
MAMU FORMATION	47-61 61-75 75-76 86-87 91-99 99-100 100-101 104-106	*Longapertites sp 3 Assemblage Zone*	*Characterized by Syncolporites marginatus, Triorites sp cf Inverseni, Ephedripites multicostatus, Gleichenidites senonicus, Tricolporopollenites scl 428 Top is defined by Buttinia andreevi, Cingulatisporites ornatus, Foveotriletes margaritae and Auriculidites sp*	Campanian –Early Maastrichtian	Continental to Marginal marine

Figure 15b: Palynological zonation of BH-1267.

The BH-1008 has a thickness of about 34 m (Fig. 3). It is fairly rich in palynomorphs, and dinoflagellate cysts (algae). The interval is characterized by dark to light grey, fissile shale at the top, while the coal beds intercalated the sand and shale facies down to the base of the stratigraphic section analyzed. Interval 201-202 m is marked by *Triporites sp*, trilete spore, and *monocotyledonous* forms such as *Verrucatosporites sp, Laevigatosporites sp, Monocolpites sp. 4, Monocolpites marginatus* with few fungal spores (Fig. 7a). The presence of these sporomorphs indicates an environment characterized by admixture of salt water and fresh water. Interval 206-220 m (14 m thick) is composed of diagnostic environmental forms such as *Triporites* sp*, Monocolpites* sp*, Echitriporites trianguliformis* (Van Hoeken- Klinkenberg, 1964, 1966), *Leiotriletes* sp, and dinoflagellate cysts such as *Isabelidinium* sp*, Batiacasphaera* sp and fungal spore. The presence of *Echitriporites trianguliformis* as described by Germeraad et al (1968) shows that its botanical affinity is unknown. Thus, the interval is assigned a fluviomarine environment. Interval 220-235 m (15 m thick) is defined by *Leiotriletes sp,* Monocolpate pollen, *Proxapertites sp; Triporites cf. iverseni, Triorites africaensis*, *Batiacasphaera* sp*,* and *Senegalinium* sp, and moderate abundance of fungal spore. Fredricksen (1985) reported that the presence of *Triorites* group which are palmae indicates restriction to brackish environment. Other planktons present such as *Batiacasphaera sp*, *Senegalinium sp*, and dinoflagellate cysts are indicative of shallow marine environment (Schrank, 1984). Therefore, the entire interval of the well varies from fluviomarine through brackish to shoreface environments (Fig. 7b).

BH-1213 has the same lithological characteristics as BH-1008; the well ranges from 52-135 m (83 m thick) (Fig. 3). The upper part is barren (58 m thick). Interval 126-135 m (6 m thick) is composed of *Leiotriletes sp, Proxapertites* group, *Spinizonocolpites baculatus* and fungal spore (Fig. 11a). The presence of this group of grains is depictive of brackish to marginal marine environment (Fig. 11b).

In BH-1002 (Fig. 3), the main marker forms for paleoenvironmental delineation are *Proxapertites* group described to indicate lacustrine environment (Fredricksen, 1985). Other sporomorphs present at lower part of the well are *trilete* spores (165-193 m), monocolpate pollen, dinocyst, *Phelodinium belonuenae*; *Andalusiella sp*, *Senegalinium* sp *2*, and *Batiacaspaera sp* (planktons) are present in the samples (Fig. 6a). They are suggested to indicate shallow marine environment (Schrank, 1984, Oloto, 1987). Thus, Well-1002 is suggested to vary from lacustrine to shallow marine environment (Fig. 6b).

BH-1353 (Fig. 3) shares the same characteristic sporomorphs with BH-1002. It contains *Peridinacean* forms which define shallow marine (Fig. 13b) environment (Oloto, 1987). In the case of Well-1239 (Fig. 3), rare environmentally diagnostic forms are present such as *trilete spore*, *monocotyledonous* forms, *Triorites sp*, and one specimen of dinoflagellate cyst and rare occurrence of fungal spore (Fig. 14a). The co-occurrence of these forms is indicative of lacustrine environment (Fig. 14b).

BH-1219, BH-1235 and BH-1220 (Fig. 3) do not contain marker forms that could suggest paleoenvironment of deposition. However, few forms such as monocolpate pollen, trilete spores, fungal spore, and algae present could suggest a lacustrine depositional setting for the sediments.

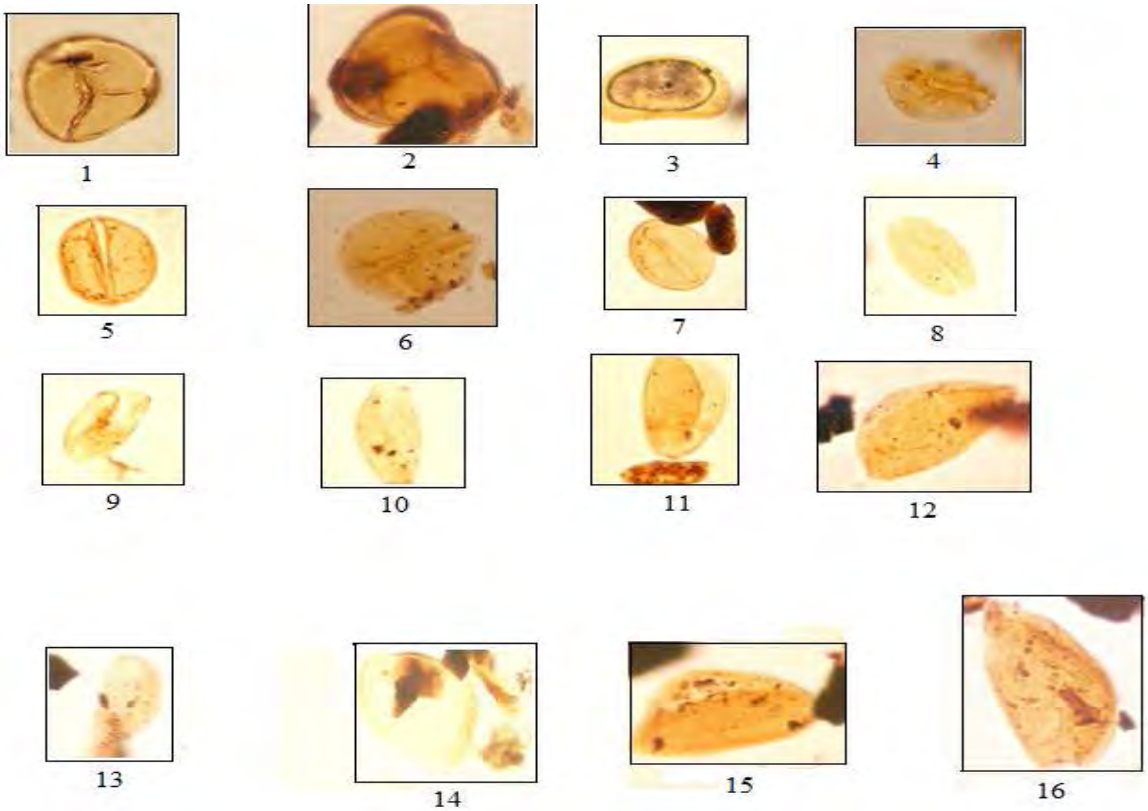

Plate 1
(All magnification at ×800)

1	*Leiotriletes sp*	(Potonie and Galletich) Krutzsch, 1959
2	*Leiotriletes sp*	
3	*Verrucatosporites usmensis*	
4-7	*Monocolpites marginatus*	Van der Hammen, 1954
8-10	*Monosulcites sp*	Lawal and Moullade, 1986
11-12	*Longapertites marginatus*	Van Hoeken-Klinkenberg, 1964
13	*Longapertites marginatus*	
14-16	*Longapertites vaneendenburgi*	Germeraad et al 1968

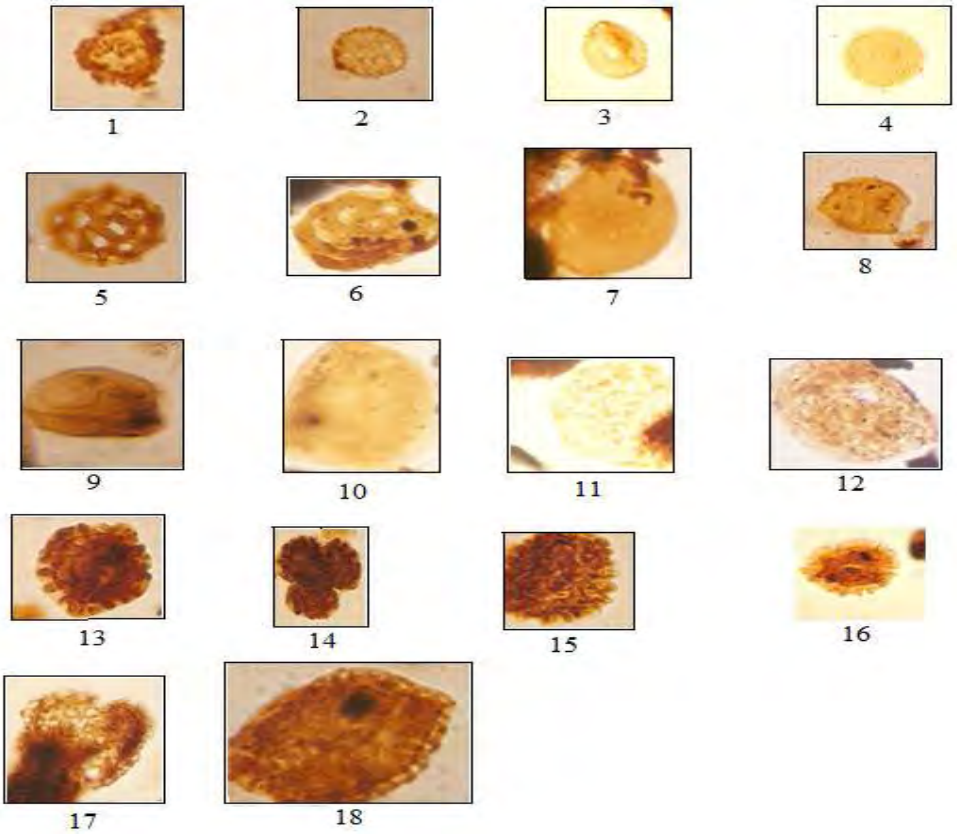

Plate 2

(All magnification at ×800)

1	*Distaverrusporites simplex*	Muller, 1968
2-4	*Constructipollenites ineffectus*	Van Hoeken-Klinkengerg, 1964
5-6	*Buttinia andreevi*	Boltenhagen, 1967
7-9	*Retidiporites magdalenensis*	Van der Hammen and Garcia, 1966
10-11	*Periretisyncolpites giganteus*	Kieser and Jan du Chene, 1979
12-15	*Periretisyncolpites sp*	Lawal and Moullade, 1986
16-17	*Periretisyncolpites sp*	
18	*Proteacidites sp*	

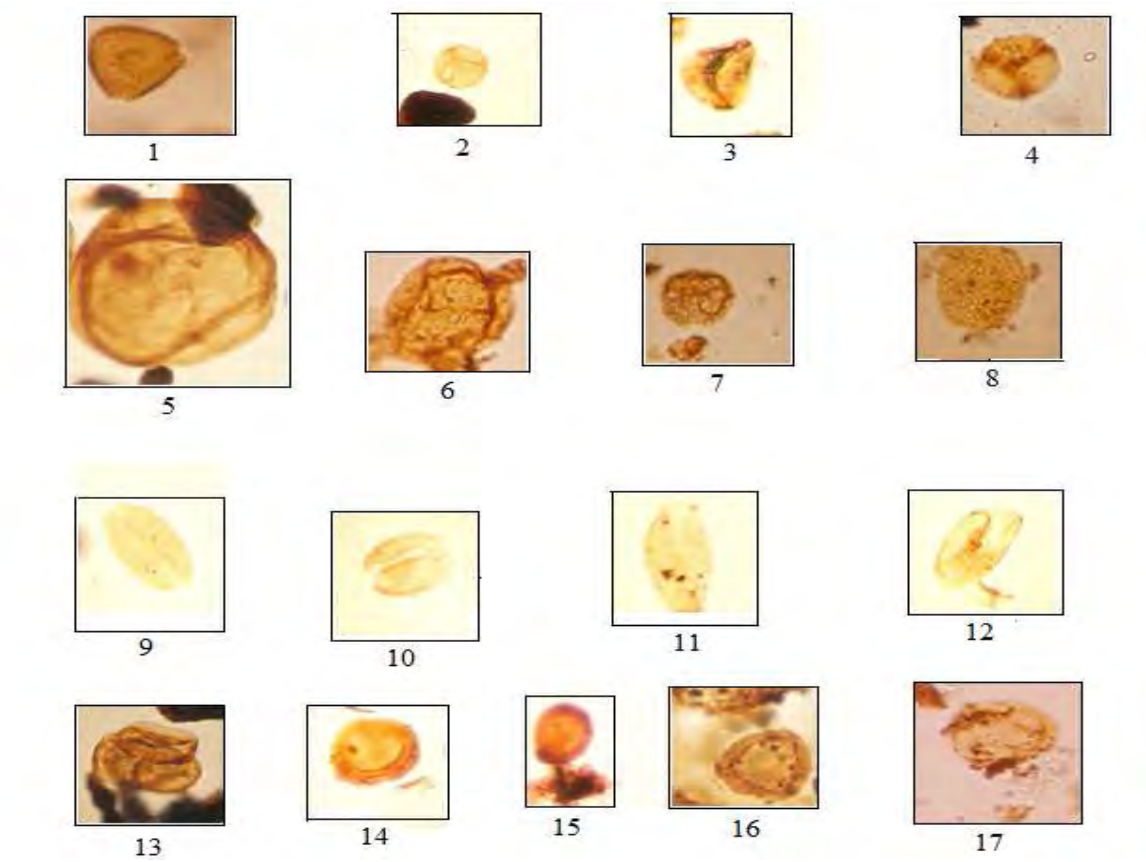

Plate 3

(All magnification at ×800)

1	*Triporites sp*	
2	*Syncolporites marginatus*	
3-4	*Syncolporites sp*	
5	*Inaperturopollenites sp*	Lawal and Moullade, 1986
6-7	*Zlivisporites blanensis*	Pacltova, 1961
8	Retimonocolpites sp	
9-12	*Monosulcites sp*	
13	*Tetradites sp*	
14-17	*Cingulatisporites ornatus*	Van Hoeken-Klikenberg, 1964

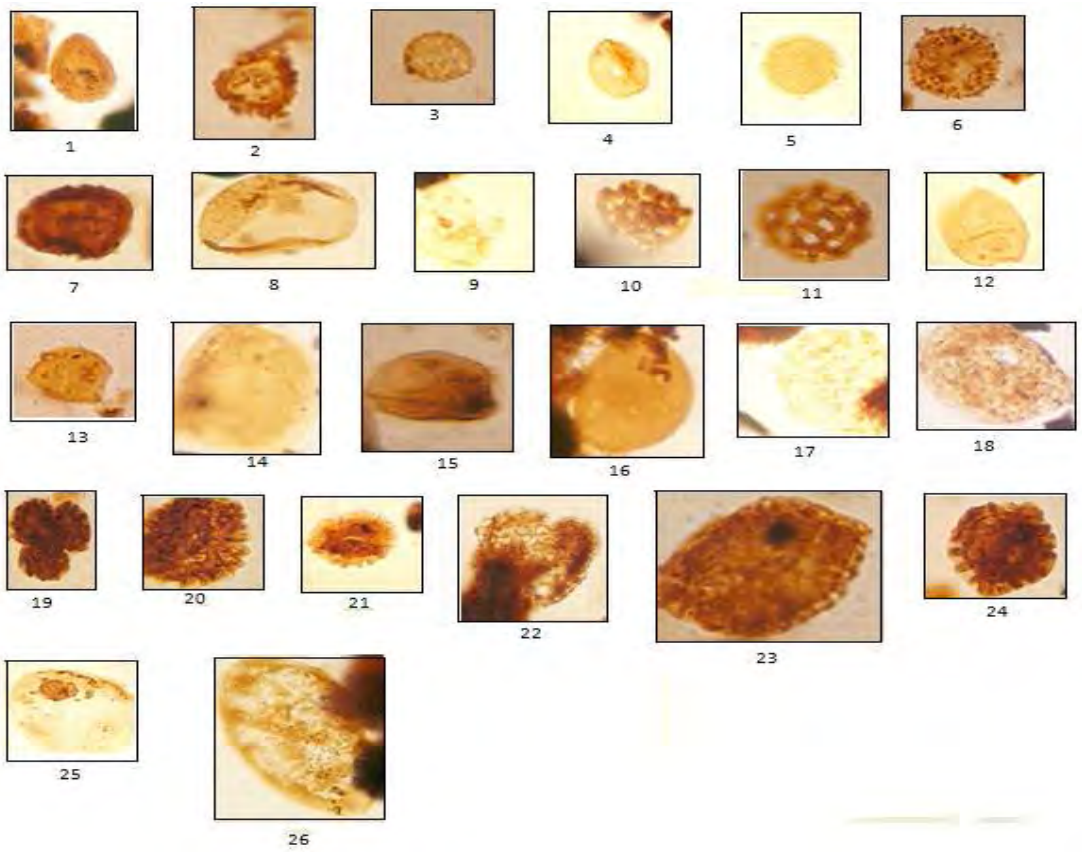

Plate 4
(All magnification at ×800)

1-2	*Distaverrusporites simplex*	Muller, 1968
3-5	*Constructipollenites ineffectus*	Van Hoeken-Klinkenberg, 1964
6-7	*Spinizonocolpites baculatus*	Muller, 1968
8-9	*Spinizonocolpites echinatus*	
10-11	*Buttinia andreevii*	Boltenhagen, 1967
12-16	*Retidiporites magdalenensis*	Van Hoeken-Klinkenberg, 1964
17-18	*Periretisyncolpites giganteus*	Kieser and Jan du Chene, 1979
19-24	*Periretisyncolpites sp*	Lawal and Moullade, 1986
25-26	*Periretisyncolpites sp*	

CONCLUSION

The Maastrichtian Coal Measures in the Anambra Basin were investigated for their miospore content. Lithostratigraphic description carried out on the core samples revealed that the wells are characterized by intercalations of white to light grey, fine grained laminated sandstone and light to dark grey, fissile shale with interbeded coal seams. The spores and pollen-grains identified were used to enhance biostratigraphic deductions including zonations, dating and palaeoenvironment of deposition.

Two palynostratigraphic zones belonging to Middle-Upper Maastrichtian age were established for the Mamu Formation following the standard zonation scheme of Lawal and Moullade, (1986). The lower part consisting of dark grey shale is characterized by the abundance and maximum development of *Longapertites marginatus* referred to as *Longapertites marginatus* Acme Zone I, dated Middle Maastrichtian. This period is marked by marine transgression which resulted to the deposition of basal facies (shale and laminated sand) in Mamu Formation. The zone is also characterized by high peak of palynomorph abundance and diversity.

The upper part defined by intercalation of sand and shale with coal seam layers interbedding belong to *Spinizonocolpites baculatus* Assemblage Zone II. The *Spinizonocolpites baculatus* Assemblage Zone II *is* characterized by *Spinizonocolpites spp.* and associated forms such as *Gemmamonocolpites sp, Syncolporiites marginatus, Longapertites spp. Constructipollenites ineffectus, Retidiporites magdelenensis*, *Distaverrusporites simplex*, *Foveotriletes margaritae*, *Buttinia andreevii*, and *Cingulatisporites ornatus*. Other forms that are also important are *Rugulatisporites caperatus*, *Proteacidites spp*., *Zlivisporites blanensis*, *Periretisyncolpites giganteus*, *Periretisyncolpites sp*, and *Proxapertites cursus*. These forms characterize Upper Maastrichtian sediments and as such used to date the Mamu Formation as Upper Maastrichtian age.

This study has shown that there is a change in age from North (Okaba) to South (Enugu). The studied lithostratigraphic intervals of the eleven wells vary in age from Early-Middle Maastrichtian in the North to Middle-Late Maastrichtian in the South. All the coal seams

belong to the Zone 2 of *Spinizonocolpites baculatus* assemblage zone dated Late Maastrichtian.

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