PALAEOPALYNOLOGY AND SEQUENCE STRATIGRAPHY OF THE MAMU FORMATION AROUND ORHUA, SOUTHWESTERN NIGERIA.

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ABSTRACT

A section of the Mamu Formation exposed at River Adewogun in Orhua, southwestern Nigeria, consists of dark grey, fissile, shale overlain by dark -brown, fine to medium- grained moderately sorted, thinly bedded sandstone of the Ajali Sandstone. The shale yielded a rich assemblage of spore and pollen of Late Maastrichtian age namely, *Monocolpites marginatus, Longapertite marginatus, Constructipollenites ineffectus, Foveotrilete margaritae, Spinizonocolpites echinatus,* and *Ulmaideipites krempii.* A back mangrove to nearshore palaeoenvironment of deposition is inferred. The sequence stratigraphy revealed a flooding surface with high organic productivity representing a short period of poor circulation associated with transgressive events.

Key words: *Palynology; Sequence stratigraphy; organic; nearshore, transgressive*

INTRODUCTION

The Mamu Formation (Reyment, 1965) is also known as the Lower Coal Measures (Tattam, 1954; Simpson, 1954). Exploration for hydrocarbon commenced in the Benin Flank between 1908 and 1914 by the defunct Nigerian Bitumen Corporation. Hydrocarbon shows in various sand horizons with poor oil and gas occurrences were reported (Coker *et al.,* 1983). Detailed accounts on the geology, palynology, and economic potentials of the Mamu Formation have been reported by previous workers (Reyment, 1965; Murat, 1972; Akande *et al*., 1992; Umeji, 2005) and among others. According to De Swardt and Casey (1961) five coal seams at Enugu which simulate rhythmic sedimentation occur in the deposit.

The Mamu Formation is Early Maastrichtian age (Reyment, 1965; Murat, 1972). Umeji (2005) examined the Okaba coal seams palynologically and date it Late Maastrichtian – Paleocene.

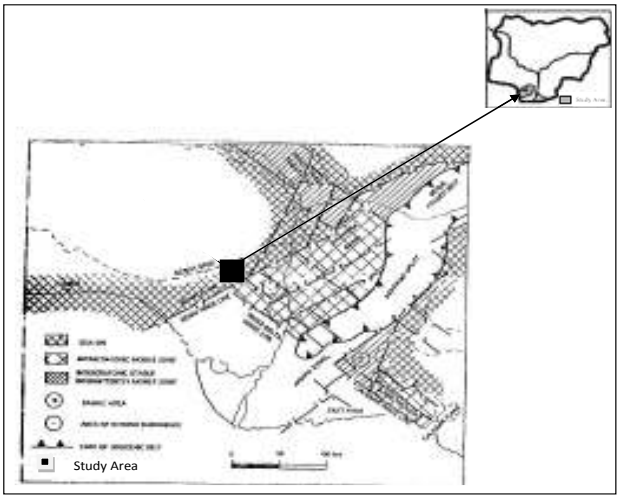
The area under investigation lies within latitude $6^0\,45^1$ and $6^0\,49^1$N and longitude $5^0\,57^1$ and $6^0\,00^1$ E (Fig. 1). The purpose of this study is to document the palynology and sequence stratigraphic framework of the Mamu Formaton around Orhua, southwestern Nigeria. Most of the studies of the Mamu Formation have been limited to exposures in the southeastern sector of Nigeria, due to explorations for oil, coal and availability of outcrops for study. No published palynological information on the Mamu Formation exists for the deposits from the Benin Flank in the southwestern part. Such data when available would contribute to the geological knowledge of the basin. In this study, sections encountered were described sedimentologically and integrated with palynomorphs recovered from the sediments for detailed sequence analyses. This synergy which could be useful both in exploratory work and for delineating probable source rock intervals would complement other geoscientific methods of exploration.

GEOLOGICAL SETTING

The origin of many sedimentary basins in West Africa is associated with the breaking up of the Gondwana super continent. The evolution of the related sedimentary basins began in the Cretaceous when South America was separated from the African plate (Burke *et al.,* 1972). Crustal doming also produced a three-armed radial rift system which made a "Triple ridge junction" at the Gulf of Guinea and was active during the Early Cretaceous (Burke *et al.,* 1972).

The area under study straddles the Niger Delta to the north. Its tectonic evolution is closely related to that of the adjoining sedi-

mentary basins (e.g. Niger Delta and Dahomey Basin). The formations encountered from bottom to top in the study area include Mamu Formation and Ajali Sandstone.



METHODOLOGY

A detailed field mapping was carried out on the scale of 1:25,000 base map (Fig.2) and the outcrops encountered were described. Samples were collected for palynological analysis and macerated following standard procedures: hydrochloric acid (HCl) was used to remove carbonates, after which it was treated with hydrofluoric acid (HF) to remove silicates. The residue was then sieved through 10 µm mesh and straw mounts were prepared with the residue retained on 10 µm mesh. One slide per sample was prepared and studied under the binocular microscope. Identification and numerical abundance of palynomorphs were done.

LITHOLOGIC DESCRIPTION OF THE MAMU FORMATION AROUND ORHUA

The exposed section, 10 m thick consists of seven lithologic units from base to top as described in Figure 2. Sedimentary sequence consists of shale, which are dark to grey in colour, fissile and laminated while the 4 m thick sandstones units belonging to Ajali Sandstone lie above, which are light brown, fine – medium grained, moderately sorted, and thinly laminated. Around Ekpon, another Mamu section is seen to outcropped and is made up of 2.4 m thick laminated shale units which constitute the basal succession(Fig. 3). Lying above is a sandstone; brownish-white in colour, medium grained, parallel bedded and exhibit sedimentary attributes of Ajali Sandstone.

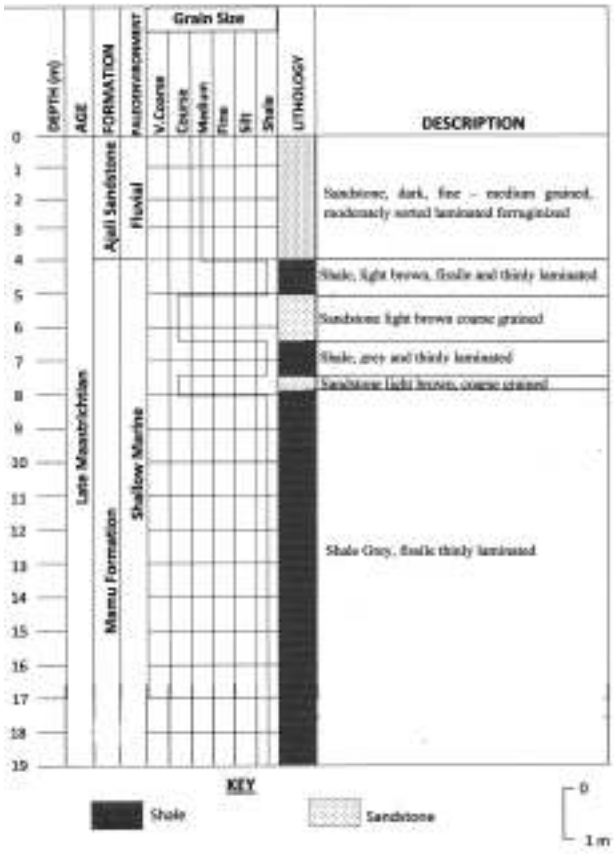


Fig 2: *Litholog of the Mamu Formation around Orhua, South western, Nigeria.*

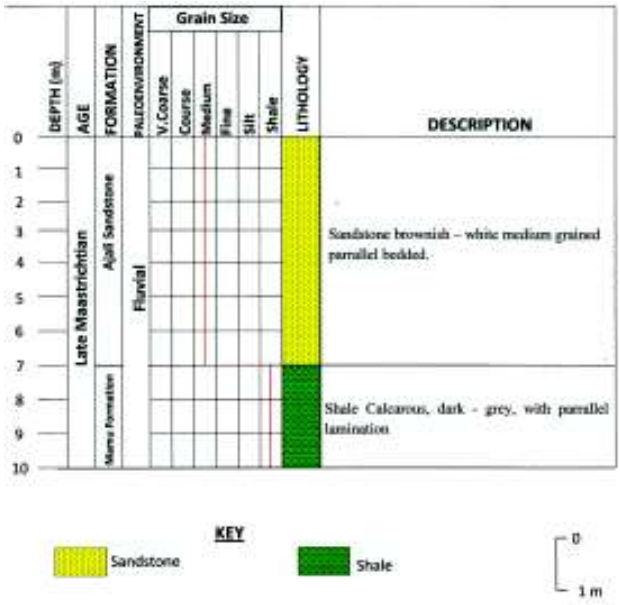


Fig.3. *Litholog of the Mamu Formation around Ekpon, Southwestern, Nigeria.*

SEQUENCE STRATIGRAPHY

The proposed sequence stratigraphic framework of the Mamu Formation using palynomorphs shown in Figure 4 has revealed a transgressive system tract, highstand system tract, sequence boundary and a flooding surface. Transgressive system tract in the succession is made up of shale and bounded at the top by a flooding surface. It contains palynomorphs such as *Graminites sp., Inaperturopollerites sp.,* and *Syncolpites* sp. (Fig. 3) with percentage ranging from 0.7% to 6.6% and may serve as a potential source rock. The transgressive system tract represents a marine transgressive cycle, deepening of the facies and relative rise in sea- level. Palynofloral assemblages recorded in this unit were not abundant and diverse .This may be due to oxidation and fluctuating salinities. The second depositional sequence in the succession is the highstand system tracts bounded at the base by flooding surface and at the top by sequence boundary. This sequence contains palynomorphs which include *Monocolpites maginatus, Leiotriletes sp.,Monosulcites sp. and Longapertites sp.* (Fig.4) with their percentage varying from 2.2% to 9.6% probably representing a relative fall in sea level. This unit is predominantly shale, thinly laminated and fissile. Palynofloral assemblages were abundant and diverse, indicating dominant brackish palaeoenvironments. This is corroborated by the biomarkers signatures shown in Fig.3. The stratigraphic context, palynomorphs dynamics and depositional environment of the Mamu Formation are all consistent with a landward facies shift (Fig.4). The top of the Mamu Formation defines a sequence boundary and parasequences are arranged in aggradational to progradational stacking pattern (Fig.4). This sequence is thinner than any other sequence in the study area, indicating reduced sedimentation rates. Increased rate of sedimentation resumed 65 m.y. ago and deposited the overlying Ajali Sandstone (Fig. 4). A candidate flooding surface can be interpreted slightly above the base of the highstand system tract deposits where a peak of *Leiotriletes sp*., was identified. This distinct peak of palynoforms at the upper part of the Mamu Formation on the Benin Flank may be due to trangressive and stable environmental conditions which favour the blooming of the organic facies. The flooding surface is characterized by the maximum diversity and abundance of *Leiotriletes* (16.9%) and other palynomorphs (Fig.3). This indicates short – lived periods of poor circulation and organic productivity associated with transgressive events (Fig.3). The colours of the palynomorphs vary from yellow to light brown (Fig. 4) indicative of immature organic source rocks (Tucker, 1988).

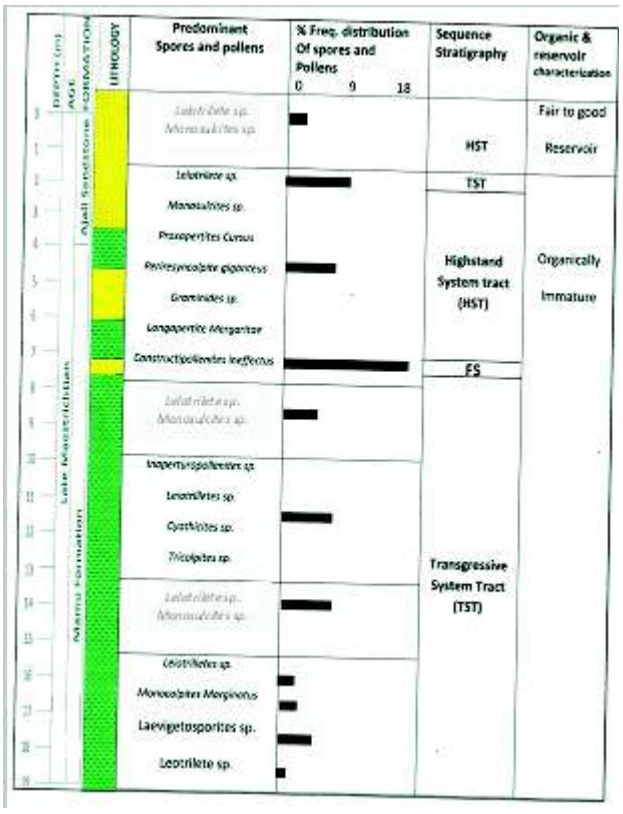


Fig 4: *A proposed sequence stratigraphic framework in the Mamu Formation on the Benin Flank, southwestern Nigeria.*

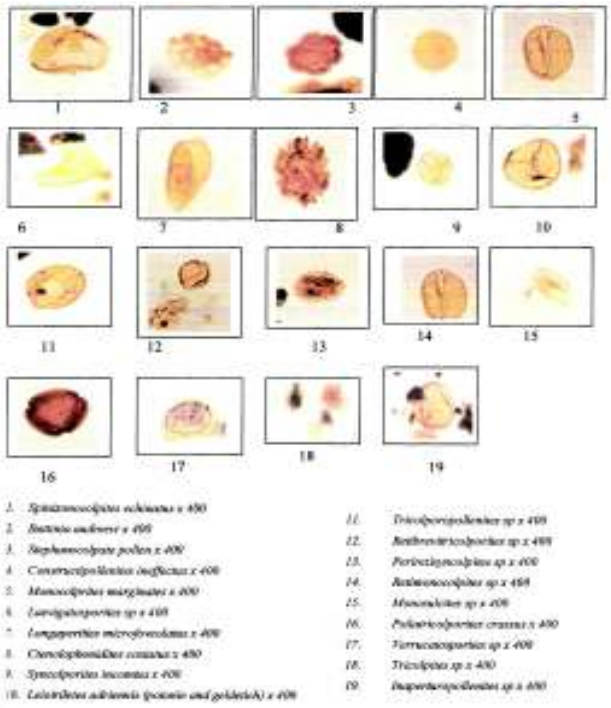


Fig.5. *Some characteristics palynomorphs from the Mamu Formation at Orhua, southwestern Nigeria*

BIOSTRATIGRAPHIC AGE

The age of the palynomorphs of the Mamu Formation in Orhua, southwestern Nigeria is interpreted and compared with previous works of Germeraad *et al.* (1968), Jandu Chene (1980), Lawal and Moullade (1986), and Umeji (2005). The palynomorph assemblages recorded were largely of trilete spores (Fig. 5). The basal sequences (shaly unit) consist of *Graminides sp., Monocolpites marginatus,* abundant *Leiotriletes* while other palynomorphs like *Foveotriletes margaritae, Laevigatosporites sp, Periretisyncolpites giganteus* are minor. These palynomorphs have been assigned Campanian to Late Maastrichtian age (Vander Hammen, 1956; Jandu Chene, 1980).

Overlying units are marked by the occurrence of *Inaperturopollenites sp. Longapertites vaneendenburgi and Longapertites sp.* These units characterized by the above species suggest Late Maastrichtian to Danian age (Germeraad *et al.,* 1968) and other markers such as *Syncolporites* sp., indicate Maastrichtian age (Van Hocken-Klinkenberg, 1964). Other palynomorphs assemblage which are abundant at the upper section of the Mamu Formation in the study area include *Distaverrusporites sp., Proxapertites cursus, Spinizonocolpites echinatus* and were assigned Maastrichtian age by Germeraad *et al.,* (1968). Lawal and Moullade, (1986) based on the appearance *of Auriculiides sp*., in association with *Distaverrusporites* sp., *Echitriporite trianguliformis* and *Ctenophonidite costatus* assigned Maastrichtian age to the sediment while other markers like *Constructipollenites ineffectus*, *Proxapertites cursus* in the upper section indicate Late Maastrichtian age .

SYNTHESIS OF PALAEOPALYNOLOGICAL INFORMATION.

The palynological examinations of the surface outcrops of the Mamu Formation indicate that the area is rich in floral diversity. The floral assemblage of upper section includes important biomakers' species such as *Spinizonocolpites echinatus, Monocolpites marginatus*, *Periretisynocolpites giganteus, Leiotrilete* sp., *Monosulicite* sp. (Fig. 4). These forms have been dated Maastrichtian age by Lawal and Moullade (1986) while *Psilatricolpites crassus, Spinizonocolpites echinatus, sp., Tricolporopollenites costatus, Syncolpites sp., Leiotriletes* sp., and some other markers appear in the Paleocene-Eocene sediments (Germeraad *et al.,* 1968; Akkiraz et al., 2008). The predominance of these palynomorphs suggests a near shore environment (Akkiraz *et al.,* 2008). The Mamu Formation was interpreted to be a deposit of shifting forest to reed swamp environments (Akande *et al.,* 1992). It consists of fissile and thinly laminated shale in the area of study. Low palynoforms content points to a reduction in organic quality at the basal unit and transgressive system tracts are interpreted.

The basal sequence is composed of *Longapertites vaneendenburgi, Leiotriletes sp*., *Syncolpites sp., Inaperturopellenites* sp., *Tricolpites sp.,* and *Cyanthide sp.* Jardine and Maglorie (1965) described forms such as *Longapertite vaneendenburgi*, *Syncolpite s*p., *Graminides* sp., and assigned Maastrichtian age while the dominant forms represent a back mangrove environment (Vander Hammer, 1963; Akkiraz *et al.,* 2008). It recorded a relatively higher percentage of palyniforms than the basal unit and this may be due to variable degree of preservation. This sequence

grades upward from laminated shale to moderately sorted sandstone, and slightly ferruginous. The general upward increase in grain size and traces of ferruginization suggest an oxidizing environment and a change from a retrogradation to progradation stacking pattern. Stratigraphic context, palyniforms and depositional environment are consistent with a major landward facies shift. This unit fulfills the criteria for a transgressive system tract. Overlying this unit is a thin unit of sandstone, probably represents a general progradation consistent with a moderate energy depositional environment (Ojo, 1999).

Upper section also displays characteristics which are similar to other units in terms of grain sizes, palynomorphs assemblage and sedimentary structures. It consists of thinly laminated shale. This unit represents suspension deposition in a quiet water setting. The shale is separated by lowstand deposits above and is a correlated landward with small-scale sequence boundary indicating small-scale depositional sequences. The occurrence of *Buttinia andreevi* in the present study strengthens the Late Maastrichtian age. The Palyniforms abundance and assemblage show similarity with Late Maastrichtian assemblage Zone II, Gongola Basin (Ojo, 1999), Yessoma Formation, Somalia (Shrank, 1994) and Maastrichtian El – Mahamid area of Southern Egypt (Sultan, 1985). The predominance of parallel laminated shale suggests a dominance of suspension in quiet low energy conditions.

PALAEOENVIRONMENTAL RECONSTRUCTION

The Mamu Formation at Orhua, southwestern Nigeria, yielded palyniforms with abundant land derived pollen and spores such as *Foveotrilete margaritae*, *Echitriporites trianguliformis, Longapertites marginatus* and among others(Fig.5). The scheme employed in reconstructing the depositional environment included the abundance and type of pollen preserved in the sediments, co-existence approach and sedimentological data. A list of pollen and spores recorded from this study is shown in Figure 5. The miospore association indicates a swampy vegetation of abundance trilete spores: *Leiotrilete sp, Foveotrilete margaritae, Monocolpite marginatus* (Allien, 2004). Palm pollen such as *Leiotrilete sp, Proxapertites sp., and Longapertites sp. are* present in all samples and were attributed to back mangrove in brackish water condition, indicating a high sea level (Vander Hammen, 1963; Akkiraz *et al.,* 2008). Germerad et al., (1968) also described *Longapertites sp.* and *Proxapertites sp.* as palm pollen while *Syncolporites incomptus* indicates herbaceous plants. The pollen *Spinizonocolpites sp., Psilatricolporites* sp., *Inaperturopollenites* sp., *Periretisyncolpites sp., and Monosulcites sp.,* indicate a shoreline deposition (Akkiraz *et al*., 2008). These flora assemblages give credence to the marine incursion, and thereafter the resumption of fluvial sedimentation which continued towards the end of the sections (Fig.3). The biosignatures suggests a Back mangrove with little marine influence for the study area.

PALAEOCLIMATIC IMPLICATION AND PALAEOECOLOGY

Palynological data is a useful tool in analyzing and deducing palaeoclimatic conditions. It is used to infer the geographical distribution of plant species in a particular climatic condition and changes in plant communities which are dependent on climatic conditions (Akkiraz *et al.,* 2008). The palynomorphs identified in the study area including *Spinozonocolporites sp. Monosulcites sp. and Psilatricolporites sp.* suggest brackish water conditions comparable to mangrove swamp (Gemeraad *et al.,* 1968) and are known to be elements of modern mangrove vegetation especially in low diversity flora communities. According to Jimenez (1984), *Monocolpites marginatus,* and *Proxapertites sp.,* indicate both tropical and sub-tropical conditions with high rainfall. According to Herngreen and Chlonova (1981) West Africa belongs to the Late Cretaceous Palmae Province where palynomorph such as the *Spinizonocolpites* sp., *Leiotrilete* sp., *Proxapertites,* sp., *Longapertites sp.* and the *Monosulates* flourish. The predominance of these palynoforms in the Mamu Formation suggests a prevailing tropical climate as recorded in this study.

CONCLUSIONS

The examination of outcrop of the Mamu Formation on the Benin Flank around Orhua, southwestern Nigeria, has unraveled

the geological characteristics of the basin. Playnofloral assemblages were generally rich and diverse. The recovered palynomorphs include *Auriculnidites sp., Foveotrilete margaritae, Echitriporites trianguliformis, Distaverrusporites sp., Proxapertite cursus, Laevigatosporites sp., Leiotrilete sp. and Monocolpite marginatus.* Sedimentological characteristics and species richness suggest a back mangrove to nearshore palaeoenvironments of Late Maastrichtian age. Palyniforms such as *Monocolpites marginatus*, *Proxapertites sp.,* present in the sediments also indicate both tropical and sub-tropical conditions with high rainfall. The sequence stratigraphy revealed a transgressive system tract, sequence boundary, highstand system tract and a flooding surface representing short periods of poor circulation and organic productivity associated with transgressive events.

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