Supported by tetfund TERTIARY EDUCATION TRUST FUND

PALYNOSTRATIGRAPHY OF OUTCROP SECTIONS ON PARTS OF THE WESTERN FLANK OF ANAMBRA BASIN, SOUTHWESTERN NIGERIA

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Received: March 17, 2021 **Accepted:** June 11, 2021

Abstract: Palynological investigation of Maastrichtian Shales on parts of the western flank of the Anambra Basin has been carried out using the occurrence of spores, pollens, dinoflagellate cysts, and acritarch. The shale units on the studied outcrop sections were deposited in low-energy, swamp environment. The recovered palynofloral assemblage indicates Maastrichtian age for the studied outcrop successions. The Maastrichtian is characterised by an assemblage comprising mainly the miospore species *Monocolpites marginatus, Spinizonocolpites baculatus, Longapertites* sp., and Cyathidites. The microflora assemblage reflects a freshwater swamp environment that was intermittently flooded by shallow marine water. The presence of some palmae pollen *Spinizonocolpites* and *Longapertites* indicates that the study area belongs to the Late Cretaceous Palmae Province.

Keywords: Microflora, shale, Maastrichtian, Anambra Basin, Late Cretaceous Palmae Province

Introduction

The Anambra Basin is about 55,000 km^2 in size, and is bordered to the west, east, and south by the Benin hinge line (Okitipupa Ridge), the southern Benue Trough and the Oban Massif, and the Niger Delta Basin, respectively. It is a synclinal structure consisting of more than 5,000 to 7,000 metres thick of Upper Cretaceous to Recent sediments (Ladipo, 1988; Agagu and Ekweozor, 1982; Ladipo *et al.*, 1992). The geologic evolution of the Anambra Basin is linked to Late Cretaceous tectonics that affected the Abakaliki-Benue Basin (Murat, 1972). Subsequent phases of transgression and regression brought about deposits of marine and continental origins into the Anambra Basin (Anyanwu and Arua, 1990).

Ifon area constitutes the poorly defined and debatable boundaries of Dahomey and Anambra Basins (Ojo, *et al.*, 2017). Several authors have worked on the age (relative), mineralogy, depositional environment and paleoclimate scenario of the Maastrichtian sediments around Ifon. Durugbo and Aroyewun (2012) have assigned a Late Maastrichtian-Paleocene age to outcrop sections along Ifon-Saboginda road based on rich assemblage of Maastrichtian-Paleocenepalynomorphs. The palynomorphs include *Ariadnaesporite sspinosa, A. nigeriensis, Ariadnaesporites* sp., *Foveotriletesmargaritae, Rugulatisporitescaperatus, Distaverrusporites simplex, Cingulatisporites ornatus, Zlivisporis blanensis*, with dinoflagellate cysts, diatom frustules and abundant palm pollen *Longapertites marginatus, L.vaneendenburgi, L. microfoveolatus, Proxapertites operculatus, Monocolpopollenite ssp haeroidites, Spinizonocolpites echinatus, S. baculatus, S. kostinensis, Retidiporitesmagdalenensis, Mauritidites lehmanii, Tubistephanocolpites cylindricus, Echitriporitestrianguliformis, E. longispinosus, Monocolpites marginatus, Retimonocolpites nigeriensis, Racemonocolpites racematus* and *Arecipites* sp. They also reported that the shale sediments were deposited in a swampy shallow marine/nearshore environment. Ola-Buraimo (2012) suggested an early Maastrichtian age to shale samples obtained from an exposed road cut section along Ifon-Okeluse road based on important diagnostic forms namely*Buttinia andreevi, Retidiportes magdalenensis, Periretisyncolpites spp, Cingulatisporites ornatus, Auriculiidites sp, Constructipollenites ineffectus,* and *Monocolpopollenites sphaeroidites*. There is no published report on the age, depositional environment, and paleoclimatic settings of outcrop exposures around Imoru and Ogberuwen, hence a microflora assemblage study of two (2) outcrop sections (near Imoru and Ogberuwen) was carried out to infer the age (relative), reconstruct the depositional environments, and deduce the paleoclimatic implications.

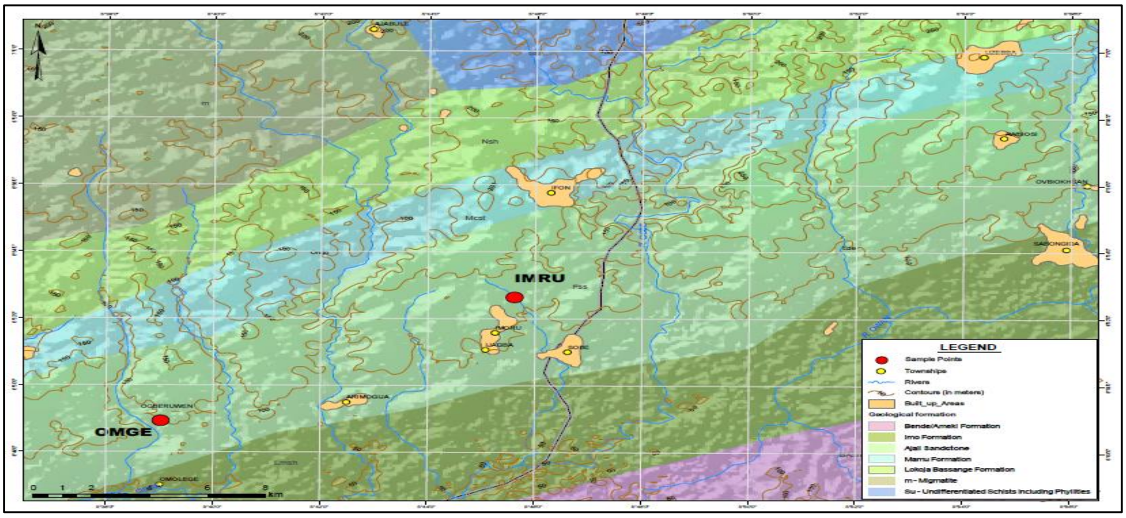

Fig. 1: The study area in simplified regional geographical and geological map (modified from Murat, 1969). Exposed outcrop locations include IMRU (Imoru outcrop section) and OMGE (Ogberuwen outcrop section)

Geological setting
The lithic fill of the Anambra Basin is part of the post-Santonian Cretaceous coeval succession of Nigeria caused by rising eustatic sea level (Edegbai *et al*., 2019b). Sedimentation began with widespread deposition of the alluvial to fluvial sediments of the Lokoja Formation in the western sections of the basin (Nwajide, 2013). The Campanian to Maastrichtian Lokoja Bassange Formation is the oldest Cretaceous Formation, that unconformably overlies the western Nigeria Basement Complex (Rahaman *et al*., 2012).
This was followed by the largely estuarine to marine sediments of Mamu Formation, which comprise of bay, marsh, central basin, fluvial-tidal channel, tidal flat, barrier-beach/was hover fan deposits (Ladipo, 1988; Edegbai *et al*., 2019a) as well as shore face, offshore transition and open shelf deposits (Dim *et al*., 2019; Edegbai *et al*., 2019a).These successions are overlain by Maastrichtian sub-tidal/shallow marine Ajali Formation. Ajali Sandstone marks the height of the regression at a time when the coastline was still concave (Obaje, 2009). The converging littoral drift cells governed the sedimentation and are reflected in the tidal sand waves which are characteristic for Ajali Sandstone (Obaje, 2009). Ajali Sandstone consists of mainly friable, poorly sorted whitish, fine to coarse grained non-fossiliferous sandstone, with interbeds of mudstone and occasional plant impressions (Rahaman *et al*., 2012; Nwajide, 2013).
A thin ironstone unit capping the Ajali Formation represents the Nsukka Formation in the western segment of Anambra Basin (Edegbai *et al*., 2019a). The Imo Shale mark the onset of another transgression in the Anambra Basin during Paleocene (Obaje, 2009). Imo Shale is considered as a regional seal for the western flank of the Anambra Basin (Rahaman *et al*., 2012).

Materials and Methods
A field study was carried out on outcrop sections near Imoru (IMRU) and Ogberuwen (OMGE) on the western flank of the Anambra Basin. The field study involved outcrop description, measurements, and sampling of outcrop exposures. Palynological analysis was carried out on nine (9) shale samples. The samples were prepared for palynological analysis according to standard extraction techniques involving HF and HCl treatments, wet sieving with 10 µm polyester sieve and mounting on glass slides using glycerine jelly.
The outcrop exposure at Imoru is about 23.5 m thick, consisting of sandstone (20 m thick), an iron-rich band (0.7 m thick), and shale (0.3 m). The grey fissile shale is at the lower part of the section and overlain by thick ferruginized sandstone (Fig. 2a) with a thin iron-rich band between shale and sandstone. The exposed outcrop section near Ogberuwen is about 1.0 m thick (Fig. 2b), consisting of shale (0.6 m thick) and densely vegetated siltstone (0.4 m thick). The basal light grey fissile shale is overlain by brown siltstone facies.

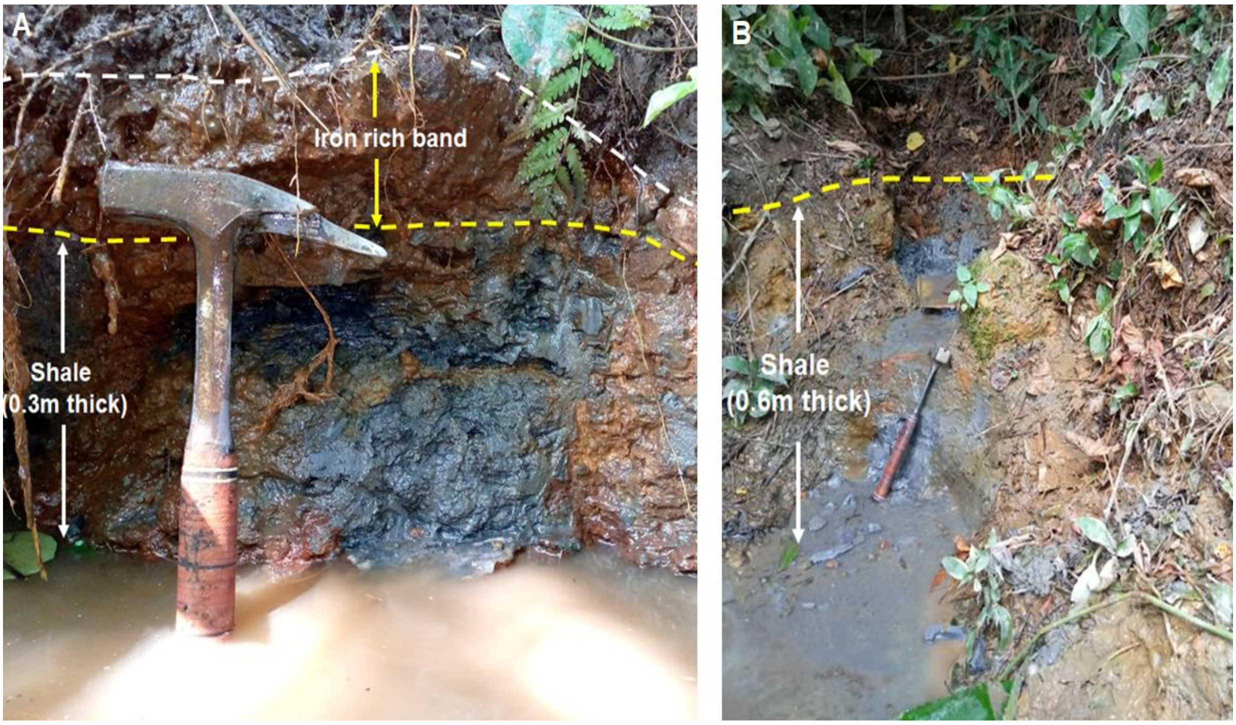

Fig. 2: Observed sedimentary succession exposed at (a) Omi-Oke River in Imoru (IMRU), and (b) water spring in Ogberuwen (OMGE)

Results and Discussion
The abundance of recovered palynomorphs in the outcrop exposures is shown in Table 1. The miospores include species of pollen (palms) and pteridophytic spores. The dinoflagellates are mainly peridiniods (Table 1). Palynomorphs are generally sparse in all the analyzed shale samples. The pollen and spore assemblage recovered from shale samples obtained from Imoru outcrop section, is composed of four (4) species with fungal spores, two (2) species of dinoflagellate cysts and an acritarch (Plate 1). The miospore assemblage obtained from Ogberuwen exposure, is composed of six (6) species, no fungal spore, seven (7) dinocysts, and an acritarch (Plate 1).

Table 1: Table showing the distribution of terrigenous and marine species in the outcrop sections observed at Imoru (IMRU) and Ogberuwen(OMGE)

Exposures	**IMRU**					**OMGE**			
Sample Numbers	**IMRU-1**	**IMRU-2**	**IMRU-3**	**IMRU-4**	**IMRU-5**	**OMGE-1**	**OMGE-2**	**OMGE-3**	**OMG-4**
Terrigenous species									
Pollen (Palms)									
Longapertites sp.						2			
Monocolpites marginatus						2	1	1	
Spinizonocolpites baculatus		1							
Spinizonocolpites sp.			1						
Tricolporopollenites sp.							1		
Spores									
Charred Gramineae cuticle						1			
Cyathidites minor	1	2			1	4	1		1
Cyathidites sp.				1				1	
Fungal Remains									
Fungal spore				1	1				
Marine species									
Dinoflagellate cysts									
Achomosphaera sp.						1			
Cerodinium striatum									1
Oligosphaeridium sp.			1	1			1	1	
Paleocystodinium sp.									1
Homotryblium sp.					1				
Selenopemphix sp.						1			
Nematosphaeridium sp.							1		
Cleistosphaeridium sp.						2		1	
Acritarch									
Leiosphaeridia sp.	1		2	2	1	1	2		1

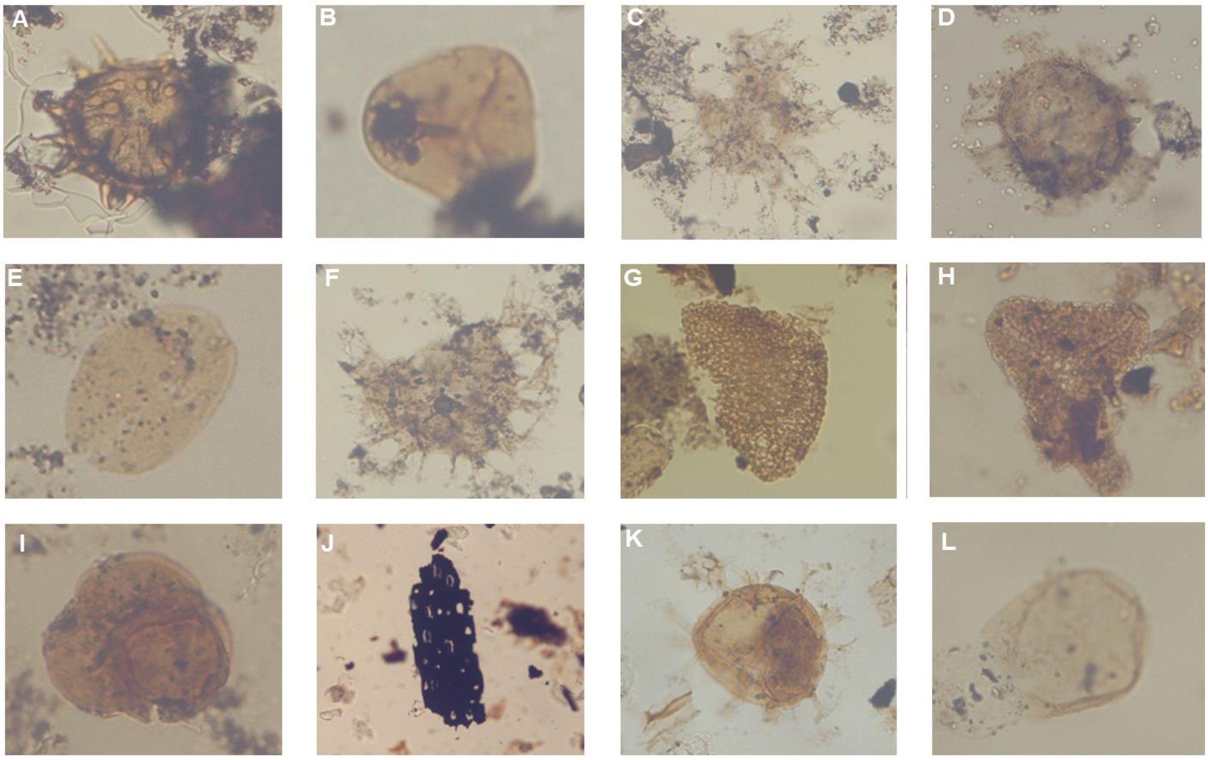

Plate 1: Photomicrographs of some of the palynomorphs retrieved from IMR and OMG outcrop sections; Mag: 400 × **A:** *Spinizonocolpites baculatus* (Sample IMRU-2), **B:** *Cyathidites minor* (Sample OMGE-1), **C:** *Selenopemphix* sp. (Sample OMGE-1), **D:** *Oligosphaeridium* sp. (Sample OMGE-3), **E:** *Monocolpites marginatus* (Sample OMGE-2), **F:** *Nematosphaeridium* sp. (Sample OMGE-2), **G:** *Longapertites* sp. (Sample OMGE-1), **H:** *Cyathidites* sp. (Sample IMRU-4), **I:** *Tricolporopollenites* sp. (Sample OMGE-2), **J:** Charred gramineae cuticle (Sample OMGE-1), **K:** *Achomosphaera* sp. (Sample OMGE-1), **L:** *Leiosphaeridia* sp. (Sample IMRU-4)

Age dating

The low abundance of land-derived species namely *Spinizonocolpites baculatus*, *Spinizonocolpites* sp., *Cyathidites minor*, and *Cyathidites* sp. was observed in shale samples from exposed river section near Imoru. The recovery of assemblage species namely *Spinizonocolpates baculatus*, and *Spinizonocolpates* sp. is an indication of late Maastrichtian age (Lawal and Moullade, 1982; Edet and Nyong, 1994). The late Maastrichtian is defined by the presence of the miospore species *Spinizonocolpites baculatus* (Edet and Nyong, 1994).

The recovery of *Monocolpites marginatus* and *Longapertites* sp. from shale samples obtained near Ogberuwen indicates an early Maastrichtian age. *Longapertites* and *Monocolpites marginatus* are well represented in the early Maastrichtian assemblage of Nkporo Shale of the southeastern Nigeria (Edet and Nyong, 1994; Ojo and Akande, 2006). A late Maastrichtian age is assigned to Imoru outcrop section, while early Maastrichtian age is assigned to Ogberuwen outcrop section.

Paleoenvironments

Reconstruction of the depositional environment of outcrop sections is based on recovered pollen, spores, dinoflagellates, algae, and fungal spores present in the nine (9) shale samples.

The recovery of *Cyathidites* from some samples obtained from the Imoru outcrop section is indicative of open fresh water swamps (Lawal and Moullade, 1987). Fungal sporesin shale samples obtained from Imoru outcrop exposure (IMRU-4 and IMRU-5) is not in significant amount, but suggestive of swampy conditions (Akpofure and Akana, 2016). The low number of dinoflagellate cysts namely *Oligosphaeridium* sp., and *Homotryblium* sp. in shale samples recovered from the Imoru outcrop section are indicative of a shallow marine influence (Ojo and Akande, 2006; Schrank, 1984; Edet and Nyong, 1994).The occurrence of *Leiosphaeridia* sp. reflects marine waters incursion (Bolaji *et al*., 2020).

The recovery of *Monocolpitesmarginatus* and *Longapertites* in shale samples of Ogberuwen out crop section, and the presence of pteridophyte (dominated by *Cyathidites*) are indicative of wet mangrove to marsh vegetation withina predominantly warm and humid climate (Lawal and Moullade, 1987; Adeigbe and Amodu, 2015; Ojo *et al.*, 2020). The recovery of peridiniods dinoflagellate cysts namely *Achomosphaera* sp., *Cerodinium striatum*, *Oligosphaeridium* sp., and *Paleocystodinium* sp. in shale samples obtained from Ogberuwen outcrop section suggest shallow marine influence (Ojo and Akande,2006; Schrank, 1984).The occurrence of Acritarch *Leiosphaeridia* sp. in the studied shale samples reflects occasional marine flooding in near shore or brackish water (Okeke and Umeji, 2016; Singh *et al*., 2017; Bolaji *et al*., 2020).

Paleoclimate implications

The paleoclimatic scenario of the Cretaceous strata was studied using microflora data. The occurrence of Palmae pollen *Spinizonocolpites* and *Longapertites* in the studied sections suggest that vegetation developed under warm, humid to tropical climate (Schrank, 1994; Ojo and Akande, 2004; Ojo and Akande, 2006). This present study shows that the study area was part of the West Africa South American phytogeographic province and Palmae province during Maastrichtian.

Conclusions

The main findings of this study show:

1. That the studied shale beds in the investigated outcrop exposures near Imoru and Ogberuwen were deposited in a low-energy, swamp environment.
2. Maastrichtian age is inferred for the shale samples recovered from outcrop sections near Imoru and Ogberuwen based on microflora data. A late Maastrichtian age is assigned to the shale unit of the Imoru outcrop section, while early Maastrichtian age is assigned to shale recovered from an exposed outcrop section near Ogberuwen.
3. The microflora assemblage reflects a fresh swamp environment that was intermittently flooded by shallow marine water.
4. The presence of some Palmae pollen *Spinizonocolpites* and *Longapertites* indicates that the shale sediment belongs to the Late Cretaceous Palmae Province.

Acknowledgement

Author is indebted to Crytal Age Limited for the provision of materials used for the preparation and analysis of the shale samples.

Conflict of Interest

The author declares that there is no conflict of interest related to this work.

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