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Palynostratigraphy of Lemna Road Transect of Benin Formation, Calabar Flank, Nigeria

Asukwo E. Itam[1], David O. Inyang[1], Umana S. Umana[1], Etie B. Akpan[1] and Efosa Udinmwen[1*]

[1]Department of Geology, University of Calabar, P.M.B. 1115, Calabar, Nigeria.

Authors' contributions

This work was carried out in collaboration between all authors. Author AEI wrote the first draft of the manuscript and analyzed the data. Author DOI designed the study. Author EBA checked the protocol of the study. Author USU appraised data quality. Author EU checked the grammar and language. All authors read and approved the final manuscript.

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ABSTRACT

Three lithosections of Benin Formation located along Lemna – Parlimentary Road Transect in Calabar, consisting of clay, gray shale intercalated with peat, mudstone , medium to coarse grained sandstones and pebbly sandstones were studied stratigraphically with a view to discern its depositional environment and age using pollen and spores. Twelve (12) samples were collected from these lithosections and they yieled the following notable palynological taxa: *Psilastephanocolporites laevigatus, Retricolporites irregularis, Zonocostite ramonae, Pachydermites diedeorixi, Echiperiporites estelae, Psilatricolporite crassus, Psilatricolporites* sp, *Retibrevitricolporites obodoensis, Ctenolophonidites costatus* and *Brevicolporites guinetii* for the pollen. Spores (ferns and fungi) include *Laevigatosporites discordatus, Acrostichum aureum, Verrucatosporites alienus, Polypoddiaceoisporites retirugatus, Magnastriatites howardi, Fusiformisporites sp* and fungi spores. These results show that these sedimentary units are of Early –Miocene to Late –Miocene age. The environment of deposition is alluvial/ fluvial and coastal settings characterized by freshwater swamp / rain forest and mangrove forest. This result infer environment of warm, humid and high rainfall climate of tropical vegetation.

**Corresponding author: E-mail: udinmwenefosa@gmail.com;*

Keywords: Lithosection; stratigraphically; palynological taxa; environment and vegetation.

1. INTRODUCTION

Recent excavations in connection with the construction of Lemna road (southeastern part of TINAPA) linking MCC -round out to the Murtala Mohammed highway in Calabar has exposed good sections which have been studied for palynological and environmental significance. Palynological analysis has application in dating and paleoenvironmenental reconstruction and this has been documented by several authors such as [1–3]. There is no much literature regarding the palynology of this basin. The only available literature is by [4] who studied the palynology Maastrichtian Nkporo Shale. Most research work done on this basin is on the Cretaceous sediments [5–8]. Little information exist on the detail geology of the Benin Formation of Calabar Flank except the work by [9] who looked at the textural characteristics of sediment exposed along the same study area, to infer the paleodepositional environment.

In order to contribute to the little known Neogene biostratigraphy in Calabar Flank, a preliminary study of the palynological analysis of sediments deposits along along Lemna – Parliamentary Road Transect in Calabar was carried out. The thrust of this research is primarily to describe the biostratigraphy of this area based on palynoflora as well as to make initial stratigraphic interpretation for paleoecological and paleoclimatological reconstruction.

2. LOCATION OF THE STUDY AREA

The area of study is located along Lemmna Road (southeastern part of TINAPA) in Calabar Municipality of Cross River State south-south geographic zone of Nigeria. Geographically the study area lies within latitude N05°01'42'' to N05°01'54'' and longitude E08°21'50'' to E08°01'57'' and is part of Calabar Flank (Fig. 1).

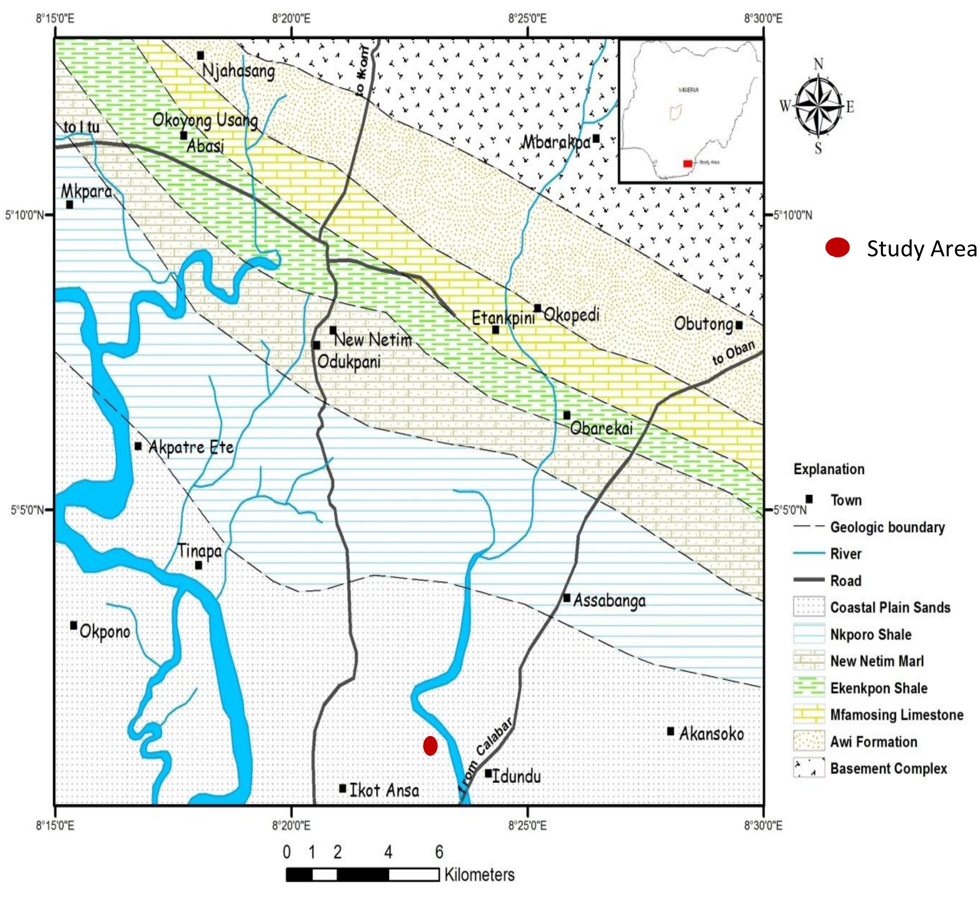


Fig. 1. Geologic map of the study area

The lithology of the study area (Fig. 2) is made up of reddish brown clay with some of woody materials at the base and overlain by a thick sequence of gray black shale intercalated with peat .The peaty material is rich in woody, leafy and root matters. A thin band of reddish-brown ironstone separates the underlying carbonaceous shale from the overlying variegated pebbly sandstone. The pebbly sandstone has pebbles, coarse, medium and fine grained that is poorly to moderately sorted sand grain and the cyclic is capped by overburden earth materials with vegetation.

3. GEOLOGICAL SETTING

The Calabar Flank is an epirogenic sedimentary basin in southeastern Nigeria [10]. The basin according to [5] is bounded by the Oban Massif in the north, Calabar hinge line separates the basin from Niger Delta basin in the south, Ikpe platform and Cameroon volcanic trend delineate it in the west and east respectively (Fig. 2). The origin of this basin is associated with the opening of the South Atlantic in the Mesozoic era when the South American plate drifted away from African plate. The major tectonic structures operating within the basin include the Ikang Trough (graben structure) and Ituk High (horst) which were mobile depression and stable mobile submarine ridge that influenced the distribution sedimentary facies [5,10].

The stratigraphic succession in the Calabar Flank is shown in Table 1. Sediment thickness is over 3500m with the onlap (or featheredge) of the outcropping units, along the fringes of the Oban Massif basement complex. The Formations are best exposed along Calabar – Ikom road and a succession consists of five (5) Cretaceous and a Tertiary lithostratigraphic units. Awi Formation is the oldest basal unit and sits nonconformbly on the basement complex of Oban Massif. The Formation is Aptian in Age [11]. This is overlain by Mfamosing Limestone of Middle- Upper-Albian age [12] which indicates the first marine transgression into the basin. This in turn is succeeded by Late Albian- Cenomanian to Turonian, Ekenkpon Shale Subsidence on the faulted blocks of horst and graben allowed wide spread deposition of shales with minor marl and mudstone intercalation. The New Netim Marl of Coniacian [5] in age, succeeded the shale. The Santonian period was marked by a major unconformity in Nigeria. Nkporo Shale of Late Campania to Early Maastrichtian [4] capped marine transgression and Mesozoic sedimentation in Calabar Flank. The Tertiary continental sands and gravel of Benin Formation completes the sedimentation episode in the basin (Fig. 1).

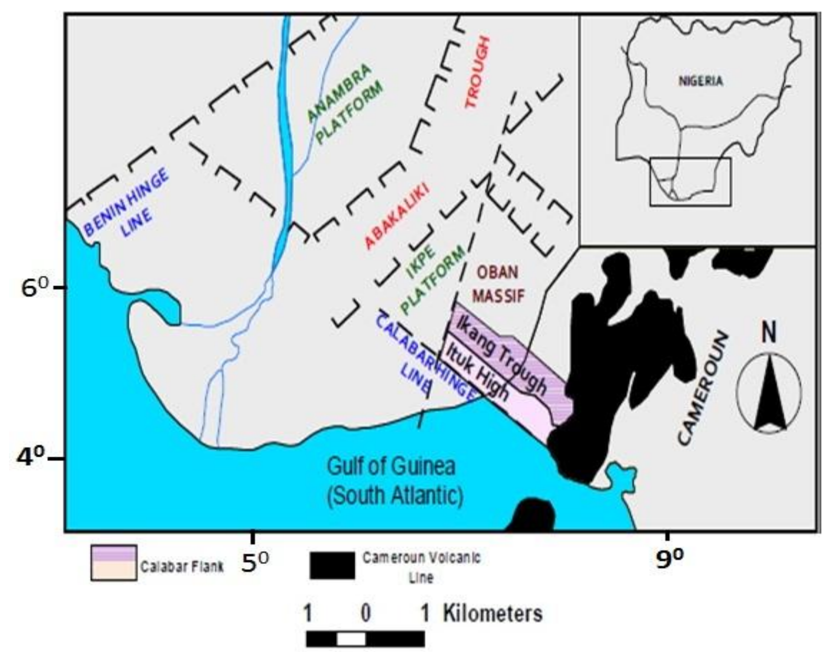
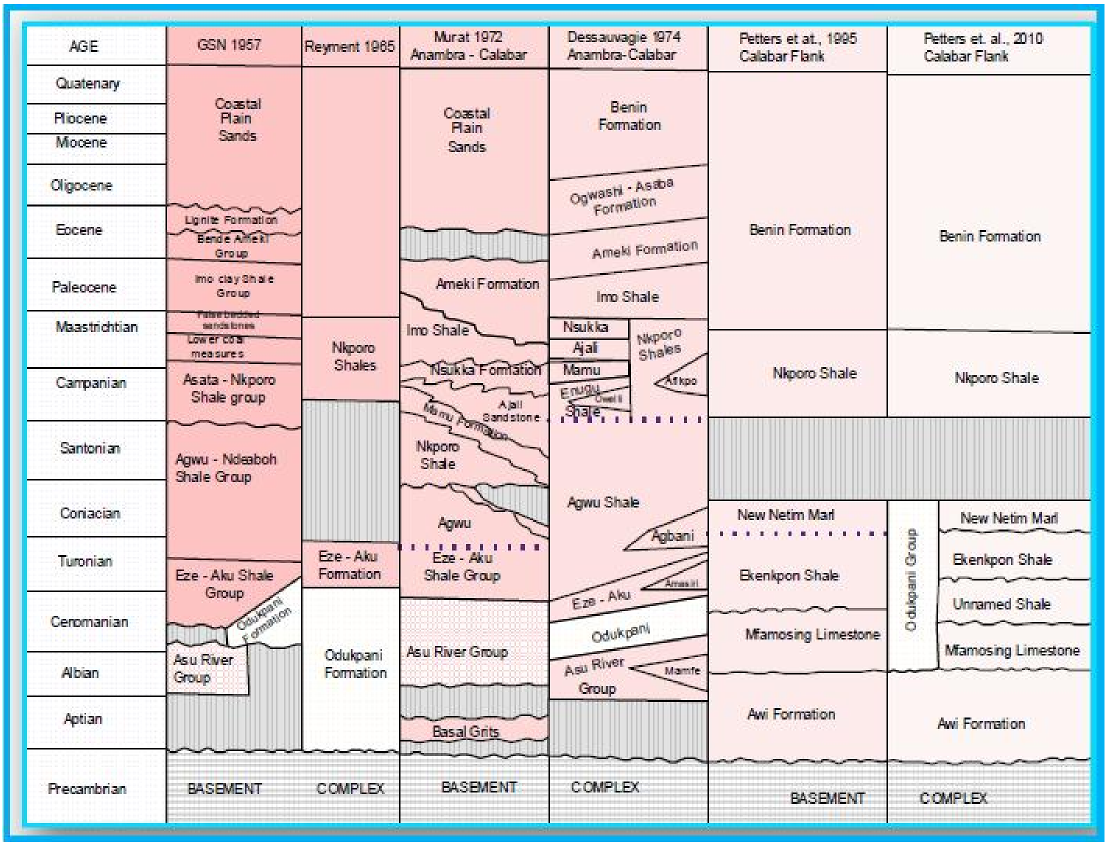


Fig. 2. Map showing Calabar Flank location with respect to the Benue Trough (Modified from [13])

Table 1. Lithostratigraphic correlation between Calabar Flank, Abakaliki Trough, Anambra Basin and the Middle Benue Trough. After [5 and 14]



The lithology of the study area (Fig. 2) is made up of reddish brown clay and overlain by a thick sequence of gray black carbonaceous shale intercalated with peat and woody materials. The peaty material is rich in woody, leafy and root matters. A thin band of reddish-brown ironstone separates the underlying carbonaceous shale from the overlying variegated pebbly sandstone. The pebbly sandstone has pebbles, coarse, medium and fine grained that is poorly to moderately sorted sand grain and the cyclic is capped by overburden earth materials with vegetation.

4. MATERIALS AND METHODS

Twelve (12) samples collected from three lithosections were used for this study. Ten grams (10 gm) of each sample were crushed for palynological analyses, using the normal treatment with HCl, HF and $ZnBr_2$ [15]. The resultant residues were sieved using water and oxidized with HNO_3, then washed with KOH and centrifuged. The final residues were preserved by adding a drop of glycerol/glycerin to each of the properly labeled vials. The mounted microscopic slide for each sample is usually added with small quantity of glycerin jelly at the centre and warm. The identification of the palynomorphs taxa was done with guided work of [16] and some published palynomorph microphotographs. The numerical distribution for the recovered palynomorphs was recorded.

5. RESULTS AND DISCUSSION

5.1 Palynological Assemblages

The palynomorphs recovered and identified are exclusively of continental origin, with few reworked marine palynomorphs found in the sample. A total of one thousand and thirty eight (1038) specimens of pollen, spores and algae were counted from the study site (Table 2) and some of the key species are shown in Fig. 3.

Table 2. Palynomorph distribution in the study area

Species	**Number of count in different locations**		
	L_1	**L_2**	**L_3**
Echitriporites sp	Ab	/	Ab
Distaverrucosisporites simplex	Ab	Ab	/
Retibrevitricolporites obodoensis	/	O	/
Fungal spore	●	O	/
Laevigatosporites discordatus	●	●	/
Acrostichum aureum	●	●	/
Verrucatosporites farvus	Ab	/	/
Polypodiaceoisporites sp	Ab	Ab	/
Verrucatosporites alienus	O	/	/
Pachydermites diederixi	●	●	O
Polypodiaceoisporites retirugatus	●	/	/
Striatricolporites catatumbus	/	Ab	/
Aletesporites sp	/	Ab	Ab
Fusiformisporites sp	O	/	Ab
Regulatisporites sp	/	Ab	Ab
Adanantherites simplex	/	/	Ab
Multicellites sp	/	Ab	Ab
Hilidicellites sp	/	Ab	Ab
Magnastriapites howardi	Ab	/	Ab
Pilosisporites sp	/	Ab	Ab
Retitricolporites irregularis	●	O	/
Psilatricolporites crassus	●	O	O
Multitiareolites formosus	/	Ab	Ab
Psilatriporites sp	/	Ab	Ab
Ctenolophonidites costatus	/	/	/
Psilatricolporites sp	O	Ab	/
Brevicolporitesguinetii	/	/	/
Retitricolporites amazoensis	●	/	/
Zonocostites ramonae	●	●	/
Botryococcus brauni	/	O	/
Spirosyncolporites bruni	Ab	/	Ab
Psilastephanocolporites laevigatus	O	/	Ab
Echiperiporites estelae	●	Ab	Ab
Nypa sp	/	Ab	Ab
Retitriporites sp	/	Ab	Ab
Concentricystes circulus	O	Ab	Ab
Echiperiporites sp	/	Ab	Ab
Dinocyst indeterminate	/	/	Ab
Peregrinipollis nigericus	/	Ab	Ab
Psilastephanocolporites sp	/	/	Ab
Fenestrites sp	/	Ab	Ab
Elaeis guineensis	/	Ab	Ab
Cyperaceopollis sp	/	Ab	Ab
Nympheapollis clarus	/	/	Ab
Striamonocolpites sp	/	Ab	Ab
Acritarch sp	/	Ab	Ab

KEY: / = 1 – 5 *ab = absence*
● *= >16* *O = 6 – 16*

Among the recovered palynomorphs a total of 22 species pollen were identified from a palynological count of 660. They include *Retitricolporites irregularis, Retibrevitricolporites obodoensis, Striatricolpites catatumbus, Psilatricolporites* sp, *Brevicolporites guinetii, Retitricolporites amazoensis, Pachydermites diederixi, Zonocostites ramonae,* *Ctenolophonidites costatus, Psilastephano-colporites laevigatus, Psilastephanololporites* sp*, Echiperiporites estelae, Psilatricolporites crassus, Echiperiporites* sp*, Psilatriporites* sp*, Peregrinipollis nigericus, Spinizonocolpites, echinatus, Elaeis guineensis, Cyperaceopollis* sp*, Nympheapollis, clarus, Spirosyncolpites brunl* and *Striamanocopites* sp*.*

The analyzed sample has a playnoflora contents of seventeen (17) diverse spores assemblages including: Distaverrucosisporites simplex, Laevigetosporites discordatus, Acrostichum aureum, fungal spores, *Verrucatosporites farvus, Verrucatosporites alienus*, *Polypodiaceoisporites retrirugatus, Polypodiaceoisporites* sp., *Echistephanoporites echinatus, Aletesporites* sp*, Rugulat sporites simplex, Fusiformosporites* sp*, Multicellites* sp*, Hilidicellites* sp*, Magnastriatites howardi*. Freshwater algae include *Concentricyst circulus* (six specimens) and 7 specimen of *Botryococcus braunii*.

Attempt was made on the biozonation using the Pantropical Zones of [16–17]. Based on occurrence of some index markers such as *Zonocostite ramonae*, Pachydermites *diederixi, Magnastriatites howardi*, *Echiperiporites estelae, Psilatricolporites crassus, Ctenolophondites*

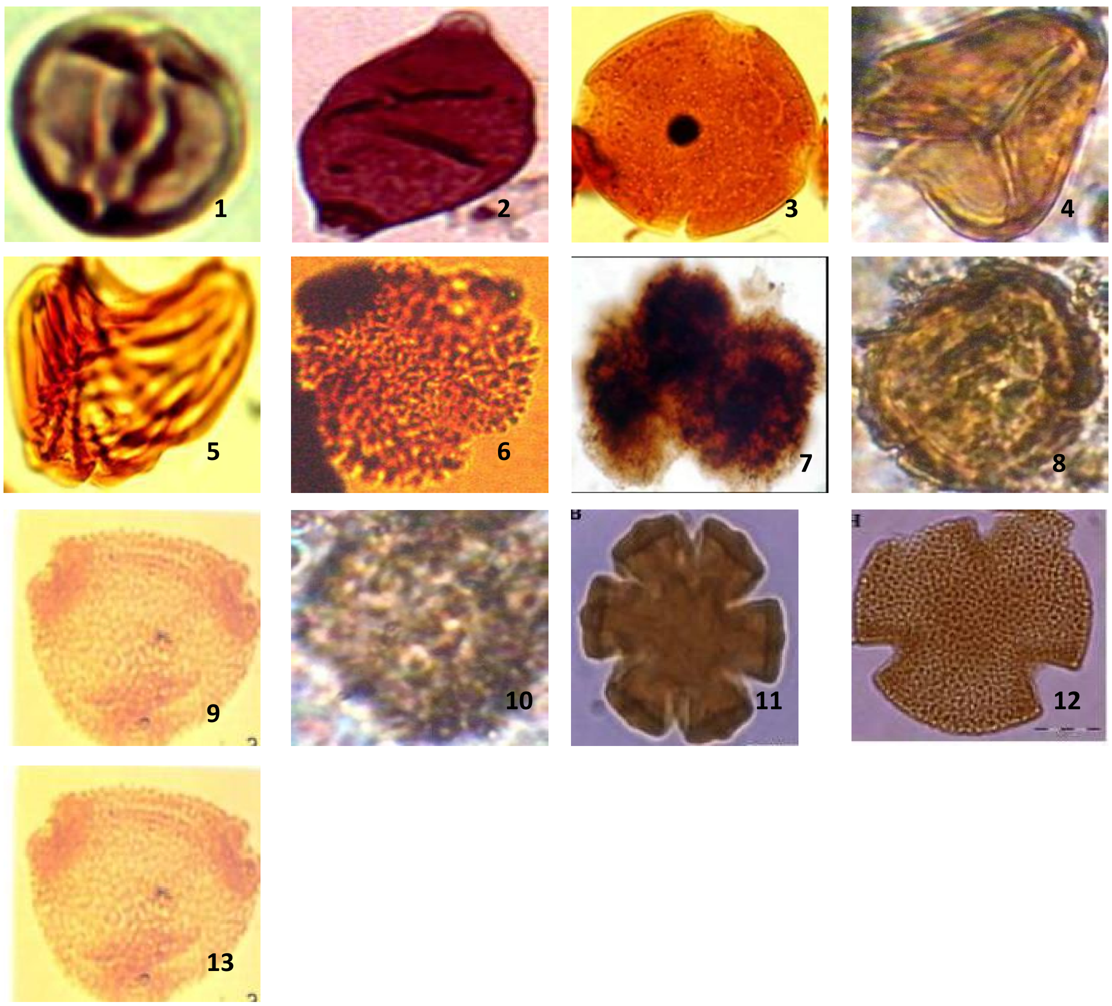


Fig. 3. Photomicrographs of Some selected Palynomorps identified in the study area.
1 *Zonocostites ramonae;* 2 Fungal spore*;* 3, 10. *Pachydermites diederixi*; 4. *Achrostichum aureum*; 5. *Magnastriatites howardii;* 6. *Retitricolporites irregularis;* 7. *Botryococcus brunii;* 8*. Psilatricolporites crassus; 9. Elaies guineensis*; 11. *Ctenolophonidites costatus*; 12. *Retitricolporites* sp; 13*. Retibrevitricol porit es obodoensis*

Table 3. Composite stratigraphical ranges of some selected palynomorphs from the study area

Age							Species
Late paleogene	Neogene						
Oligocene	Miocene			Pliocene			
	E	M	L	E	L		
							Zonocostites ramonae
							Pachydermites diederixi
							Magnastriapites howardi
							Echiperiporites estelae
							Psilatricolporites crassus
							Ctenolophonidites costatus
							Multitiareolites formosus
							Psilastephanocolporites laevigatus
							Nympheapollis clarus
							Retitricolporites irregularis
							Peregrinipollis nigericus
							Brevicolporites guinetii
							Retibrevitricolporites obodoensis
							Striatricolpites catatumbus

KEY: E = Early
M = Middle
L = Late

coastatus, Multiareolites formosus, Psilastenphanocolporites laevigatus, Nympheapollis clarus, Peregrinipollis nigericus, Brevicolporites guinetii, Retibrevitricolporites obodoensis and Striatricolpites catatumbus. Three palynozonations were established. These are: Upper *Magnstriatites howardii*, *Crassoretitriletes vanraadshoveni* and *Echitricolporites spinosus* Zones of [16].

The oldest Palynozone is *Magnstriatites howardii* (P600). The quantitative occurrence of *Z. ramonae* throughout the bases of the sample sections (L1-L3) marked the penetration of this zone. According to [16], Rhizophora (*Z-ramonae*) is absent from pre-Miocene sediments and start occurring suddenly in high percentages in the lowermost Miocene. The rare occurrence of *Magnstriatites howardii* in the lower section of location 2 (L2), shows the penetration of *Magnastriatites howardii* zone.The following palynoflora show the penetration of this palyzone (*Magnastriatites howardii* zone): *Ctenolophondites costatus*, *Psilatricolporites Crassus* and *Retitricolporites irregulari*. The occurrence of *Psilastenphanocolporites laevigatus* which is marker species of Late – Miocene [18] confirms this palynozone.The quantitative occurrence of *Multiareolites formosus* and *Nympheapollis clarus* at the top of locations 1 and 2 (L1-2) and the occurrence of *Psilastenphanocolporites laevigatus* infer *Echitricolporites spinosus* Zones of Late - Miocene [17–19].

The occurrence of these age diagnostic palynomorphs suggest that the deposition of these sediments occurred during Early-Miocene to Late Miocene period (Table 3).

6. DEPOSITIONAL ENVIRONMENTS AND PALEOCLIMATOLOGICAL ANALYSIS

The reconstruction of the depositional environment of the samples occurring in the studied section is done basically on the palynomorphs association. From the work of [20] show that environmental factors such as water temperature, salinity, hydrography and proximity to shoreline areas affect the distribution pattern abundance and morphology of palynomorphs. The absence of significant dinoflagellates which is a marine palynomorphs is a good indicative of a non-marine influence (almost zero saline water condition) in this area of study.

The high occurrence of *Rhizophora* type (*Zonocoastites ramonae)* is indicative of mangrove environments [16] in the coastline and infer proximity to ancient shoreline. The rare occurrence of *Botryococcus brunii* algae indicates deltaic/fluvial/lagoon deposits of fresh water condition in the studied section while *Concentricyst circulus* a fresh water algae is typical alluvial environment characterized of freshwater swamp of [21]. The co-occurrence or association of *Pachydermites diederixi, Verrucatosporites* and *Laevigosporites* indicate a swamp fresh water or brackish water environments [22]. This may likely occur in the freshwater swamp behind the mangrove. The high representative of fungi components in the studied represents rapidly degradning woody tissue in an ecosystem where there are dense plants [23]. This condition according to the later author occurs under aerobic condition and is preponderant in deltaic environment. Terrestrially- derived pollens and spores are the only occurring palynomorphs in the studied section and the may be localized on the little transported by wind and /or waters medium. This may also be signalled by occurrence of fine to coarse grained lithofacies of ferruginised siltstone, carbonaceous shale, coal and sandstone. The relatively high frequency of the terrestrial/marine ratio, shows total absence of any marine influence in the area. The terrestrially derived palynomorphs are characterized by high abundance of *Zonocoastites ramonae. Retritricolporites regualris R. amazoensis Psilatricolporites crasssus, Pachydermites diederixi, Lacvigatosporites* sp*, verrucatosporites* sp, and *Achrostichum aureum*. These micro flora are environmental indicators of coastal swamp environments consisting of mangrove and freshwater swamp/forest settings in the vicinity of the deposited sediments. These micro floral elements are in corroboration with [24] on palynological aspects of the site 767 in the Calebs Sea which indicates the presence of existence wetland deposits consisting of mangrove forest coastal and low land swamps during Middle and Late Miocene. These wetland deposits can be infer in this study with the presence of coal deposits which represents fluvial floodplain/ swamp influence. The high occurrence of these mangrove and freshwater swamp and rainforest pollens and spores taxa in the studied section indicate deposits that were affected by humid, warm and wetter climate in the tropical lowland climate [25–27]. This wet climate condition indicates high abundance of mangrove swamp forest vegetation and abundance of monolete and trillete spores [28]. Abundance of ferns spores and fungal elements in the study area infer heavy precipitation and warm humid condition [29].

The total, almost absence of savanna pollen taxa (except paucity taxa of *Fenestrites sp, Cyperaceopollis sp, Multiareolites formosus)* indicate non-presence of drier climate [16,26,30]. These authors pointed out these climates of wetter and drier conditions to be associated with fluctuation of sea level. They have it that humid and wetter climate is associated with rise in the sea level while low ratio of humidity vs. aridity is low seal level fall Therefore these sea level oscillation infer transgression and regression phases [31]. This area studied have high humidity vs aridity ratio signifying transgression, which would have flourish with marine taxa but was total absence except some few reworked/transported acritarch and indeterminate dinoflagellates cysts. The dearth of the marine taxa as recorded in the study sections may have attributed to high influence of freshwater swamp/mangrove conditions of the area and the high influx of freshwater deposits from the continental areas. This is also due to higher concentration of pollens in the Middle and Upper Miocene sediments, which according to [24] is affected by much higher terrigenous organic component of those sediments. This may also be attributed to a non-marine activities in the Neogene sediments of Calabar flank unlike in the adjacent Niger delta, where the flourished. . The present of clay underneath the carbonaceous shale may attribute to little marine influence in the mangrove swamp condition [32]. The dearth of marine taxa show that the area under study falls within the continental sediments of Benin Formation in the Calabar flank.

7. CONCLUSION

The miospores recovered from outcrop sediments of Benin Formation sediments on the Calabar flank were relatively abundance and diverse. These microfloral assemblages shows that the sediments penetrated Early- Late Miocene time, based on the presence of some index micro floral elements. The abundance of woody and vegetation materials in the lithology indicate the prevalence of freshwater environment. The existence of non-marine swamp in the study area is strongly supported by the presence of none marine lithologies.The palynomorphs yielded mangrove swamps, freshwater swamp and rain forest phytoeclological units. The micro floral assemblage recovered from sediments of carbonaceous shale, coal, ferruginised siltstone and sandstone inferred warm, and wetter climate. The distribution of terrestrial and marine species of different palynomorphs taxa were used as a tool for the interpretation of the paleoecological/paleoenvironmental condition. Savanna and mountainous climate were absent and their micro floral markers such as *Graminidites annulatus and Podacarpidites clarus* were not recovered. However the paleoclimate of these deductions can be correlated with the presence tropical humid climate and may give a clue to detail studies of paleovegetation, paleoclimatology and paleobiogeography of Miocene to Miocene/Pliocene age.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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