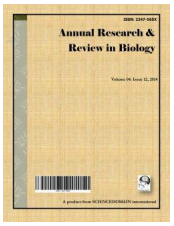

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Quantitative Analysis of Palynomorphs from Neogene Deposits in Calabar Flank: Implication for Paleoenvironmental Interpretation

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Authors' contributions

This work was carried out in collaboration between all authors. Author IAE designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors IDO and TLB managed the analyses of the study. Author AEB managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Palynological analysis of outcrops samples of Benin Formation in Southern sector of Calabar Flank, Nigeria yielded sixty seven(67) palynomorphs species, made up of thirty-eight (38) pollen species, sixteen(16) spores species, 2 species of algae with fewer indeterminate dinoflagellate cyst and microforaminiferal wall-linings. The palynological assemblage consists of abundant polyporate (30%), tricolporates (34%), triletes (14%), monolete spores (19%) and dinocyst species 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

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Brevicolporites guinetii for the pollen. Spores (ferns and fungi) include *Laevigatosporites discordatus, Acrostichumaureum, Verrucatosporites alienus, Polypoddiaceoisporites retirugatus, Magnastriatites howardi, Fusiformisporites sp* and fungi spores. The quantitative analysis of the fossil assemblage, its composition leads to the understanding of the environment of deposition as is alluvial/fluvial and coastal settings characterized by freshwater swamp/rain forest and mangrove forest. This is correlated with warm, humid and high rainfall climate of tropical vegetation.

Keywords: Palynological analysis; Calabar Flank; quantitative analysis; environment of deposition.

1. INTRODUCTION

The rapid growth of populations in Calabar Municipality of Cross River State, Southeastern Nigeria recently has led to expansion of some roads networks, which eventually excavated some rock outcrop samples. This condition has allowed for exposure of some inaccessible outcrops in these areas. The outcrops are mainly continental clastic sediments of Tertiary Benin Formation in Calabar Flank. The sediments are of continental origin, hence marine taxa may eventually be absent or rare in numbers. It is therefore necessary to look into the palynofloral contents and used it quantitatively to interpret the paleoenvironmental conditions of these outcrops which lack marine fauna and flora.

1.1 Location of the Study Area

The area of study is located along Ikot Asa in Calabar Municipality of Cross River State, Southeastern Nigeria. The geographic position lies within latitude N050 01′ 42′ to N050 01′ 54′ and longitude E008 21′ 50′′ to E008 01′ 57′′ (Fig. 1) and is part of Southern Sector of Calabar

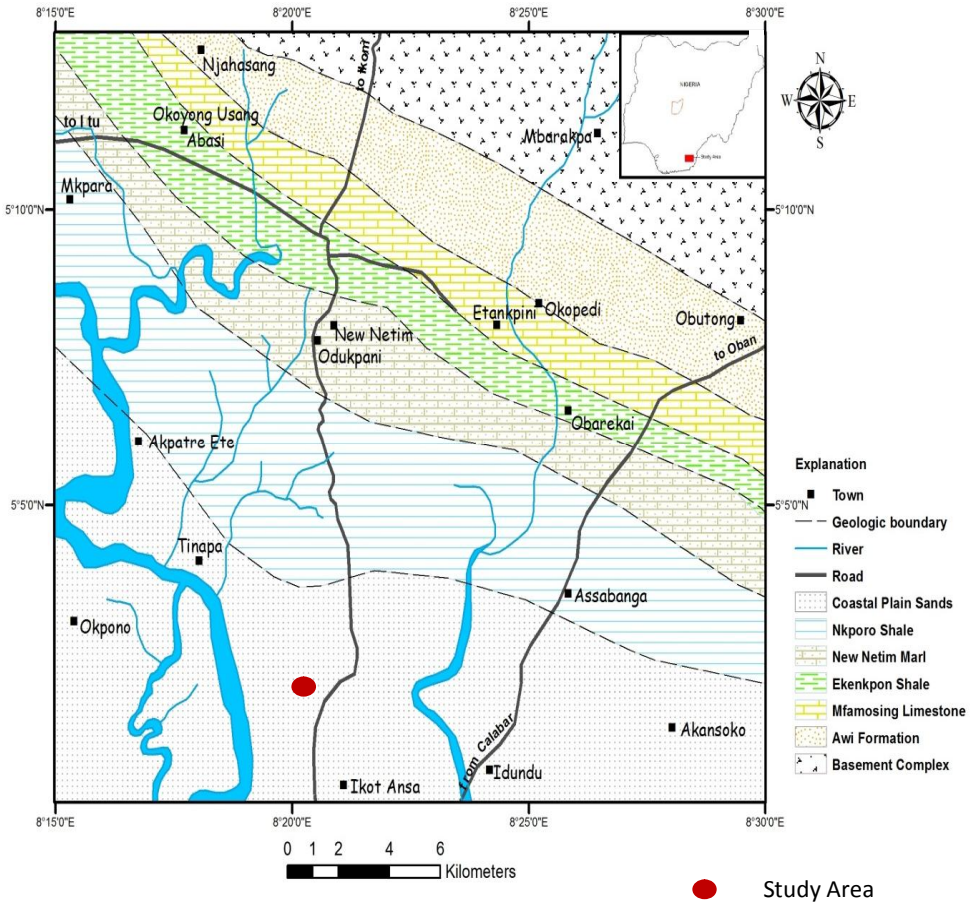


Fig. 1. Geologic map of the study area

Fig. 2. Outcrop of the study area

Flank. The lithology of the study area (Fig. 2) is made up of reddish brown clay with paucity 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 ferruginised sandstone separates the underlying carbonaceous shale from the overlying variable colour pebbly sandstone. The pebbly sandstone has pebbles, sandstone of coarse, medium and fine grained that is poorly to moderately sorted grained, in a cyclic form that is capped by overburden earth materials with vegetation.

1.2 Geologic Background

The Calabar Flank is an epirogenic sedimentary basin in southeastern Nigeria [1]. The basin bounded the southern rim of Oban Massif in the north, Calabar hinge line separates the basin from Niger Delta basin in the south,Ikpe platform and Cameroon volcanic trend in the west and east respectively (Fig. 3). The origin of this basin is associated with the opening of the south Atlantic in the Mesozoic era when the South American drifted away from African plates. The major tectonic elements operating within the basin include the Ikang Trough (graben structure) and Ituk High (horst) which were mobile depression and stable mobile submarine ridge that initiated sedimentary distribution facies [1-2].

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 north of Calabar, along the fringes of the Oban Massif basement complex. The formations are best exposed along Calabar –Ikom road and a succession consists of (5) Cretaceous and a Tertary 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 [3]. This is overlain by Mfamosing Limestone of Middle- Upper- Albian age [4-5], which is the first marine transgression into the basin. This inturn succeeded by Late Albian-Cenomanian to Turonian, Ekenkpon Shale [5]. Subsidence on

the faulted blocks of horst and graben allow wide spread deposition of shales with minor marl and mudstone intercalation. The New Netim Marl of Coniacian [6] in age, succeeded the shale. The Santonian period was marked by a major unconformity in Nigeria. Nkporo Shale of Late Campanianto Early Maastrichtian [7] 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.

2. MATERIALS AND METHODS

Twelve (12) samples were collected from three lithosections were used for this study. The retrieved samples were put into clean and well labeled sample bags to avoid contamination. Ten grams (10 gm) of each sample were crushed and taken for palynological analyses, following the normal treatment with HCl, HF and $ZnBr_2$ [8]. Then resultant residues were sieved using water and oxidized with HNO_3, then washed with KOH and centrifuged. The final residue were preserved by adding a drop of glycerol/glycerin to each of the properly labeled vials. The mounted microscopic slide for each sample are usually added with small quantity of glycerine jelly at the centre and warm. The identification of the palynomorphs taxa was done with guided work of [9] and some published palynomorph mircophotographs. Their taxonomic classification was based on the external morphology, by comparing them with some published literatures such as [9-11]. The numerical distribution for the recovered palynomorphs are recorded.

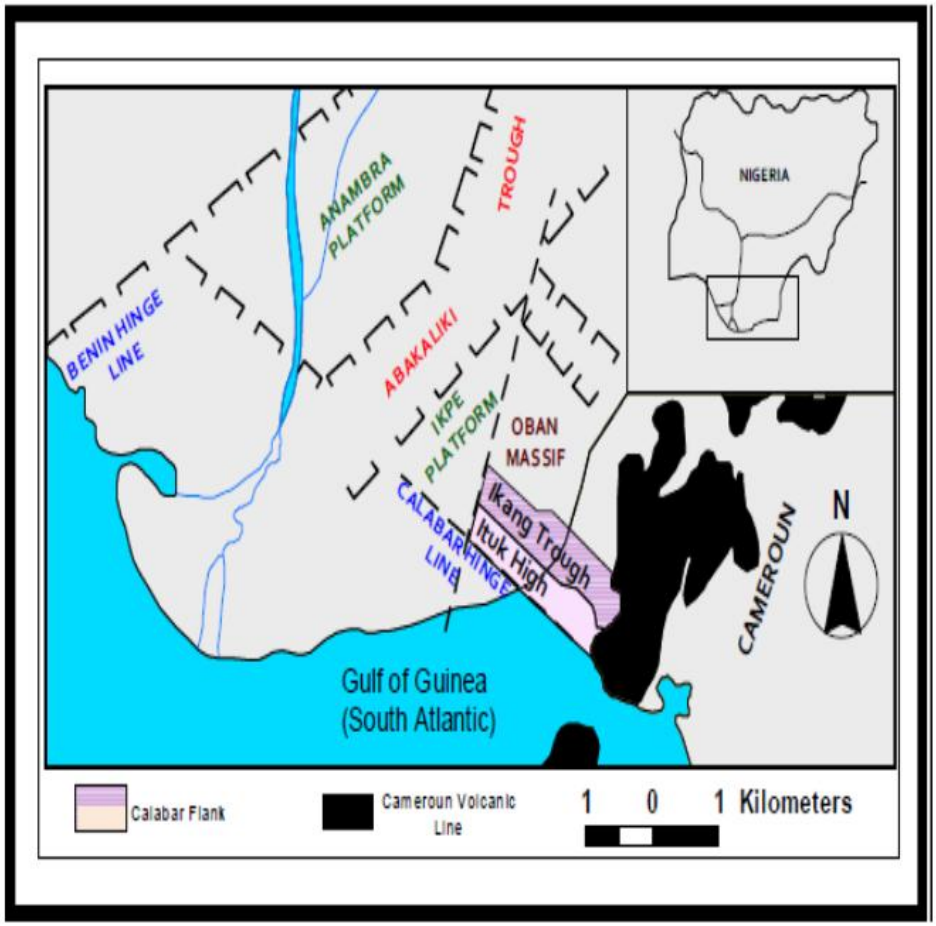
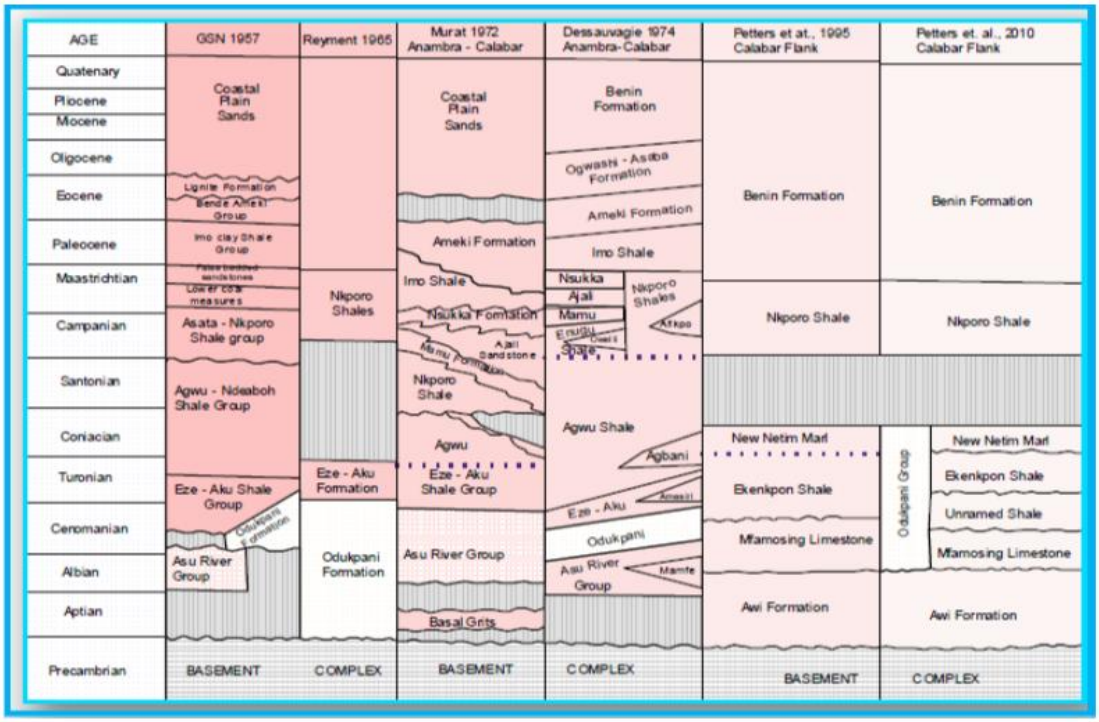


Fig. 3. Map showing Calabar Flank location with respect to the Benue trough [1]

Table 1. Stratigraphic correlation between Calabar Flank and other Nigerian sedimentary basins [2,6]



3. RESULTS AND DISCUSSION

3.1 Palynological Analysis

The Benin Formation in Calabar Flank lacks marine microfossils because of its predominate clastic continental nature. However some carbonaceous shale, clay and few sandstone/ ferruginsed sandstone deposits in the study section, yielded moderately rich palynomorphs.These palynomorphs were moderately persevered. Their internal structures could not be adequately examined and studied. Their systematic description/paleontology of individual species are shown below from some publications. There was therefore no need to describe their morphological reports here.

Generally, the studied outcrops contain very good amount of palynomorphs with atotal of 57 species encountered and a sum total of 1,106 specimen of palynomorphs were counted. The floral elements showed that the assemblage consist of angiosperm pollen, spores (pteridophytes and fungi), algae and with some indeterminate dinocyts and foraminiferal linings. This is made up of 39 species of angiosperm pollen grains, 16 species of spores (pteridophyte and fungi), and 2 species of algae. Angiosperm pollen grains has the highest abundance and diversity and the statistical of summary of other microflora are presented below in Fig. 5.

Some of the common pollen taxa recovered are: *Retitricolporites irregularis, Retibrevitricolporites obodoensis, Striatricolporites catatumbus, Pachydermites diederixi, Psilatricolporites crassus, Psilatricolporites sp, Brevicolporites guinetii, Retitricolporites amazoensis, Zonocostites ramonae, Botryococcus brauni, Psilastephanocolporites laevigatus, Echiperiporites estelae, Elaeis guineensis, Cyperaceopollis* sp*, Echitriporites* sp, *Ctenolophonidites costatus.*

Common occurrence of spores recovered include: *Distaverrucosisporites simplex, Laevigatosporites discordatus, Acrostichum aureum, Fungal spore, Verrucatosporites farvus, Polypodiaceoisporites retirugatus,, Verrucatosporites alienus,, Fusiformisporites* sp,, *Magnastriapites howardi* Algae present are *Botryococus br*and *auni Concentricystes circulus*. Marine taxa are and indeterminate dinocyst and microframiniferal linings.

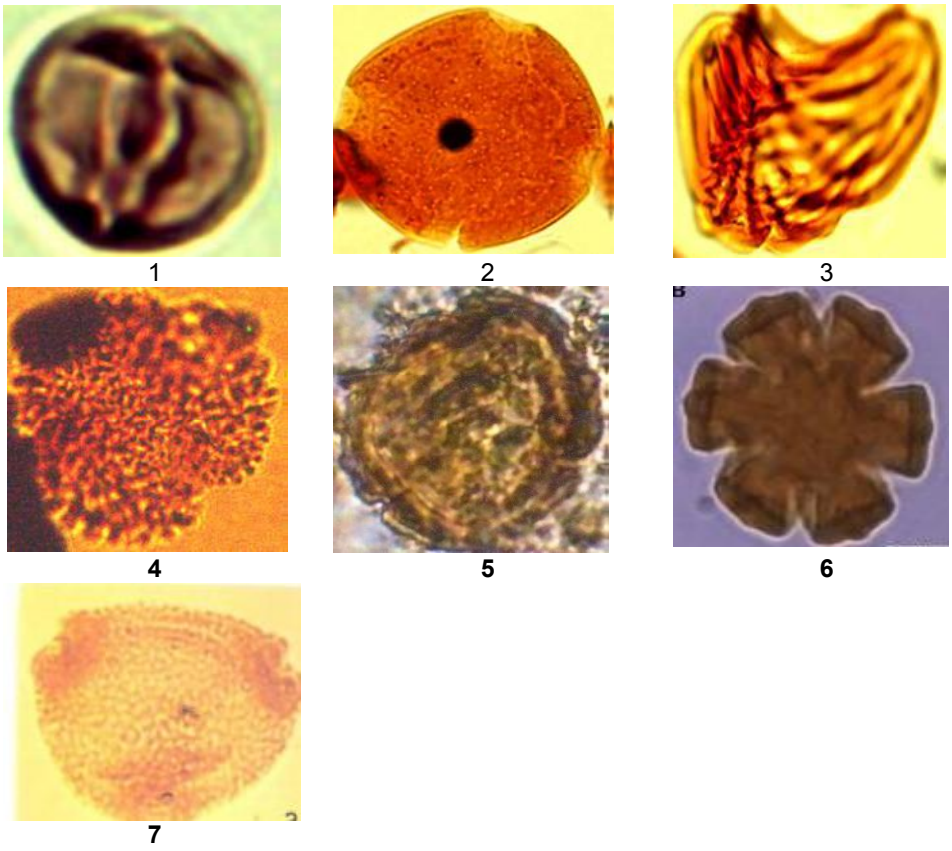


Fig. 4. Photomicrographs of Some selected Palynomorps identified in the study area: 1 *Zonocostites ramonae; 2. Pachydermites diederixi; 3. Magnastriatites howardii; 4 Retitricolporites irregularis; 5. Psilatricolporites crassus; 6. Ctenolophonidites costatus and 7. Retibrevitricol porit es obodoensis*

The palynological assemblages were dominated by pollen and spores. The pollen grains make up the highest frequency of the recovered palynoflorals. This consists of several species of tricolpate, tricolporate, polyporate, polycolpate, triporate and polycolporate while the spores are made up of several species of monolete, trilete and fungal spores. The compositional distributions of thses palynoflora is shown in Fig. 5.

Tricolpate has *Striatricolpates catatumbus* (1%) and common among the tricolporate are *Psilatricolporites crassus (10%), Retitricolporites irregularis (7%) and Zonocostites ramonae (12%).* Polyporate pollen is dominated by *Pachydermites diederixi* which is one most of the abundant *(26%)* and Echiperiporites estelae *(3%).* The rest of the pollen groups are rare. The trilletes spores are dominated with *Laevigatosporites sp (11%)* and *Verrucatosporites sp (2%).* Among the monoletes spores *Acrostichum aureum,* is the most abundant *(12%)* and *Magnastriapites howardi (2%).* Fungi spores dominated by *Fusiformisporites sp* and is 15% of palyno assemblage.

Only 2 species of freshwater algae were encountered and include *Botryococus brauni* and Concentricystes *circulus*. Marine taxa have a total of 4 count of indeterminate dinocyst and microframiniferal linings.

3.2 Paleoenvironmentation Proxies and Distribution of the Sporomorphs

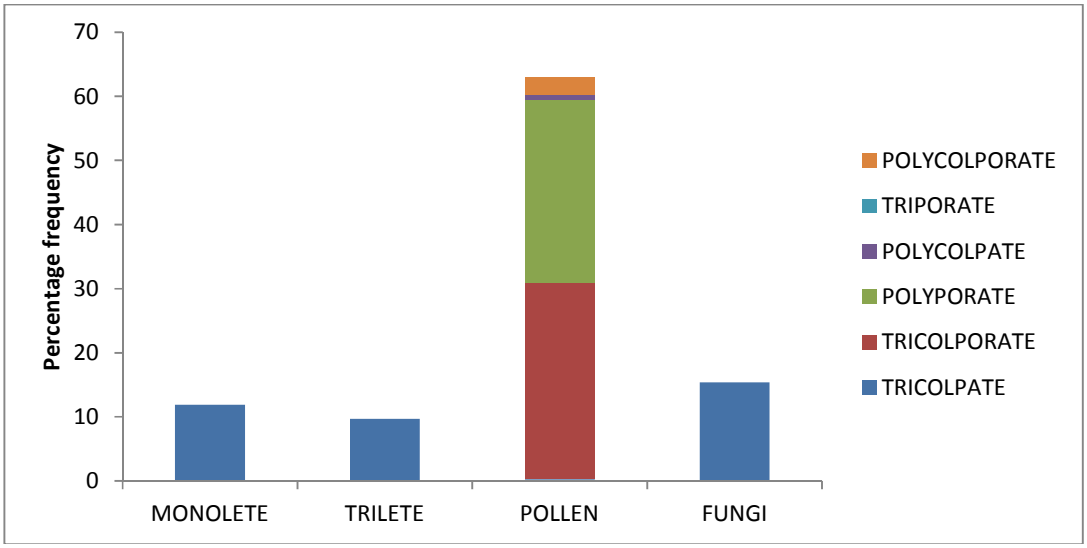
Paleoenvironmental analysis is the interpretation of the depositional environment in which the rock unit was formed, based upon the fossils found within the unit [12]. The paleoenvironmental interpretation of the palynomorphs in the studied area was done based on quantitative analysis of some

diagnostic taxa related to paleoenvironment proxies as describe below:

3.2.1 *Zonocostites ramonae* (*Rhizophora*)

This is tricolprate pollen grain and the species occur in the 3 locations sampled. The taxon is mangrove species which occur along the coastlines, where there is brackish influence especially on mud flats. The percentage of this species varies between 20%-70% in the three locations. According to [13-14] an abundance of fossil *Rhizophora* above 40% in sediments indicates good representation of mangrove swamp that infer a rise in sea level and a humid tropical lowland climate.

LOCATION ONE (L1)



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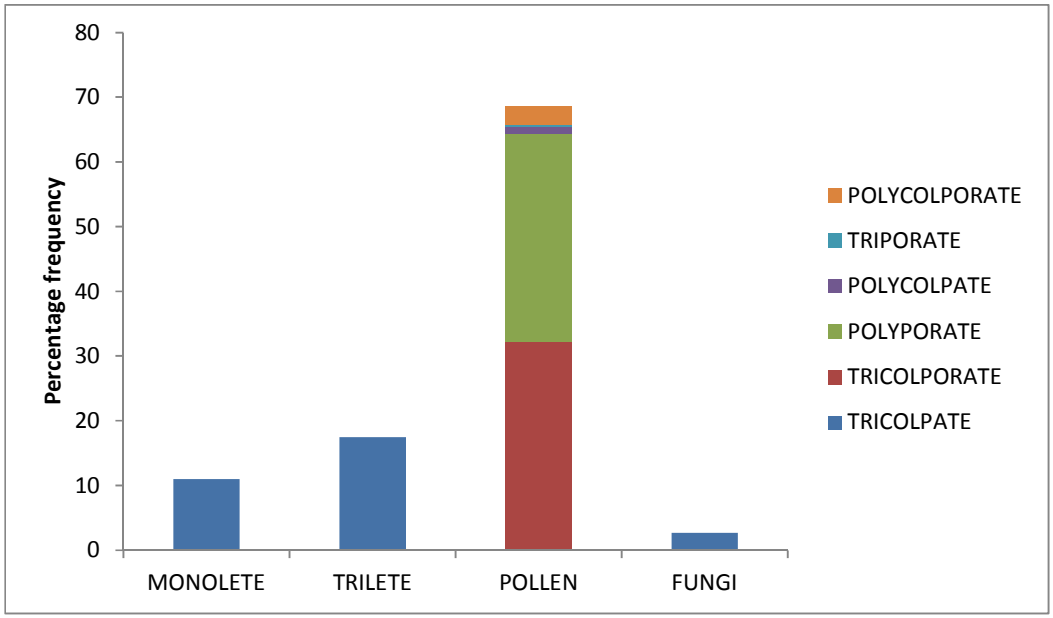
LOCATION TWO (L2)



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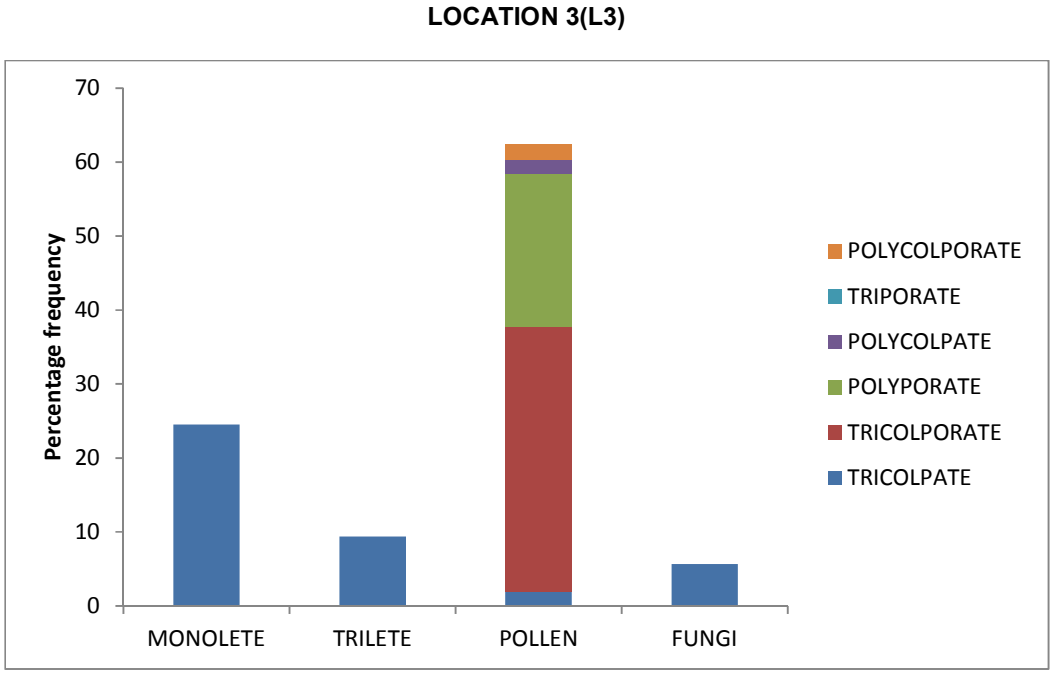

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Fig. 5. Frequency (%) distribution of sporomorph groups in the 3 locations (L1-3)

3.2.2 *Pachydermites diederixi* (*Symphona*)

P. diederixi is grouped as the most abundant polyporate angiosperm pollen grains in this study. This is an important pollen producer in the swamp forest as identified by [15]. This species thrives on the upper delta plain and along the rivers. In the studied sections *Pachydermites diederixi* occurred as the most abundance flora with highest abundance in L-1, and infer species infer freshwater swamp.

3.2.3 *Retitricolporites irregularis (Amanoa)*

This one of the dominant tricolporate pollen grains in the study area. According [15], this taxon is a good indicator of hinterland rainforest. Rainforest are restricted to well drained areas and their distributions are of climatic influence. The species distribution is moderate and occur within all the stratigraphic sampled units as rainforest taxon.

3.2.4 *Acrostichum aureum*

This is a fern plant characterize of mangrove and associated with lakes and freshwater marshes in the Cenozoic times [16], while [9,17] classify this pteridophyte as a back mangrove fern on their observation of microfossils assemblages as proxies for paleoenvironmental determination from Miocene sediments of northwest Borneo. The dominant of this trilete pteridophyte fern spores in this study suggest a tidal swamp shoreline inhabited by mangrove.

3.2.5 *Botryococcus brauni*

This chlorococcales green algae flora fossils occur in deposits of fluvial, lakes and deltaic facies [18] and can tolerate little/low salinity. Their low occurrence in the sediments of investigated area signifies minimal marine influence.

3.2.6 Fungi spores

The presence of fungi spores and form such *Fusiformisporites* sp are often associated with rapidly degrading woody tissues under oxic condition [15]. Variation in their abundance infer closeness to the coast [18]. Fungi spores occurrence is over 70% in the study area and signify adverse conditions in a deltaic setting [19].

3.2.7 *Magnastriatites howardi*

This species is a small spores fern of alluvial plain and coastal swamp in shallow water [9].

The occurrence of this trilete fern spores which is environmental marker species in this study, signifies coastal (lower deltaic plain) environment. The sporadic occurrence of this species shows incursion of freshwater and the presence of open vegetation [19].

3.2.8 *Laevigatosporites*

This genus occurred in all the 3 studied locations as the most abundance and diverse taxa. It is the most dominating monoletes fern spores. These spores inhabit freshwater swamp and marshes in a low rainforest areas [20-21]. The maximum occurrence of these species infer warm and humid climate.

3.2.9 *Polypodiaceoisporites sp*

Polypodiaceoisporites sp *is* the less occurring monoletes fern spores in this study. This species is refer to as *Pteris* by [22-23]. It is a fern spore inhabiting lower coastal wet and humid environment [24]. This genus is constantly occurring throughout the entire sections.

3.2.10 *Ctenolophonidites costatus*

This is the only occurring polycolpate pollen grain in the investigated area. The parent plant is *Ctenolophon engler* is still living in West Africa [9]. This species belongs to the family of *Ctenolophonacea* which is of a wet tropical coastal vegetation. The family is the representative of trees in humid swamp forest environments and along river banks [25,26].

3.2.11 *Psilastephanocolporites laevigatus*

P. laevigatus is a polycolporate pollen grain. This species is a tropical rainforest plant [11] and were seen in all the sampled areas in a significant representation.

3.2.12 *Psilatricolporites crassus*

This taxon which is a tricolporate pollen grain, inhabit coastal environment of wet and humid condition [24,27] The species flourishes in environment under marine water inundation and tidal activities. The present of this species infer tropical coastal climate.

3.2.13 *Concentricystes circulus*

This is a freshwater algae indicating sedimentation in coastal environment close to mangrove and shallow marine vegetation [28]. This freshwater species are more of typical of freshwater environment and can tolerate variation in salinity [18]. The presence of *C. circulus* in all the sampled locations infer alluvial environment characterized by freshwater swamp.

4. SUMMARY

Palynological analysis of outcrops samples of Benin Formation in Southern Sector of Calabar Flank, Nigeria was carried out and the result yielded sixty seven (67) palynomorphs species, made up of thirty-eight (38) pollen species, sixteen(16) spores species, 2 species of algae with fewer indeterminate dinoflagellate cyst and microforaminiferal wall-linings. The quantiatative and qualitative occurrence of some paleoevironmental flora markers taxa such as *Zonocostites ramonae, Pachydermites diederixi, Retitricolporites irregularis, Acrostichum aureum, Botryococcus brauni,* Fungi spores, *Magnastriatites howardi, Laevigatosporites, Polypodiaceoisporites sp, Ctenolophonidites costatus, Psilastephanocolporites laevigatus, Psilatricolporites crassus, Concentricystes circulus* infer that the environment under study is coastal deltaic plain characterized heavy precipitation in wet and humid tropical climate.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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