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Palynological Evaluation of Cretaceous Sediments of Ekenkpon Shale, Calabar Flank, Southeastern Nigeria

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Abstract Palynological biostratigraphic analysis was carried out on sediments deposited within Calabar/ Odukpani Road Junction. This study aimed at evaluating the age of the sediments utilizing the index palynomorphs and paleoenvironmental significance of this deposit. Lithological description of the samples reveal that this section is predominantly made up of shale showing dark grey to black colours. They are sometimes thin laminated with ammonites mounds while some minor interlaminated mudstone, calcareous mudstone, marlstone and sand occur. The biostratigraphic results reveal that the sediments contain dominantly of pollen and spores of gymnosperms (46%), angiosperms (26%), and pteridophytes (15%) with rare occurrence of fungi spores (10%) and dinoflagellate cysts (3%). The microfloral assemblages have occurrence of some important index biostratigraphic forms such a *Classopollis jardinei*, *Classopollis* sp, *Cretacaeisporites mulleri*, *Cyathides* sp, *Ephedripites multicostatus*, *Ephedripites jansoni*, *Gnetaceapollenites* sp, *Monocolpollenites sphaeroidites*, *Steeves ipollenitesebi nodosus*, *Triorites africaensis* and *Cribroperidinum* sp belonging to the Cenomanian–Turonian age. The occurrences of the afore-mentioned palynomorphs correlate with the palynlogicalzone of *Afropollis jardinus/ Triorites africaensis/ Cretacei porites scrabratus* Assemblage Zone. The encountered palyno-assemblage suggests a marginal depositional environment. The paucity of marine palynomorphs in these sediments may be due to high occurrence of land derived palynomorphs. The paleoenvironmental setting consists of semi-arid, humid and wet condition.

Keywords Palynostratigraphy, Ekenkpon Shale, Marginal marine, Cenomanian-Turonianage, Calabar Flank

Introduction

The Calabar Flank, located in Southeastern Nigeria, is one of the least investigated sedimentary basins in the country, in terms of its hydrocarbon potentials even with almost a zero militia insurgency, governmental and non-governmental attentions are unfocused in this region. Due to lack of hydrocarbon exploratory wells, only little geologic research has been carried out within this basin. The Calabar Flank basin is among the coastal basins in Nigeria and is located on the eastern flank of the Lower Benue Trough (Abakaliki Trough which is part of the Lower Benue Trough) in Southeastern Nigeria (Fig. 1). Few investigations carried out by many scholars in the Calabar Flank focused on the sedimentology, foramimferal biostratigraphy and other related area of geology. Palynological biostratigraphic information is rare and lacking with respect to this basin, with only few exceptional ones including Edet and Nyong [1] and Itam *et al.*, [2-3] which concentrated on the Campanian-Masstrichtian Nkparo Shale and Tertiary Benin Formation respectively. Based on the relevance of this study,

there is need to increase the knowledge of palynological study of this basin by carrying out investigation on the shale outcrop sample exposed around Calabar / Odukpani Road Junction, in a view to use the encountered palynomorphs for the identification of the sediment age and evaluating the paleoenvironmental condition of the setting.

Location of the Study Area

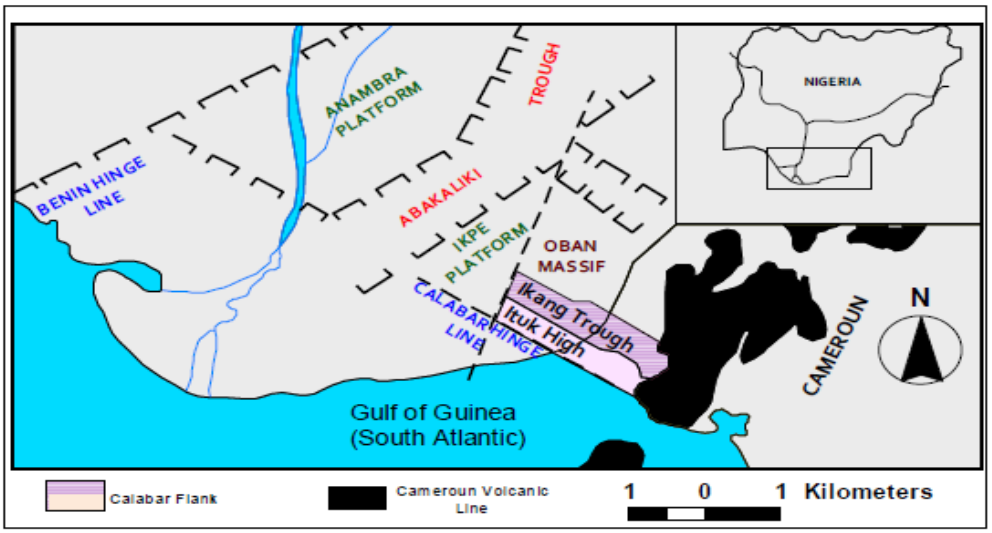


Figure 1: Geologic sketch map showing location of Calabar Flank [4]

This study area under investigation is located along Calabar / Odukpani Road Junction; one of the Unicem newly constructed road truck carriage way in the southeastern part of Nigeria. The area has geographical coordinates of latitudes N05° 08′ 56.2″ of the Equator and longitudes E008° 20′ 18.2″of Greenwich Meridian (Fig. 2). The outcrop samples are predominantly shale with mudstone and minor mud stone, marl stone and sandstone occurrences.

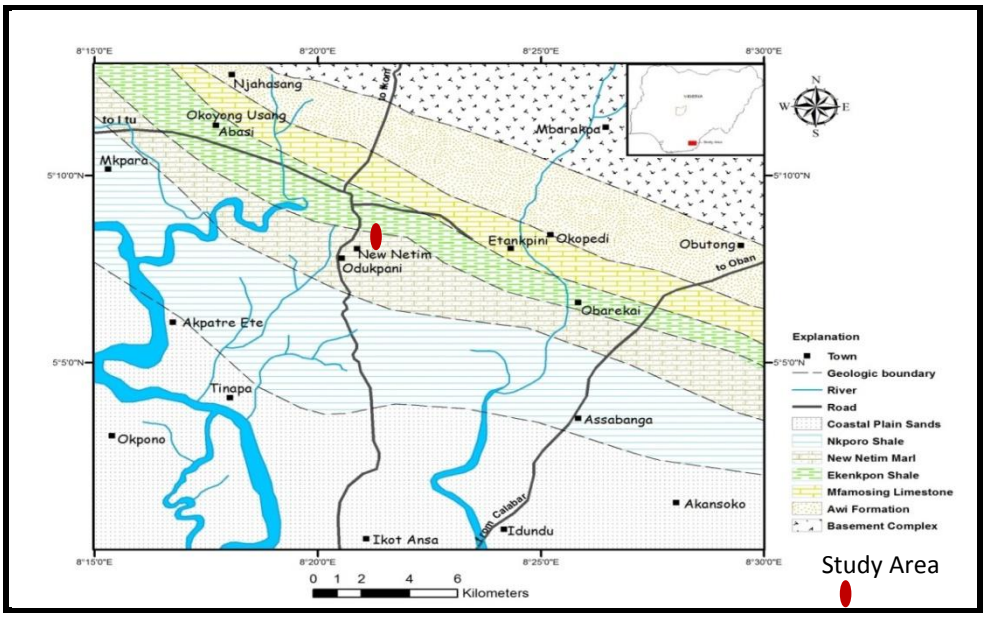


Figure 2: Geological map of the study area

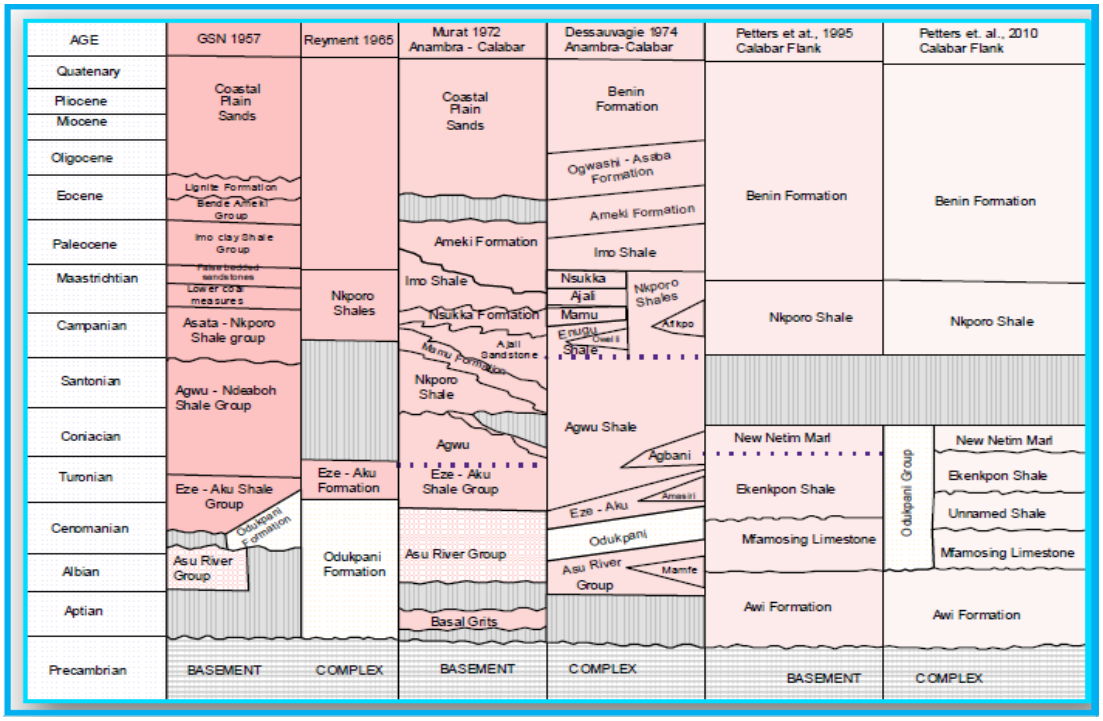
Geological Setting

The Calabar Flank is an epirogenic sedimentary basin in the southeastern part Nigeria [5]. The basin according to Nyong [4], 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 delineates it in the west and east

respectively (as seen in fig 1). 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 within the basin include the Ikang Trough (graben structure) and Ituk High (horst) which were mobile depression and stable submarine ridges that influenced the distribution of the sedimentary facies [4-5].

The stratigraphic succession in the Calabar Flank is shown in table 1. The encountered sediment thickness is over 3500m with the onlap (or featheredge) of the outcropping units, along the fringes of the Oban Massif Basement Complex. This formations best exposed along Calabar -IkomRoad with succession of five (5) Cretaceous subdivisions and a Tertiary lithostratigraphic unit. Awi Formation is the oldest basal unit and sits non-conformably on the Basement Complex of Oban Massif. This formation is Aptian in Age [6]. This is overlain by Mfamosing Limestone believed to be Middle– Upper Albian age [7]. This however, indicates the first marine transgression into the basin. This in turn is succeeded by Late Albian- Cenomanian through Turonian, Ekenkpon Shale [8-9]. Subsidence on the faulted blocks of the horst and graben structures allowed wide spread deposition of shales with minor marl and mudstone intercalations. The New Netim Marl of Coniacian [4] in age succeeded the shale. The Santonian period was marked by major unconformity within this basin and in other related Cretaceous basins in Nigeria. Conversely, the Nkporo Shale dated Late Campanian-Early Maastrichtianage [1, 3] capped the marine transgression and Mesozoic sedimentation in the Calabar Flank. The Tertiary continental deposits which consists of coarse to sometimes medium grained sand of the Benin Formation [2] completes the sedimentation episode in the basin (as indicated in fig. 2).

Table 1: Lithostratigraphic correlation between Calabar Flank, Abakaliki Trough, Anambra Basin and the Middle Benue Trough [4,7]



Materials and Method

A total number of eleven shale samples from outcrop section along Calabar / Odukpani Road Junction were analyzed for microfloral elements. About 20g of each fresh unaltered sample was broken into smaller fragments and dried; this was immediately followed by standard palynological analysis using Wood et al. [10]. The crushed samples were poured into well labeled plastic beakers and then treated with 10%concentraedHClacid to dissolve all the carbonates before treated it with 70% hot Hydroflouric (HF) acid solution and centrifuged. Washing and centrifugation were done repeatedly over times to remove fine caustic materials. This was then followed by addition of Zinc bromide ($ZnBr_2$)with a specific gravity of 2.0; and 10% solution of Ammonia solution to float and concentrate all the palynomorphs and/ordinoflagellates. The residues were then mounted on

slides for light microscopy analysis after air dried. All the encountered palynomorphs was identified to species level by comparing it with some standard and published palynological monographs. The grain occurrences in terms of their respective abundance and diversity in the analyzed elements were plotted using Stata Bug software (Fig. 3).

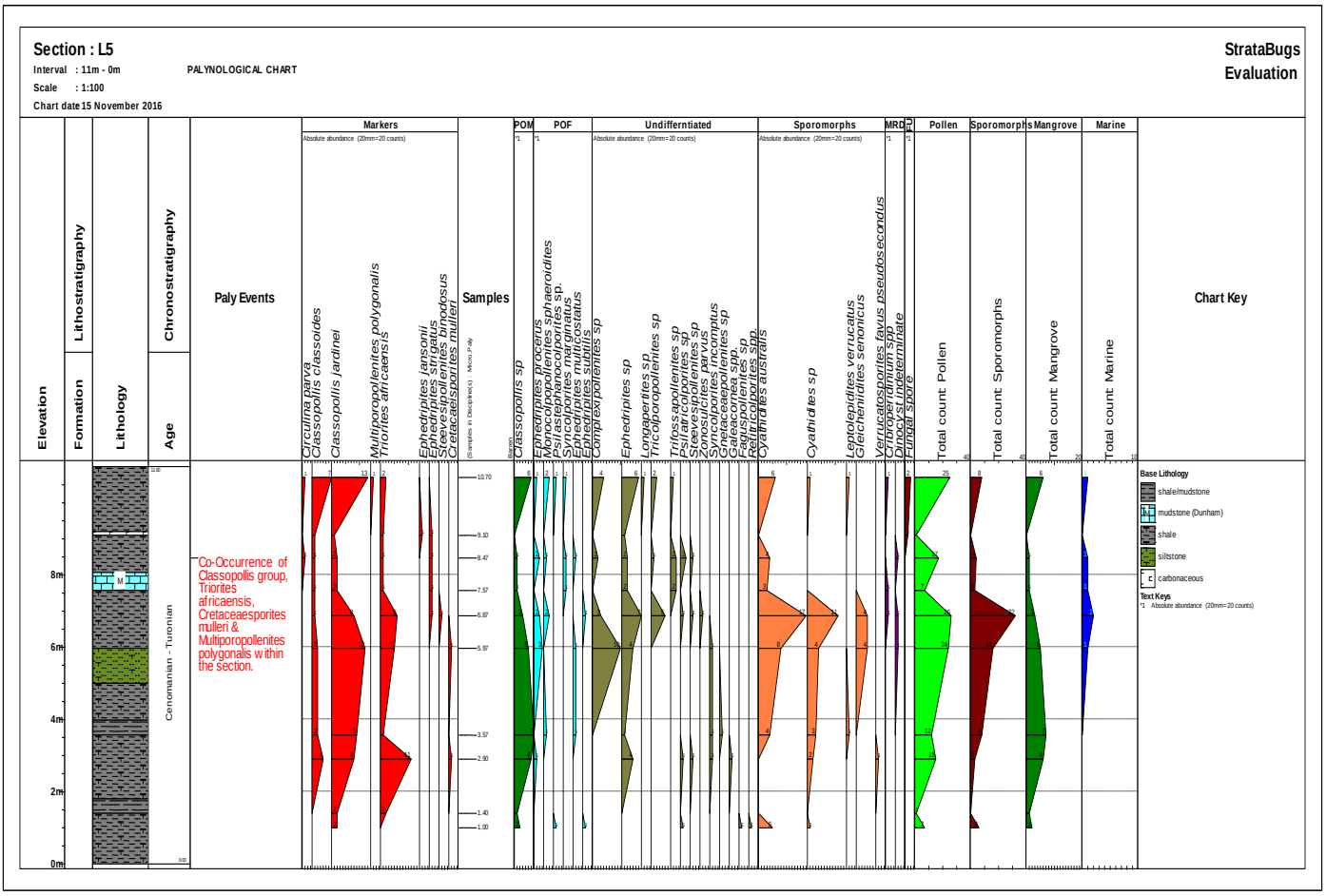
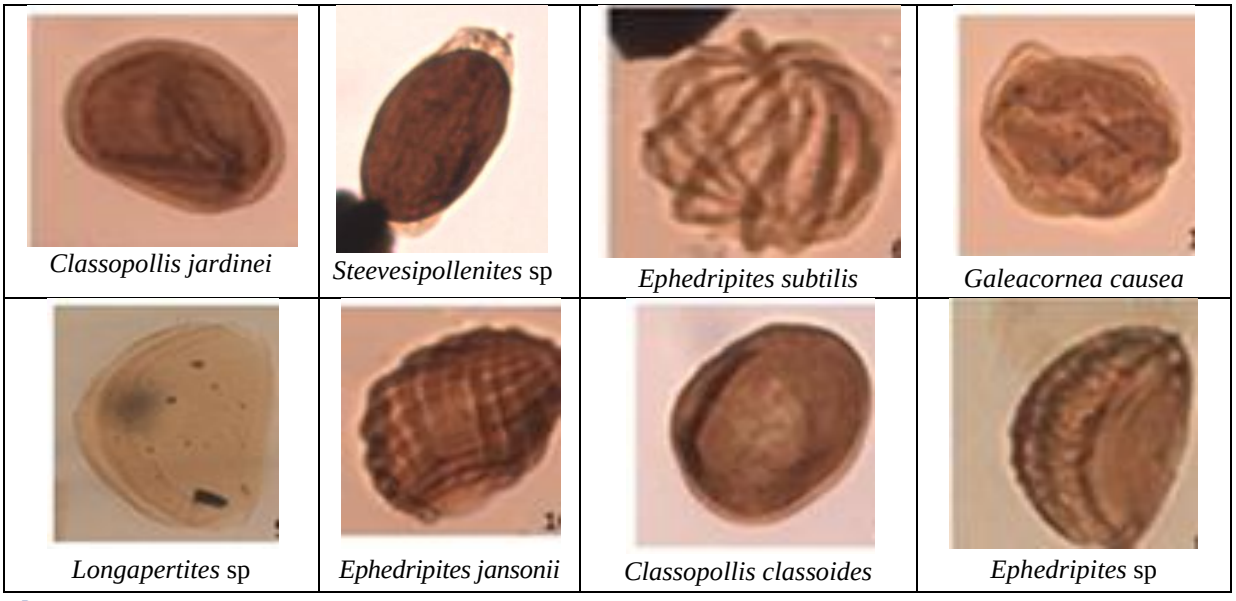


Figure 3: Palynological distribution chart from the study area

Also some key palynomorphs recovered and identified from the study area is presented in plate 1.

Plate 1: Identified palynomorphs from the study section

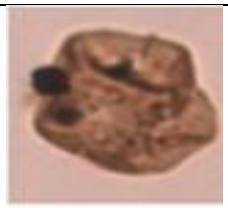


Multiporopollenites polyonalis

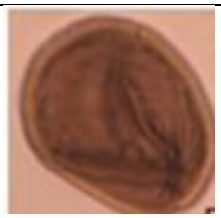
Triorites africaensis

Cretacaeiporites mulleri

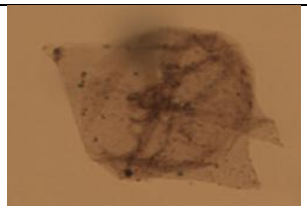
Ephedripites multicostatus



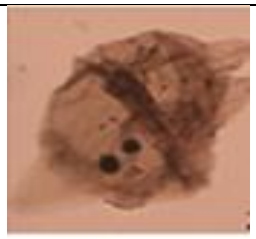
Multiporopollenites spp



Classopollis sp



Cribroperidinum sp



Dinoflagellates indet

Results and Discussion

Lithological Analysis

The litho-unit of the study area occur along a road cut and is about 11km thick. It consists predominantly of shale with rare occurrences of some interlaminated mudstone, calcareous mudstone and sand deposits (Table 2). The shale is about 85% of the total outcrop sample analyzed, however this sediment characterized by fine grained, dark grey to sometimes light brown, subfissile to fissile, moderately hard, septarian nodules, carbonaceous and micromicaceous materials. The mudstone represents about 10% and exhibited interlaminated to bedded, moderately hard and consolidated, calcareous and carbonaceous while sand deposits is 5% and are smoky white, fine grained and sometimes medium grained, well sorted, subrounded to subangular and slightly ferruginized.

Table 1: Lithological description from the study area

S/N	Depth(m)	Sediment	Description
1	0 – 2.5	Shale 100%	Dark grey to sometimes light brown, subfissile to fissile, moderately hard, carbonaceous, micromicaceous and ferruginized. Traces of fine grained sand occur.
2	2.5 – 4.0	Shale 95%	Dark grey to light brown, subfissile to fissile, moderately hard, carbonaceous, micromicaceous and highly ferruginized.
		Sand 5%	Smoky white, fine to medium grained, well sorted, subangular to subrounded and slightly ferruginized.
3	4.0 – 6.0	Shale 90%	Earthy brown to reddish, moderately hard and consolidated, calcareous and carbonaceous.
		Mudstone 10%	Grey, hard, calcareous and carbonaceous with minor sand occurrence.
4	6.0 - 8.0	Shale 95%	A/a
		Sand 5%	A/a but sometimes coarse grained with mudstone intercalation and slightlyferruginized.
5	8.0 - 11.0	Shale 90%	Dark grey to light brown, subfissile to fissile, moderately hard, carbonaceous, micromicaceous and highly ferruginized.
		Sand 5%	Smoky white, fine grained, but sometimes medium grained, well sorted, subrounded to subangular and slightly ferruginized. Traces of shale also occur.

Palynological analysis

The analyzed sediment consists of poor to moderately preserved palynomorphs. The overall results of the samples under investigation are presented in the analyzed palynological plot-chat (Fig. 3). However, microfloral occurrence of index grains, age, their interpreted palynological zone and infer paleoenviroment are shown in figure 3. Photomicrographs of some of the analyzed palynomorphs are contained in the plate 1. The result shows that a total of thirty-five (35) morphotypes of three hundred and thirty-six (336) specimen recovered and identified counted from the investigated sediments. The breakdowns of the morphotypes consist of twenty-seven (27) species of pollen, six (6) spores and two (2) species of dinoflagellates. The associated pollens recovered and identified constitute 72% of the total assemblage and is made up of 46% of gymnosperm and 26% of angiosperm pollens respectively. The gymnosperm genera consist dominantly of *Classopollis* and the angiosperm are mainly *Monocolpopollenites***,** *Complexipollenites*, *Triorites* and *Tricolporopollenites* genus predominating. The *Cyathidites* dominates the pteridophytes spore group. Detailed palynostratigraphic analysis of this section in this study is based on depth by depth interpretation as follows**:** whil**e** in

Depth (0 – 2.5m): This is the deepest section within the studied area and is considered to have penetrated the oldest encountered age in this study in accordance with the law of superposition. It is almost barren except with rare occurrence of *Classopollis jardine*, *Classopollis* sp, *Psilatricolporites* sp, *Retitricolporites* sp, *Retitricolporites* sp, *Cyathidites* sp, *Cyathidites australis*, *Psilastephanocolporites* sp, *Faguspollenites* sp and *Ephedripites subtilis* (Fig.3).

Depth(2.5 – 4.0m): This section recorded highest abundance and diversified palynofloragrains within the outcrop section (Fig. 3). However palynomorphs of *Classopollis jardine*, *Classopollis* sp, Triorites africaensis, *Ephedripites* sp, *Cyathidites* sp and *Cyathidites australis* have their highest relative frequency compare to other forms present within this interval. Other palynomorphs recorded within this interval includes *Cretaceisporites mulleri*, *Ephedripites procerus*, *Ephedripites multicosatus*, *Monocolpopollenites sphaeroidites* and *Complexipollenites* sp. Top appearances of *Ephedripites strigatus*, *Steevesipollenites binodosus*, *Synocolporites marginatus*, *Trifossapollenites* sp and *Zonosulcites parvus* showed significant occurrences and were also used in attempting the zonation of this section. This interval is relatively rich in palynomorphs while the overlying stratigraphic horizon showed sporadic to rare miospore occurrences **(**see figure 3**).**

Depth (4.0 – 5.0m): This interval is relatively low in terms of richness of palynomorphs when compare to the previous section analysed but higher in frequency of miospores over the oldest interval as observed within this section (Fig. 3). The occurrence of *Ephedripites jansoni* being an index grain and some fungi spores was first witnessed within this interval depth. However, the occurrence of *Ephedripites jansoni* within this section denotes the Cenomanian - Turonian age as adopted in this study.

Depth (5.0 – 11.0m): This is the second richest level within this section in term of miospores and is the uppermost and youngest of the horizons studied and is 6m thick (Fig. 3). There is continuous occurrence of some diagnostic and highest frequency occurring taxa in this section.

From the general overview of the microflora fossils recovered and identified from Calabar / Odukpani shale section, it shows that the sampled sediments belong to the *Afropollis jardinus/ Triorites africaensis*/ *Cretaceiporites scrabratus* Assemblage Zone of Cenomanian-Turonian age [11]. In comparison with the assemblages of miospores recovered from the Benue Trough sediments, the shale of the Calabar/Odukpani Road Junction sediments saw the occurrence of *Classopollis* genus which showed that these sediments are not younger than Cenomanian age [12]. However, the occurrence of *Classopollis*, *Cretacaeiporites*, *Trifossapollenites* and *Triorites* genera suggests these sediments to have been deposited in Early Cenomanian times. This is in accordance with the work of [13] on Ojo-I Well of Benin basinin Western Nigeria. The encountered palynomorphs of *Ephedripites multicostata*, *Triorites africaensis* and *Stecvisipollenites binodsus* show ever points to the penetration of Middle-Late Cenomanian epoch.

Reference is made to some Cretaceous sedimentary basins in Nigerian, it is difficult to demarcate the Cenomanian-Turoman boundary, and it is assumed to be a gradational and hence the two stage of 'early' Upper Cretaceous are inseparable [14]. Therefore part of the Turonian age sediments recognized within this section was infer from the recovered and identified miospores assembl ages associated with the occurrence of *Triorites africaensis, Cretacaeiporites mulleri* and *Tricolporopollenites* sp [11]. However, it has been observed that the absence of younger microfloral species such as *Dorseridites senonicus,* within this section showed that the investigated area is older than the Coniacian age.

Paleoenvironmental Analysis

The paleoenvironmental interpretation of the outcrop belonging to the Calabar / Odukpani Road Junction shale is based on the relative occurrence of the different palynomorphs encountered in the study which are environmentally significant. This includes pollen, spores/fungal spores and dinollagellate cysts respectively. The preponderance of continental derived palynomorphs having strong affinity with mangrove palm such as *Longapertites, Synocolporites* and *Monocolpopollenite* infer transitional environment, which may likely be marginal to marine setting [15-17]. According to the works of [18] and [19] have reported that the marine Turonian age of Brazilian (Sergipe) and Equitorial Africa (Grabon) are characterized by some abundance genus belonging to *Ephedripites* and *Cretacaeisporites* genus. The section also marked the occurrence of marine influence in Calabar Flank during Cenomanian times. The prevailing geologic condition of this time is lacking in most equivalent age sediments of Nigerian sedimentary basin and the reason may be due to closeness of it to the Atlantic Ocean, which is typified by the Calabar Flank basin.

The few dinoflagellate cysts recovered from this section infer marginal marine while the observed fungal spores probably signifies the highly dense rainy forest vegetation within the study area. The genus *Classopollis* and *Ephedripites* are the most abundance gymnosperm genus in the study section and are xeroplytes which shows dominancy in drought condition. Their present suggests warmer and aridity climatic condition that existed during the time of deposition of these sediments [20-22]. Conversely, the high occurrence of *Cyathides* genus relative to other pteridophytes spores can be correlated with vegetation growing on wetland setting [20].

The changes in the co-occurrence of continental palynomorphs (pollen and spores) with those of marine origin (dinocysts) especially of marine deposits can be used as an indicator of proximal-distal trends [23]. This ratio of continental to marine palynomorphs (C/M) generally decrease from neashore to offshore environment. From this study the ratio is very high (greater than 90%) in all the interval under investigation and infer deposition in a marginal /nearshore setting. Also the ratio of fern spores to xerophytic palynomorphs can be used to infer the climatic condition existed at the time of deposition. This is evaluated by dividing the number of all in situ (non-reworked) fern spores by the number of xerophytic forms (*Classopollis*+*Ephedripite* +Steevesipollenites+Gnetaceopollenites) [24]. This ratio is given as F/X(F = total number of in situ fern spores,X = total the number of xerophytic form mainly pollens type).The high values of this ratio reflect humid conditions, as ferns depend on water to reproduce. The value of F/X from the study section was very low infer drought (semi-arid condition).

Conclusion

Palynological biostratigraphic study was carried out for the first time on the newly constructed Unicem truck carriage way along Calabar / Odukpani Road Junction, Southeastern Nigeria. The sampled sediments belong to Ekenkpon Shale in the Calabar Flank. Pollen and spores contents were the dominant palynomorphs recovered and identified among the palynomorphs. The occurrence of some key grains (miospores) such as *Classopollis jardinei, Classopollis* sp, *Cretacaeisporites mulleri, Cyathides* sp, *Ephedripites multicostatus, Ephedripites jansoni, Gnetaceapollenites* sp, *Monocolpollenitessphaeroidites, Steeves ipollenitesbi nodosus, Triorites africaensis and Cribroperidinum* sp were used to infer the age of the investigated sediments. This section penetrated the Cenomanian – Turonian age which correlated with assemblages palynological zone of *Afropollis jardinus/ Triorites africaensis*/ *Cretaceiporites scrabratus* Assemblage zone. The shale is investigated to have been deposited under the influence of arid to warm climate, marginal marine settings using the recovered palynomorphs assemblages.

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