

Palynostratigraphy and Palaeoenvironmental Interpretation of Outcrop Formations in Parts of Ini-Akwa Ibom State, Southeastern Niger Delta Basin, Nigeria

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ABSTRACT

The palynological study of the outcrop Formations in parts of Ini Local Government Area of Akwa Ibom State, Southeastern Niger Delta Basin, Nigeria has contributed to unraveling the palynostratigraphy and paleoenvironments of the outcrops through the use of diagnostic palynomorphs. The section is made up of carbonaceous shales, sandstones, mudstones and claystones. The conventional maceration technique for recovering acid-insoluble organic-walled microfossils from sediments was used to prepare twenty outcrop samples for palynological studies. The samples produced poor to fair diversity assemblages of palynomorphs. A total of 176 palynomorphs species were recorded, with 48% pollen grains, 33% spores, 12% dinoflagellate cysts, 5% fungal spores, and 2% microforam test wall linings. Based on stratigraphically selected index taxa recovered, age determination and correlation were established. The samples from Imo Formation were assigned Late Paleocene-Eocene based on *Psilatricolporites Crassus*, *Retitricolporites irregularis*, *Psilatricolporites sp.* and *Leiotriletes adriennis* with the presence of Paleocene dinoflagellate cysts such as *Lejeunacysta beninensis* and *Selenopemphix nephroides*. Ameki samples were dated Early-Middle Eocene based on *Proxapertites operculatus*, *Retistephanocolpites williamsi*, *Mauritidites crassixinius*, *Monocolpites marginatus* and *Longapertites marginatus*. Ogwashi-Asaba shale samples were assigned Late Eocene-Early Oligocene due to the abundant presence of *Verrucatosporites usmensis*, *Laevigatosporites discordatus* and *Retitricolporites irregularis* while Eze-Aku samples were tentatively assigned Paleocene because of the presence of two pollen index fossils *Proxapertites operculatus* and *Pachydermites diderixi*. Inferred depositional conditions suggest that Imo Formation was deposited in a shallow marine or near shore brackish water estuarine environment. The Ameki Formation was accumulated in a marginal marine or near shore, brackish water-estuarine environment in the upper deltaic setting. The Ogwashi-Asaba Formation was deposited in a progradational shoreline moving between the brackish water and fresh water deltaic plain. The Eze-Aku Formation was deposited in an upper foreshore fresh water environment. The palynological study of the samples are Paleogene Formations while the paleoenvironment is in a coastal deltaic to shallow-marine environment and are appropriate for hydrocarbon accumulations and exploration.

Keywords: Coastal deltaic, Organic-walled, Paleoenvironmental, Palynomorphs, Palynostratigraphy.

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I. INTRODUCTION

Palynology, which is the science of palynomorphs, has several applications in geology. Stratigraphic applications center on biostratigraphy, paleoenvironmental analysis, palynofacies and paleoclimatology while botanical applications pertain to taxonomy and evolution. The use of palynomorphs and their paleoecology for paleoenvironmental reconstruction has been particularly developed among these applications. Pollen and spores represent the land flora, and hence are of greatest values in

applied palynological studies of terrestrial rocks. A means for paleoenvironmental analyses of these rocks can be provided by pollen. In some places, to provide age data for non-marine strata, pollen and spores may be the only available fossils. It is in these applications that terrestrial palynomorphs are of greatest value to geology. Even rocks deposited in open marine environments may contain few or no marine fossils but may contain pollen. Pollen assemblages also may help in correlating marine rocks of strongly dissimilar facies, carrying specialized assemblages of marine fossils. Therefore, palynomorphs are one of the most recognizable

aspects of geology and are interesting objects of study, their morphology is substantially varied in a package so small that the wonder of their attractiveness never ceases to captivate.

A. Location of the Study Area

The study area is located in Ini Local Government Area of Akwa Ibom State, Southeastern Niger Delta Basin and it extends to the south-easternmost edge of Anambra basin, Nigeria. The geographic position is between latitudes 5°16" to 5°30" N and longitudes 7°39" to 7°51" E as seen in Fig. 1. The study location is reachable through footpaths and roads. Good geological sections from which the samples for this work were collected were provided by road cuts, gutter excavations, stream sections and quarries.

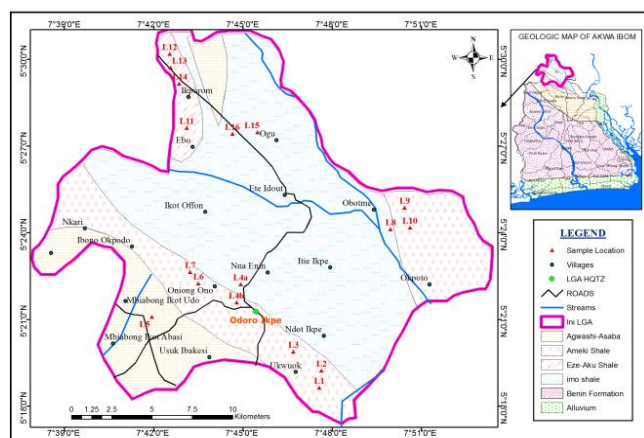


Fig. 1. The geological map of the study area showing outcrop locations, accessibility and sample sites. L. = Location numbers.

B. Previous Studies

Diverse works have been acknowledged on the palynological studies of the Niger Delta Basin. Most of the works are majorly on the subsurface sector of the Niger Delta Basin, which include the works of [1]-[8]. Until now, the inland part of the basin received little attention.

Reference [9] documents the palynomorph assemblage bio-zonations of the up-dip areas of Niger Delta Basin's Paleogene strata uncovered along the Bende-Umuahia axis, southeastern Nigeria. They established six familiar palynomorph assemblage zones, named zone A to zone F on the basis of the first and/or the last occurrence of two or more species. Reference [10] carried out the palynological and paleoenvironmental study of outcrops around Bende and Umuahia area. Age determination/correlation was attained based on the stratigraphically significant age-diagnostic palynomorph assemblages gotten from the examined samples. They suggested the Paleogene age for the Formations and Deltaic to shallow marine as their environment of deposition. Reference [11] used palynological information to describe the palynofacies, palaeoecology, palynostratigraphy and sequence stratigraphy of the Paleogene sandy succession along Onitsha-Awka transect.

However, little or no palynological work has been reported or published on outcrop Formations around the northern parts of Akwa Ibom State (the boundary between Niger Delta Basin and Anambra Basin), southeastern Niger Delta Basin. This work, therefore, aims to identify the recovered palynomorphs and use them to date and infer the depositional

environment of the study area. An understanding of the age and paleoenvironment of sediments deposition is important in the evaluation of basin and the successful exploration of both organic and inorganic mineral resources.

C. Geological Background and Stratigraphy

The Niger Delta Basin is situated geographically between latitudes 3°N and 6° N and longitudes 5°E and 8°E. It occupies the continental margin of the Gulf of Guinea in equatorial West Africa as displayed in Figure 2 and has a total area of about 75,000 km² with entirely clastic sedimentary-fill up to 12,000m thick [12]. The large continental drainage systems which constructed arcuate and bird-foot deltaic wedges prograde basinward into the oceanic crusts were supplied the fill [13].

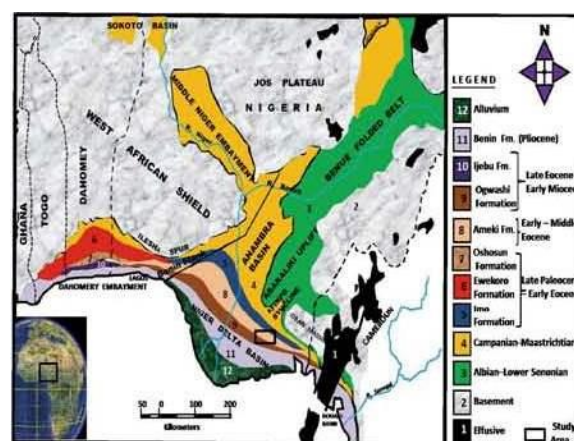


Fig.2. The geological map of the Niger Delta Basin showing the study area (modified after [14], [15]. Fm. = Formation; R. = River.

Paleogene sediments consisting of Imo, Ameki, and Ogwashi-Asaba Formations were known as parts of the Afikpo Basin by the previous research in the region [16], [17] and [18]. These sediments are detached from the Campano-Maastrichtian stages developed in Anambra and Afikpo Basins based on dating results. The Imo, Ameki, and Ogwashi-Asaba Formations have the same microfloral assemblages with those in the subsurface of the Niger Delta. These Formations form the up-dip series of the Niger Delta Basin, and they are the lateral equals of the down-dip Akata and Agbada Formations as shown in Fig. 3. Imo Formation is the oldest stratigraphic unit in the up-dip part of the Niger Delta Basin which consists of blue, grey clay and shale, black shale with bands of calcareous sandstone, marl, and limestone [16] while the lateral differences into sandstone facies occur in some places such as Ebenebe, Umuna and Igbabu [16].

The Imo Formation, according to [19] overlies the Nsukka Formation in the east and outcrops at Oduenyi village extending to the west through Ndiwo and stops at Itu-Mbuzor where it is conformably overlain by the Ameki Formation. Also, [16] and [17] assert that the Ameki Formation predominantly consists of alternating shale, sandy shale, clay sandstone and fine grained fossiliferous sandstone, with thin band of limestone. Also, as displayed in Fig. 3, the Ameki Formation is uncovered at Bende Itu-Mbuzor town extending towards northwest through Ozu-Item to Uzuakoli town and discontinues at Amogugu town where it is overlain by the Ogwashi-Asaba Formation. The Ogwashi-Asaba Formation is made up of alternating coarse grained sandstone, lignite,

and light-colored clays of continental origin as explained by [20] while Benin Formation consists of coarse pebbly continental sandstones, gravels with minor shale intercalations. Also, the Formation is deposited in alluvial or coastal plain environments following a southward shift of the delta into a new depobelt as affirmed by [21].

II. MATERIALS AND METHOD

Twenty samples were analyzed for palynomorph content analysis. The standard palynological acid maceration technique was used for the sample preparation according to [24]-[27]. Each 10g of the sample was absorbed for 30 minutes in 38% hydrochloric acid to remove carbonate and for 72 hours in 40% hydrofluoric acid for removal of silicate. Ten microns nylon sieve mesh was used to wash the extracts. To make the fossils translucent for transmitted light microscopy, the sieve-washed residues were oxidized for 30 minutes in 70% HNO₃ and 5 minutes in schulze solution. The oxidized residues were rinsed in 2% KOH solution to neutralize the acid.

In order to get rid of the resistant coarse inorganic mineral particles, swirling treatment was carried out. To enhance the contrast for study and photography, the residues were stained with Safranin O. Polyvinyl alcohol was used to disperse Aliquots, which were dehydrated on cover-slips and mounted

in araldite resin. Twenty (20) slides were analyzed with the aid of a transmitted light Amscope microscope.

III. RESULTS

A. Palynological Analysis

The studied sections yielded poor to fair diversity assemblages of palynomorphs as seen in Figure 8, making the interpretation indeterminate for some of the samples. Table I shows the absolute counts of the distribution of palynomorph species in the study area and Figures 4, 5, 6 and 7 show the percentage frequencies of palynomorphs in the Formations.

1) Imo Formation

The selected samples from Locations 4 and 16 from Imo Formation yielded fair to poor palynomorph species. The terrigenous spore's species recorded are, *Laevigatosporites discordatus*, *Acrostichum aureum*, *Cyathidites minor*, *Lycopodium sp.* and *Leiotrilete adriennis*. The pollen grains are *Psilatricolporites crassus*, *Zonocostites ramonae*, *Psilatricolporites sp.*, *Retimonocolpites sp.*, *Retitricolporites irregularis* and *Longapertites sp.* Marine species recovered are *Selenopemphix nephroides*, *Lejeunacysta beninensis* and *Pterospemella sp.* However, the fissile shale sample of Location 8 yielded very few terrigenous palynomorphs species which include *Cyathidites minor* and *Psilatricolporites sp.* (2 grains) with no marine species as seen in Table I and Fig. 4.

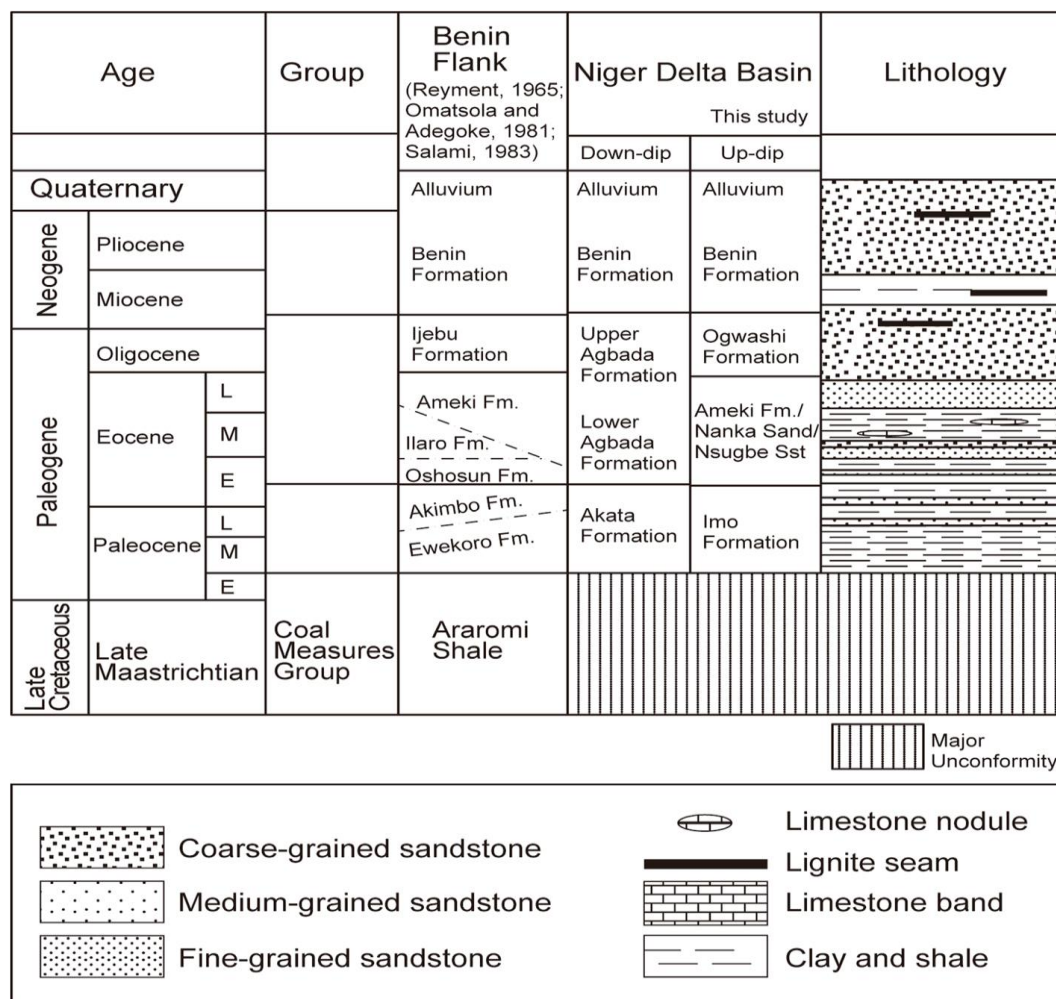


Fig. 3. Stratigraphic column of Niger Delta Basin and other coastal basins in Nigeria.
(Source:[16], [22],[23]). E = Early; M = Middle; L = Late.

2) Ameki Formation

The representative shale and sandstone samples from Locations 3, 6, 9 and 10, in this Formation bear moderate to fair terrigenous sporomorphs. The terrigenous species include spores such as, *Laevigatosporites discordatus*, *Verrucatosporites usmensis*, *Leiotriletes adriennis*, *Cyathidites minor* and *Acrostichum aureum*. Pollen grains are *Proxapertites operculatus*, *Retistephanocolpites williamsi*, *Longapertites marginatus*, *Mauritidites crassiexinous*, *Monocolpites marginatus*, *Retitricolporites* sp., *Psilatricolporites* sp., *Zonocostites ramonae*, *Tricolpopollenites hian* and *Calamuspollenites petsus*. Marine species include *Leiosphaerida* sp., *Operculodinium centrocarpum*, *Pterospermella* sp., and *Selenopemphix nephroides*. The silty and clayey sands samples (UK/L2/01 and UK/L2/02) yielded very poor to zero palynomorph counts as shown in Table I and Fig. 5.

3) Ogwashi-Asaba Formation

The carbonaceous mudrock and claystone samples from Location 5 of this Formation yielded moderately rich

palynomorphs assemblage. Terrestrially land-derived spores and pollen were the most predominant. Marine species were rare to absent. The spores include *Verrucatosporites usmensis*, *Acrostichum aureum*, *Laevigatosporites discordatus*, *Cyathidites minor*, *Elaeis guineensis*, *Verrucatosporites salienus* and *Verrucatosporites fervus*. Pollen are *Pachydermites diderixi*, *Retitricolporites irregularis*, *Psilatricolporites crassus*, *Striatricolpites catatumbus*, *Psilatricolporites* sp., *Polyadopollenites vancampori*, *Longapertites* sp., *Crototricolporites scrotonoisculptus*, *Striamonocolpites undatostratus*, *Zonocostites ramonae* and *Echimonocolpites* sp., as displayed in Table I and Fig. 6.

4) Eze-Aku Formation

An extremely poor recovery of palynomorphs characterized by *Laevigatosporites discordatus*, *Acrostichum aureum*, *Elaeis guineensis*, *Longapertites* sp., *Proxapertites operculatus* and *Pachydermites diderixi* were recovered from Location 11, 12 and 13. No marine species was recorded as shown in Table I and Fig. 7.

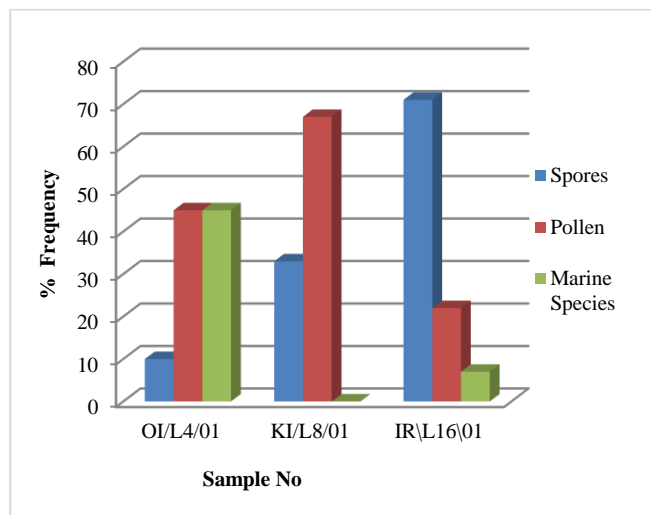


Fig. 4. Histogram showing the (%) frequency of palynomorphs of the Imo Formation.

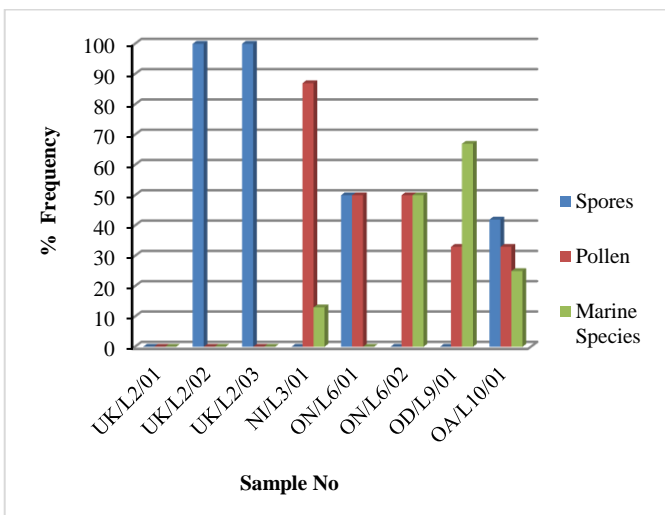


Fig. 5. Histogram showing the (%) frequency of palynomorphs of the Ameki samples.

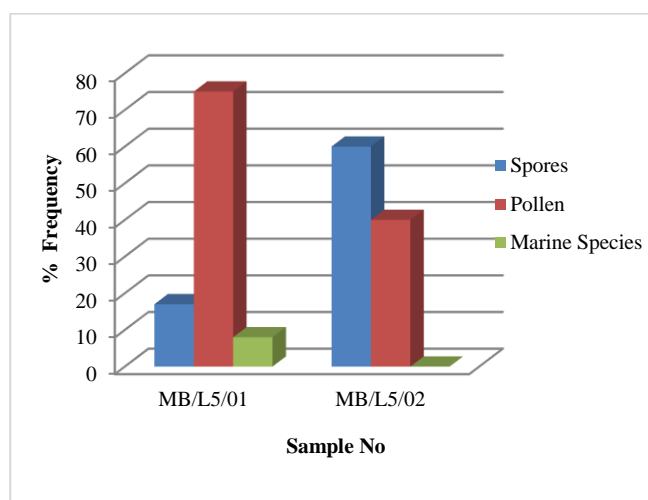


Fig. 6. Histogram showing the (%) frequency of Palynomorphs of the Ogwashi-Asaba Formation.

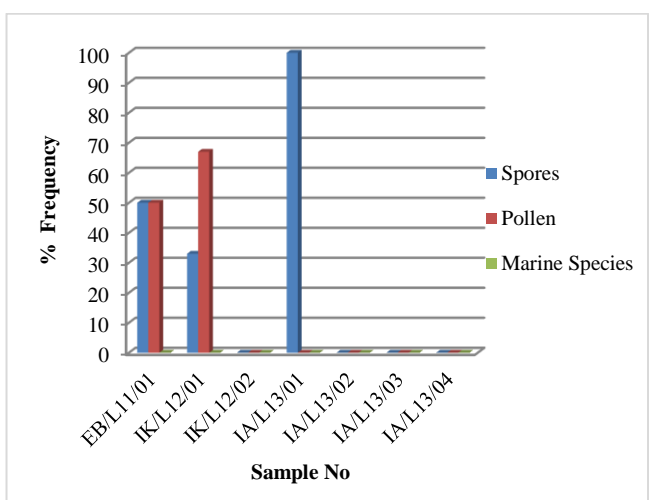


Fig. 7. Histogram showing the (%) frequency of palynomorphs of the Eze-Aku Formation.

TABLE I: ABSOLUTE PALYNOMORPH COUNTS IN THE STUDY AREA

Palynomorphs species	EB/L 11/01	IK/L1 2/01	IA/L1 3/01	OI/L 4/01	IR/L1 6/01	UK/L 3/01	ON/L6 /01	ON/L6/ 02	OD/L9 /01	OA /L1/01	MB /L5 /01	MB/L5 /02
TERRIGENOUS SPECIES												
Spores												
<i>Acrostichum aureum</i>	1	1	1	1	5	-	-	-	-	2	-	6
<i>Cyathidites minor</i>	-	-	-	1	1	-	-	-	-	2	3	-
<i>Laevigatosporites discordatus</i>	1	-	-	-	2	1	1	-	-	-	10	-
<i>Verrucatosporites usmensis</i>	-	-	-	-	-	1	-	-	-	-	3	-
<i>Verrucatosporites farvus</i>	-	-	-	-	-	-	-	-	-	-	1	-
<i>Verrucatosporites alienus</i>	-	-	-	-	-	-	-	-	-	-	11	-
<i>Elaeis guineensis</i>	-	-	5	-	-	-	-	-	-	-	1	-
<i>Selaginella myosurus</i>	-	-	-	-	-	1	-	-	-	-	-	-
<i>Leiotriletes adriennis</i>	-	-	-	-	1	-	-	-	-	1	-	-
<i>Lycopodium sp.</i>	-	-	-	-	1	-	-	-	-	-	-	-
Pollen												
<i>Retitricolporites irregularis</i>	-	-	-	-	1	-	-	-	-	-	12	-
<i>Retimonocolpites sp.</i>	-	-	-	-	1	-	-	-	-	-	-	-
<i>Psilatricolporites sp.</i>	-	-	-	3	2	1	-	1	-	-	-	2
<i>Zonocostites ramonae</i>	-	-	-	1	-	1	-	1	-	-	-	21
<i>Psilatricolporites crassus</i>	-	-	-	1	-	-	-	-	-	-	-	1
<i>Longapertites sp.</i>	1	-	-	-	1	-	-	-	-	-	-	1
<i>Retistephanocolpites williamsi</i>	-	-	-	-	-	1	-	1	-	-	-	-
<i>Mauritidites crassixinus</i>	-	-	-	-	-	1	-	1	-	1	-	-
<i>Longapertites marginatus</i>	-	-	-	-	-	1	-	-	-	-	-	-
<i>Pachydermites diderixi</i>	-	1	-	-	-	-	-	-	-	-	-	1
<i>Echimonocolpites sp.</i>	-	-	-	-	-	-	-	-	-	-	-	1
<i>Proxapertites operculatus</i>	1	1	-	-	-	1	-	-	-	1	-	-
<i>Monocolpites sp.</i>	-	-	-	-	-	1	-	-	-	-	-	-
<i>Tricolpopollenites hians</i>	-	-	-	-	-	-	-	1	-	-	-	-
<i>Retitricolporites sp.</i>	-	-	-	-	-	-	-	1	-	-	-	-
<i>Monocolpopollenites sphaeroidites</i>	-	-	-	-	-	-	-	-	1	-	-	-
<i>Calamuspollenites petsus</i>	-	-	-	-	-	-	-	-	-	2	-	-
<i>Monocolpites marginatus</i>	-	-	-	-	-	-	1	-	-	-	-	-
<i>Striamonocolpites undatostratus</i>	-	-	-	-	-	-	-	-	-	-	1	-
<i>Crototricolporites crotonoissculptus</i>	-	-	-	-	-	-	-	-	-	-	2	-
<i>Polyadopollenites vancampori</i>	-	-	-	-	-	-	-	-	-	-	1	-
<i>Striatricolpites catatumbus</i>	-	-	-	-	-	-	-	-	-	-	2	-
MARINE SPECIES												
DINOFLAGELLATE CYSTS												
<i>Selenopemphix nephroides</i>	-	-	-	1	-	-	-	1	-	-	-	-
<i>Lejeunecysta beninensis</i>	-	-	-	1	1	-	-	-	-	-	-	-
<i>Operculodinium centrocarpum</i>	-	-	-	-	-	-	-	1	-	1	-	-
<i>Paleocystodinium sp.</i>	-	-	-	-	-	-	-	-	1	-	-	-

*EB = Ebo, IK = Ikporom, IA = Ikporom Abia, OI = Odoro Ikpe, IR = Ikporom road, UK = Ukwuok, ON = Oniong Ono, OD = Odon, OA = Odoro Anwa, MB = Mbiabong, L = Location.

IV. DISCUSSION

A. Biostratigraphic Age Determination and Correlation

Fig. 9 displays the stratigraphic distribution range chart of selected age-diagnostic species across the study area. As displayed in Table I, the shale samples from Locations 4 and 16 of Imo Formation were assigned Late Paleocene-Eocene age on the basis of the recovered palynomorph assemblage: *Psilatricolporites crassus*, *Retitricolporites irregularis*, *Longapertites sp.*, *Laevigatosporites discordatus*, *Retimonocolpites sp.*, *Zonocostites ramonae*, *Psilatricolporites sp.* and *Leiotriletes adriennis*. Although, these are all Eocene ranging palynomorphs but the presence of co-occurrence Paleocene dinoflagellate cysts assemblages such as *Lejeunacysta beninensis* and *Selenopemphix nephroides* confirmed the age Late Paleocene-Eocene [15], [19], [28]-[33], [36].

The clayey shale, carbonaceous shale and sandstone samples from Locations 3, 6, 9 and 10 were assigned Early-Middle Eocene based on *Proxapertites operculatus*, *Retistephanocolpites williamsi*, *Zonocostites ramonae*, *Psilatricolporites sp.*, *Retitricolporites sp.* *Mauritidites crassixinus*, *Monocolpites marginatus*, and *Longapertites*

marginatus [9]-[11], [19], [28], [30], [31], [34], and [35]. The age was further established by the presence of notable Eocene dinoflagellates and acritarch assemblage, such as: *Operculodinium centrocarpum*, *Selenopemphix nephroides*, *Paleocystodinium sp.* and *Leiosphaerida sp.* [19], [31], and [35] as shown in Table I. The above sporomorph assemblage possibly belongs to the Ameki Formation which correlates with the Early-Middle Eocene pantropical *Proxapertites operculatus* Zone of [28]. The assemblage also coincides from P300 to P370 pollen zone of [37], in the Niger Delta Basin. The assemblage further correlates with the Early Eocene-early Middle Eocene *Proxapertites operculatus* Zone C of [9]. *Proxapertites operculatus* are assemblages of palynomorphs usually recorded in Eocene of West African Basins. This evidence was corroborated by the findings of [28] that *Proxapertites operculatus* were not present from post Eocene strata in West Africa. However, they were evidenced in the Pliocene to Pleistocene in Borneo and the Caribbean Basins.

The carbonaceous mudrock and pink clay shale samples from Locations 5/01 and L5/02 were assigned Late Eocene-Early Oligocene age due to the abundant presence of *Verrucatosporites usmensis*, *Laevigatosporites discordatus* and *Retitricolporites irregularis*. The age was further

reinforced by co-occurrence of the sporomorphs assemblage, such as *Pachydermites diderixi*, *Psilatricolporites crassus*, *Striamonocolpites undatostratus*, *Zonocostites ramonae*, *Psilatricolporites* sp., in the examined samples [10], [15], [19], [29], [31], [36]. The above assemblages notably belong to Ogwashi-Asaba Formation. The sporomorph assemblage (Ogwashi-Asaba Formation) coincides with the Late Eocene pantropical *Verrucatosporites usmensis* Zone of [28]. The assemblage correlates with P450 to P480 pollen zone of [37], in the Niger Delta Basin. The assemblage also correlates well with the Late Eocene-Early Oligocene *Verrucatosporites usmensis* Zone E of [9].

The carbonaceous shale samples from Locations 11 and 12 were short of adequate marker palynomorph assemblages needed for proper age diagnosis as shown in Table I. However, based on these two pollen index fossils *Proxapertites operculatus* and *Pachydermites diderixi*, they have been tentatively assigned Paleocene age. Others miospore in the samples are *Acrostichum aureum*, *Laevigatosporites discordatus*, *Longapertites* sp., and *Elaeis guineensis*. [32] and [33]. The above assemblage belongs to Eze-Aku Formation.

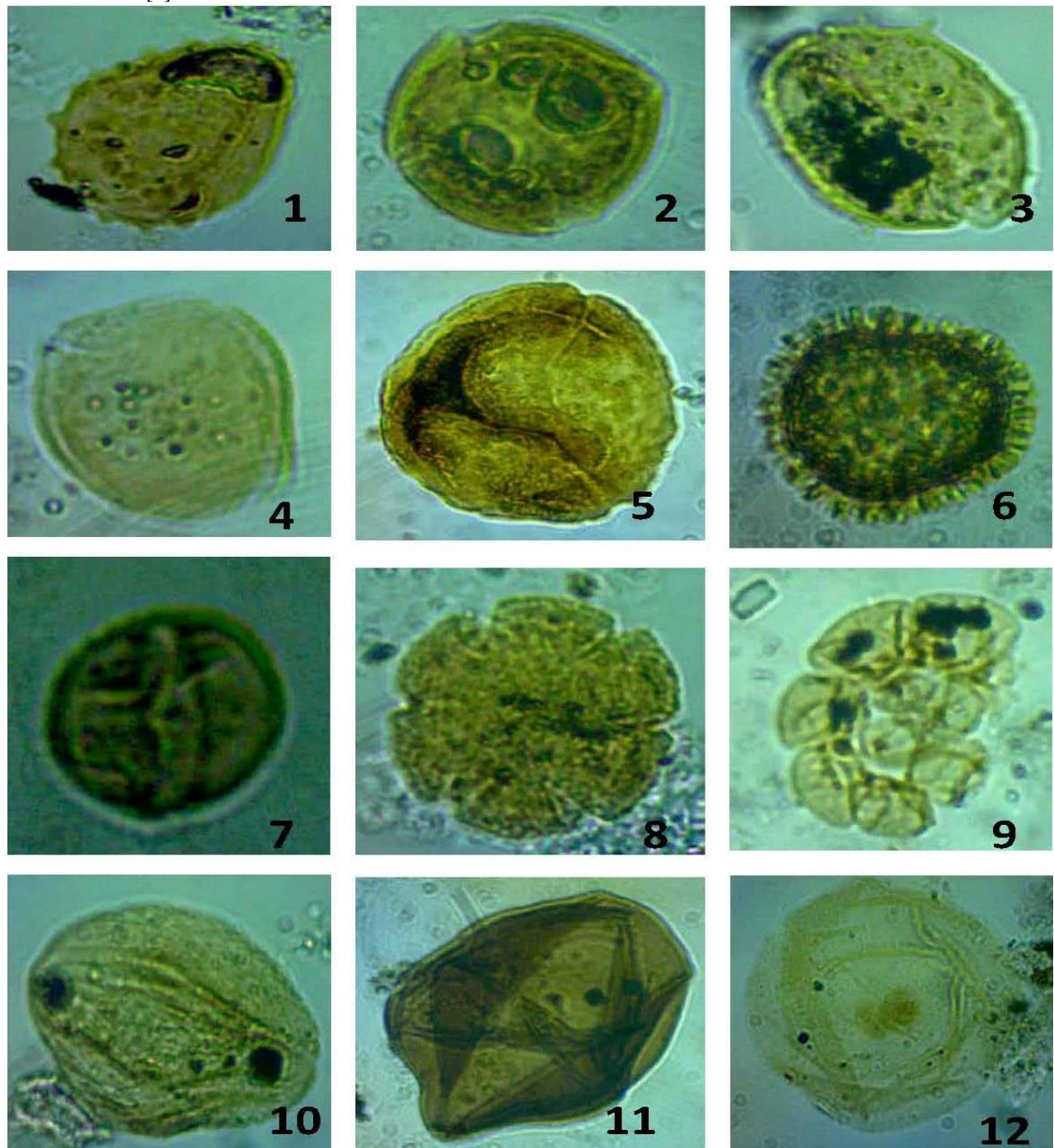


Fig. 8. Micrographs of palynomorphs species from analyzed samples.

Magnifications No. 12 (X 100 oil immersion), others (X 40).

1. *Verrucatosporites usmensis* 2. *Pachydermites diderixi* 3. *Mauritidites crassiexinous*, 4. *Proxapertites operculatus*
5. *Psilatricolporites crassus* 6. *Retitricolporites irregularis* 7. *Zonocostites ramonae* 8. *Retistephanocolpites williamsi*
9. *Foraminifera* wall lining 10. *Striatricolpites catatumbus* 11. *Leiosphaerida* sp. 12. *Selenopemphix nephroides*.

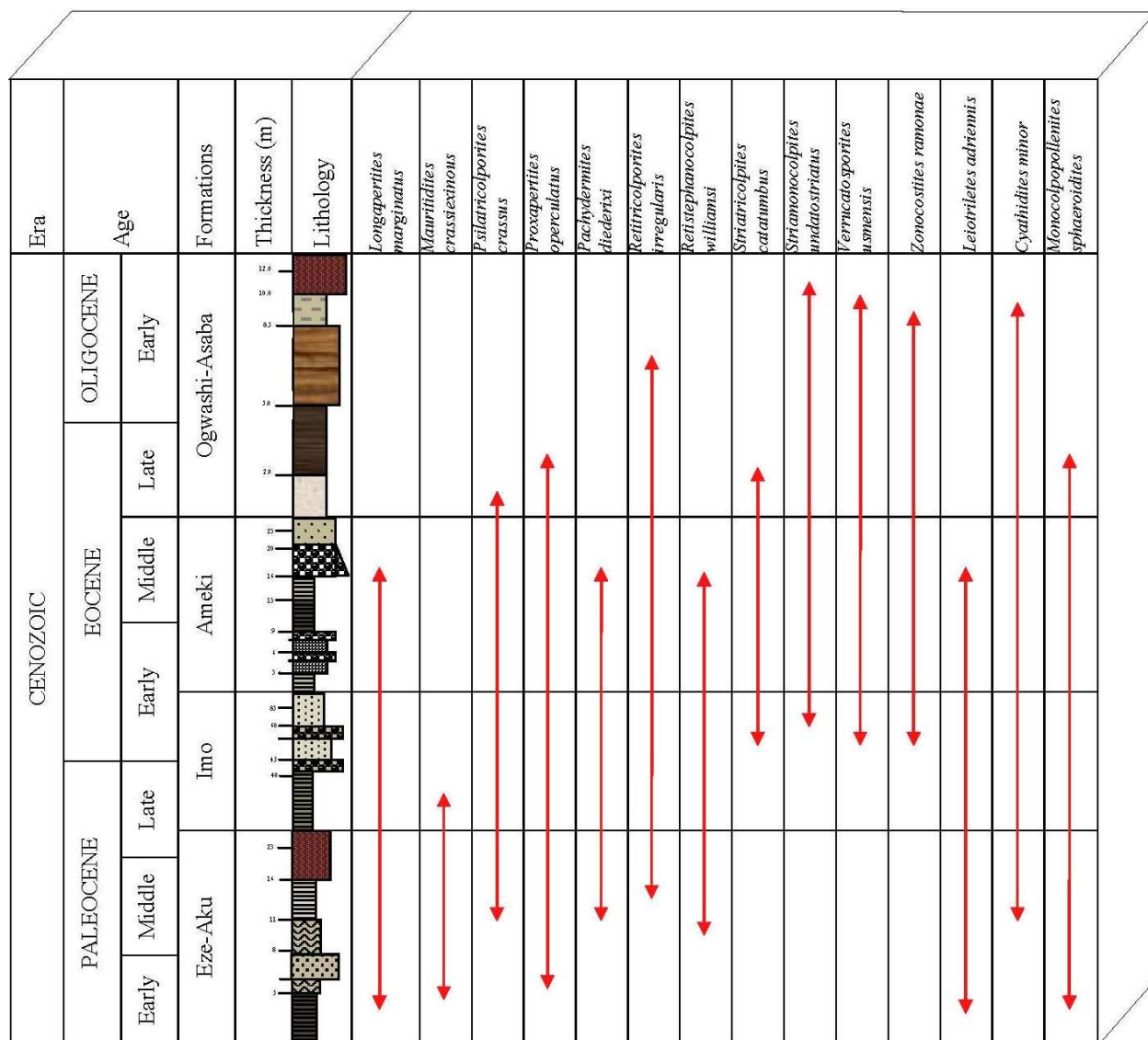


Fig. 9: Stratigraphic distribution range chart of selected age-diagnostic species across the study area.

B. Paleoenvironment of Deposition

The Table II below displays the percentage frequency distributions of the palynomorphs and their paleoenvironmental deductions.

The environmentally significant palynomorphs seen in the examined samples from Imo Formation include *Psilatricolporites crassus*, *Psilatricolporites* sp., *Laevigatosporites discordatus*, *Zonocostites ramonae* and *Acrostichum aureum*. These are sporomorphs of brackish water swamp species which suggests deposition in a shallow marine/near shore brackish water estuarine setting as seen in Table II [36], [38] and [19]. The presence of *Laevigatosporites discordatus* and *Verrucatosporites usmensis*, together with the co-occurrence of the monocolpate pollen; *Proxapertites operculatus* and *Mauritidites crassixinuous* and minor influx of the dinoflagellates species from the Ameki samples suggest strong indication of deposition in a marginal marine or near shore, brackish water-estuarine environment in the upper deltaic setting. *Laevigatosporites discordatus* and *Verrucatosporites usmensis* are fern spores of swampy fresh water [28], [36], [38], [15] and [10]. However, there is a mixed amount of freshwater species in different proportions with nearshore

brackish water forms in Ogwashi-Asaba Formation. The occurrence of *Verrucatosporites usmensis*, *Cyathidites minor*, *Laevigatosporites discordatus* and minor marine species in the samples display deposition in a marginal marine /or foreshore brackish water-estuarine environment [15]. Reference [29] suggests that the Ogwashi-Asaba Formation was placed in a progradational shoreline moving to and fro between the lower brackish water and upper deltaic plain, [34], [39]-[42]. Meanwhile, the examined samples from the Eze-Aku Formation yielded mainly terrestrial pollen and spores such as *Laevigatosporites discordatus*, *Acrostichum aureum*, *Longapertites* sp., *Elaeis guineensis* and *Pachydermites diderixi*. The Formation has no record of marine species. This therefore suggests a deposition in an upper foreshore fresh water environment as shown in Table II [11], [43]-[45].

TABLE II: PERCENTAGE FREQUENCY DISTRIBUTION OF THE PALYNOMORPHS AND THEIR PALEOENVIRONMENTAL INFERENCES

Sample No.	Palynomorphs (%) Frequency			Paleo –Salinity	Palaeoenvironments
	Spores	Pollen	Dinoflagellate Cysts		
MB/L5/01	17	75	8	Brackish Water	Marginal Marine (Proximal Estuary)
MB/L5/02	60	40	0	Fresh Water	Non-Marine/Upper Deltaic Plain
UK/L2/01	0	0	0	Non-diagnostic	Barren
UK/L2/02	100	0	0	Fresh water	Non-marine/Upper deltaic plain
UK/L2/03	100	0	0	Brackish water	Non-marine/Upper deltaic plain
NI/L3/01	0	87	13	Brackish water	Marginal marine (proximal estuary)
ON/L6/01	50	50	0	Fresh water	Non-marine/Upper deltaic plain
ON/L6/02	0	50	50	Brackish water	Marginal marine (distal estuary)
OD/L9/01	0	33	67	Brackish water	Open marine (distal estuary)
OA/L10/01	42	33	25	Brackish water	Marginal marine (estuary)
OI/L4/01	10	45	45	Brackish water	Marginal marine (distal estuary)
KI/L8/01	33	67	0	Fresh water	Non-marine/Upper deltaic plain
IR/L16/01	71	22	7	Brackish water	Marginal marine (estuary)
EB/L11/01	50	50	0	Fresh Water	Non-Marine/Upper Deltaic Plain
IK/L12/01	33	67	0	Fresh Water	Non-Marine/Upper Deltaic Plain
IK/L12/02	0	0	0	Non-Diagnostic	Barren
IA/L13/01	100	0	0	Fresh Water	Non-Marine/Upper Deltaic Plain
IA/L13/02	0	0	0	Non-Diagnostic	Barren
IA/L13/03	0	0	0	Non-Diagnostic	Barren
IA/L13/04	0	0	0	Non-Diagnostic	Barren

V. CONCLUSION

The palynological study of the outcrop Formations in the study area has been carried out. Four lithological units; carbonaceous shales, sandstones, mudstones, and claystone were encountered. Also, four Formations, the Eze-aku, Imo, Ameki and Ogwashi-Asaba were identified. The palynological analysis results assigned Late Paleocene-Eocene to Imo Formation, Early-Middle Eocene was dated for Ameki Formation, Ogwashi-Asaba Formation was assigned Late Eocene-Early Oligocene, while Paleocene was tentatively assigned to Eze-Aku Formation. Inferred depositional conditions suggest that Imo Formation was deposited in a shallow marine/near shore brackish water estuarine setting. The Ameki Formation was accumulated in a marginal marine or near shore, brackish water-estuarine environment in the upper deltaic setting. The Ogwashi-Asaba Formation was deposited in a progradational shoreline moving to and from between the lower brackish water and upper deltaic plain. The Eze-Aku Formation was deposited in an upper foreshore fresh water environment.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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