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Palynology of Bog-1 Well, Southeastern Niger Delta Basin, Nigeria

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ABSTRACT

Miospores recovered from the sediments of a section of Bog-1 well in the Niger Delta Basin are assigned a Late Oligocene-Mid Miocene age, based on the co-occurrence of pantropical stratigraphic markers such as *Zonocostites ramonae*, *Retimonocolpites pluribaculatus*, *Retibrevitricolporites protrudens*, *Psilatricolporites crassus*, *Circatricosisporites dorogensis*, *Retitricolporites irregularis*, *Racemonocolpites hians*, *Pachydermites diederixi*, *Brevicolpororites guinetii* and *Proxapertites cursus*. The mainly shaly sediments were deposited in a marginally marine environment under a terrestrial influence, as indicated by the presence of very rare dinocysts, and significant amounts of cuticular material. The dominance occurrence of the mangrove species, *Zonocostites ramonae* (*Rhizophora*) and *Foveotricolporites crassiexinus* (*Avicennia*), suggests a tidal swamp shoreline inhabited by mangroves. The palynological assemblage, which is dominated by pollen and spores, consists of well preserved and diverse taxa, most of which are characteristic of dense lowland vegetation. This study reveals the dominance of a high sea level and wet climatic condition during the deposition of the studied sediments.

Keywords: *Palynomorphs, offshore, Niger delta, Species diversity, Oligocene-Miocene*

1. INTRODUCTION

Palynology is becoming increasingly important in basin analysis worldwide [1; 2; 3; 4; 5; 6]. In modern research for petroleum, palynology has become an important tool in resolving many age and facies correlation problems. Being mostly allochtonous, palynomorphs are common, they occur in abundance in both continental and marine deposits. Hence, they can be treated statistically to reveal the degree of correlation in onshore and offshore sediments.

Chronological and environmental correlations of well and surface sedimentary sections is directed to the realization of obtaining the clearest possible picture of sedimentation in time and space within a depositional basin in order to elucidate the configuration of oil and/or gas bearing beds within a basin. This will lower the risks associated with oil exploration and production. According to [7], stratigraphic resolution can be substantially improved through the application of quantitative palynological methods, which are aimed at the identification of events reflecting climatic, tectonic, orographic and sea level changes but without resulting in widespread extinction of plant taxa. Unfortunately in the Niger Delta Basin, information on palynology is still scanty. The most comprehensive work to-date on the palynology of the Niger Delta is that of [8]. A few forms were illustrated by [9], [10] and [11]. This paper is an attempt to date the sediments using the recovered palynomorph assemblage, evaluate their species diversity and use the changes in the terrestrially-derived palynomorphs to have a better understanding of the climatic fluctuations during the period the sediments were deposited. It is hoped that the results so obtained will be useful in addressing correlation problems in the Niger Delta Basin and by extension, the Gulf of Guinea region.

2. GEOLOGICAL SETTING OF THE BASIN

The Niger Delta Basin is the largest basin on the continental margin of the Gulf of Guinea, covering an area of about 300,000 km^2 [12] with a sedimentary thickness of over 10 km in the basin centre [13]. It lies between longitudes 4^0E and 8.8^0E and latitudes 3^0N and 6.5^0N (Fig. 1).

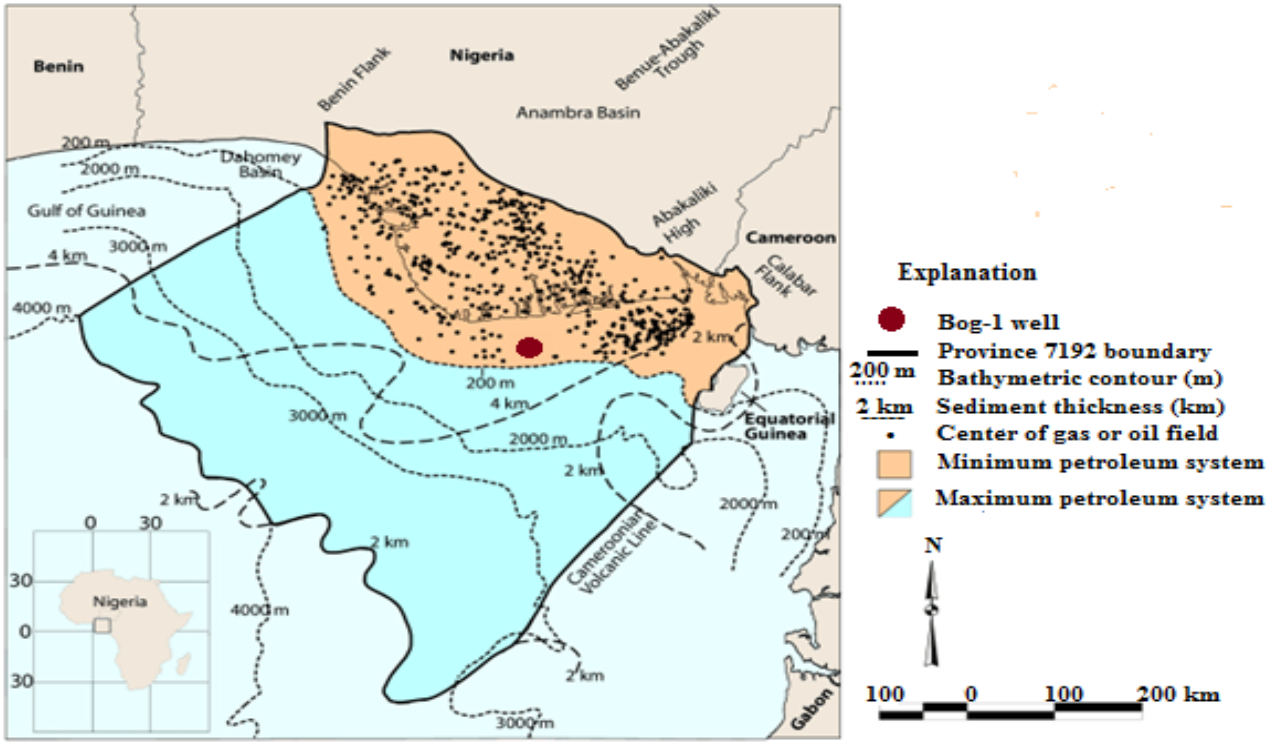


Fig. 1: Map of the Niger Delta Province Showing the Study Area and Province Outline, adapted from [14] and [15].

The basin occupies the oceanward part of a larger and older tectonic feature, the Benue Trough; hence its evolution has been linked to the Benue-Abakaliki Trough - a sedimentary complex. According to [16] and [17], the stratigraphic history of the Niger Delta Basin in terms of tectonic event revealed that the basin represents the third cycle in the evolution of the southern Nigerian sedimentary basins thus: (a) Benue-Abakaliki phase (Aptian - Santonian), (b) Anambra-Benin phase (Santonia - Early Eocene) and (c) Niger Delta phase (Late Eocene - Recent).

Based on the dominant environmental influence, the sedimentary sequence of the basin consists in ascending order of three major diachronous facies units [18], namely, Prodelta facies (marine environment), Delta front facies (transitional environment) and Delta plain facies (continental enviroment).

3. MATERIALS AND METHODS

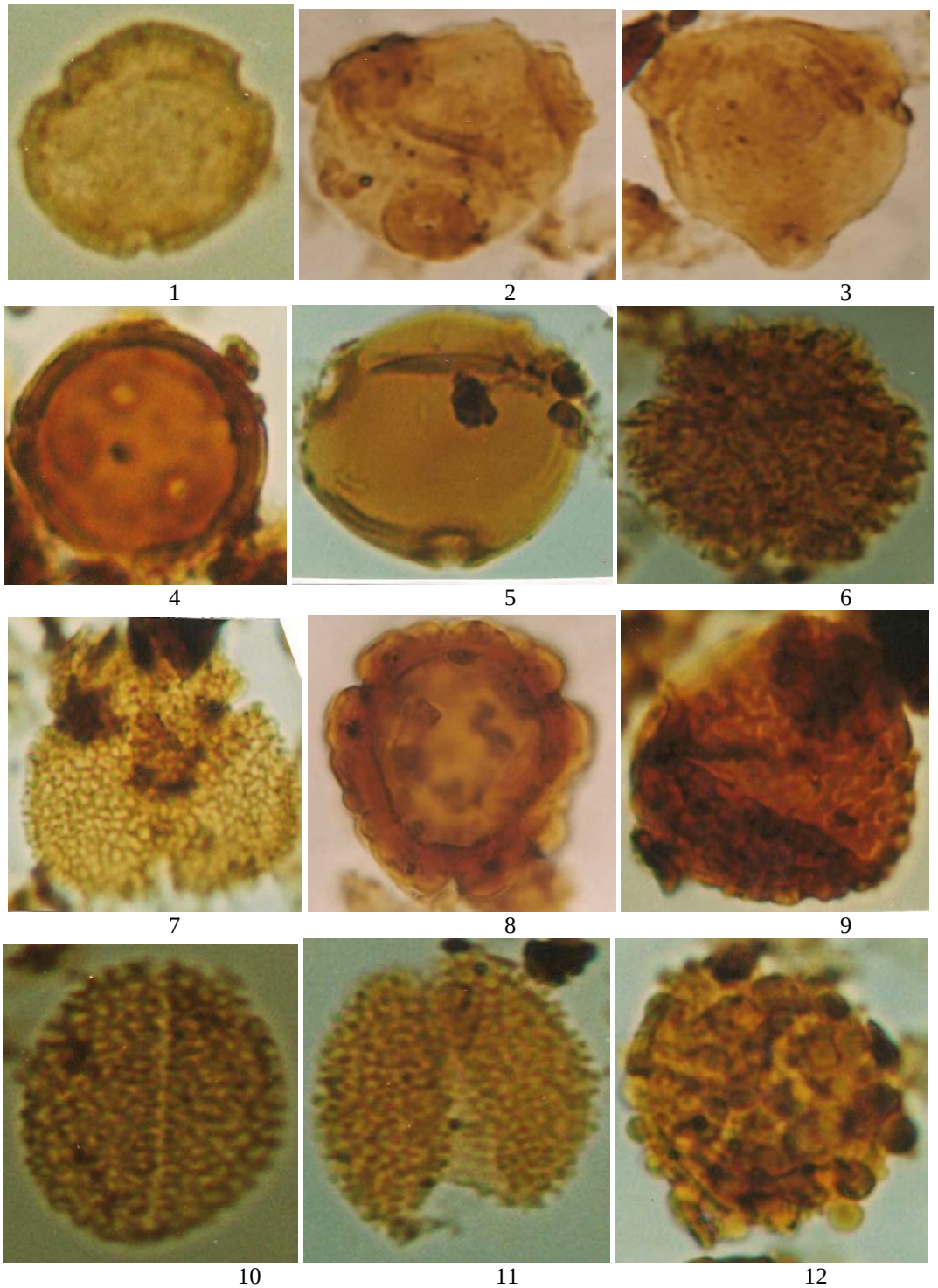
Fourteen ditch-cutting samples from Bog-1 well drilled in 2002 in the offshore section of the eastern Niger Delta, Nigeria (Fig. 1) were analysed lithologically, texurally and palynologically. The shaly samples were collected at 20ft intervals, from 5020ft-4760ft of the well. Ten grams of each sample were treated according to one of the methods recommended for palynological analyses of geologic samples [19]. Samples were treated with HF and HCl to remove calcareous and siliceous materials respectively; heavy liquid separation using zinc chloride and hydrochloric acid solution (specific gravity 2.0) and finally acetolysis to dissolve cellulose for easy identification of palynomorphs. After treatment, samples were mounted on slides and studied under x40 and x100 objectives using an Olympus CH30 camera-attached microscope. The identifications were based on about 3600 reference slides collections, and photomicrographs in the Palynology Laboratory, Department of Archaeology and Anthropology, University of Ibadan; as well as the following literature among others: [9]; [8]; [20]; [21]; [22]; [23] and [24]. Photomicrographs of the most important palynomorphs were taken with x100 oil immersion objective. All pollen and spores encountered were included in the pollen sum, on which the percentage composition of individual pollen at respective depths was based. However, in calculating the pollen sum for all the levels, *Zonocostites ramonae* was excluded as it was over-represented in the study area.

4. RESULTS

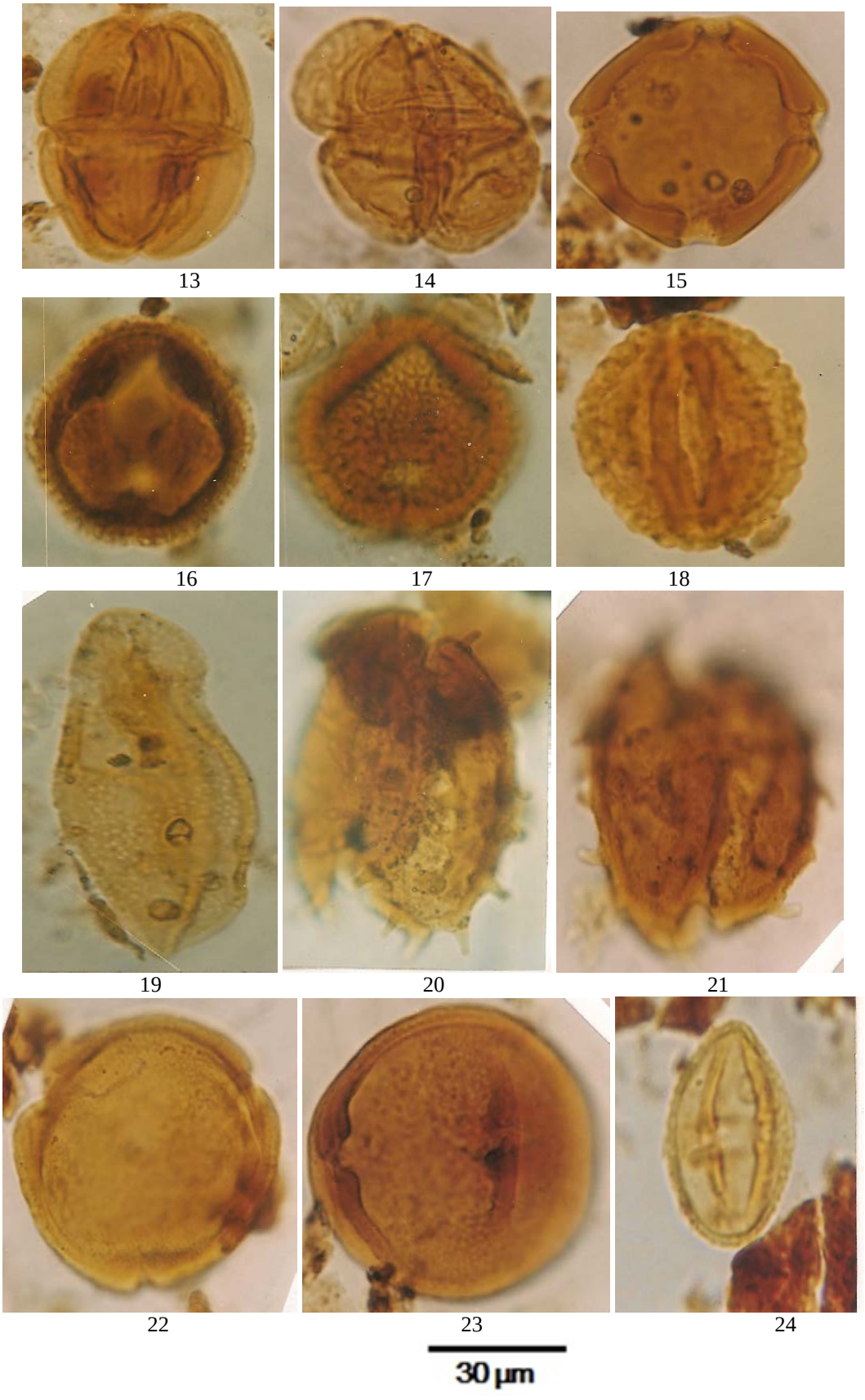
The studied sediments are dominated by shales intercalated with thin sandy shale beds (Table 1); these are generally greyish in colour, fissile with discontinous presence of ferruginous materials, gluaconite pellets and clay nodules. The recovered palynological assemblage consists of pollen, spores (fungal and pteridophytic) and dinocysts. Some cuticular materials were also recovered. The pollen grains, which dominated the recovered palynoflorules, are made up of several species of Monocolporites, Tricolporites, Triporites, and Stephanoporites. Other important angispermous species recovered is Monoporate. The

palynomorphs were well preserved (see plate) and characteristically diverse. A total of 152 palynomorphs were encountered out of which 119 were identified. The highest number of palynomorphs counted was 1186 (5020ft) while the lowest was 49 (4780ft). The recovered palynomorphs enabled the delineation of two zones, Zone I (Late Oligocene-Early Miocene) and Zone II (Early-Middle Miocene). The occurrence of *Zonocostites ramonae* was cyclic, this appeared to have followed the pattern of deposition of the shales and sandy shales from which the pollen grains were recovered (Table 1).

PLATE



PLATE(contd.)



1: Troporites sp (Triplochiton scleroxylon)
2-3: Retibrevitricolporites protrudens
4: Perisyncolporites pocokyi (Flabellaria paniculata)
5: Brevicolporites guinetii (Pentaclethra macrophylla)
6: Retitricolporites irregularis (Amanoa oblongifolia)
7: Bombacacidites sp. (Bombax sp.)
8: Gemmatricolporites sp.
9: Circatrisisporites dorogensis (Anemia sp.)
10: Arecipites/ Retimonocolporiotes pluribaculatus
11: Racemonocolpites hians
12: Gemmamonocolpites pilatus.
13-14: Adenantherites simplex (Calpocalyx dinklagei)
15: Pachydermites diederixi (Symphonia globulifera)
16-17: Fovoetricolporites crassiexinous (Avicennia africana/germinans)
18: Verrutricolporites sp.
19: Liliacidites sp. (Pancratium cf. maritima)
20-21: Maurittidites crassiexinous (Mauritia vinifera)
22-23: Psilatricolporites crassus (Tabernaemontana crassus)
24: Retitricolporites sp. (Hannoa klaindenea)

Table 1: Stratigraphic Ranges of Age Marker Taxa in Bog-1 Well

Depth	Lithology	Age	Zones/Taxa	Zonocostites ramonae	Monoporites annulatus	Psilatricolporites crassus	Retitricolporites irregularis	Psilatricolporites operculatus	Foveotricolporites crassiexinus	Arecipites sp	Verrucatosporites usmensis	Monolete spore	Retibrevitricolporites protruden	Striatricolporites catatumbus	Psilatricolporites benuensis	Circatricosporites dorogensis	Trilete spore	Racemonocolpites hians	Laevigatosporites sp.	Proxapertites cursus	Pachydermites diderixii	Gemmamonocolpites sp.	Ephedrites sp.	Perfotricolpites digitatus	Striatoticolporites sp.	Psilatricolporites annuliporis
4760				43	6	6	1	2	6	1	1	9														
4780				19	30	1				1			5	3	2											
4800				83	9	11	3	1	1		12	5	27		3	1	1									
4820				50	18	3		2		1		2	8	1	6	2	7	1	1							
4840				24	6	2	1	4		1	2		10			4	1	1	1	2	2					
4860				30	1	1	1				2		3		3	2	1		1			1				
4880		Early-Mid Miocene	Zone II	73	20	2	3	2	1	7	17		11		11	6	1	6	3	1	1	5	1			
4900				36	8	2	6	1		6	17		11		12			5	4			2				
4920				51	4	5	2	3		5	15	1	3	2	4				5							
4940				27	7	1		1	1		9	3			3	1		2	1		2	1		1	1	1
4960				31	4	3		2		2	13	8	8		6			3	3							3
4980				35	7	14	20	2			92	13	3	3	22	4	1	3	1		2		1			8
5000				212	7	7	22	2			99	14	7	1	11	3		1	1			1			2	1
5020		L. Olig.-E. Mioc.	Zone I	629	18	14	10	1	12	2	36		5	6	64			1	10				1	8		3

LEGEND
Shale
Sandy Shale

5. DISCUSSION

Palynological Age

The age of the sediment was determined based mainly on the first and last appearances (FAD and LAD) of stratigraphically significant taxa supported by their general distribution within the studied well (Table 1).

Zone I (5,020-4,940ft)

This level is characterized by the abundance of *Zonocostites ramonae, Retitricolporites irregularis, Verrucatosporites usmensis* and *Retibrevitricolporites protrudens* (Table 1). *Z. ramonae* (*Rhizophora* sp.) is a mangrove species which evolved in Nigeria in the Oligocene [25] and has continued till today. In Nigeria today, there are three species of *Rhizophora*: *Rhizophora racemosa, R. mangle* and *R. harrisonii*; the pollen of these three *Rhizophora* species are very difficult to distinguish. Other known constituents of mangrove swamp forest (MSF) in the basin include *Deltoidospora adriennis*, a salt water fern, with an age range of Eocene-Recent; *Spinizonocolpites baculatus/echinatus (Nypa fruticans*) with an age range of Upper Cretaceous to Early Miocene, and *Foveotricolporites crassiexinus*. Of all the MSF species mentioned above, only *S. echinatus/baculatus* was not recovered from the samples at this level and indeed from the entire sediments studied. Since

S. echinatus/baculatus was not recovered, it may have become extinct from this area by the time the sediments were deposited. *Nypa* evolved in the Upper Cretaceous and disappeared from Nigeria (Niger delta) at the end of the Eocene [8; 26 and 27]. However, it was recovered from Early Miocene sediments in Kaloye (Gwandu) Formation, Northwestern Nigeria [28]. Considering the fact that the extinction of *Nypa* in the Niger Delta predates that in the Northwestern Nigeria and possibly other parts of Nigeria, deterioration of the climate favouring its production may have begun earlier in the Niger Delta. *Nypa* is a palm that inhabits coastal mangrove swamps, where climate is hot and almost always wet with abundant rainfall and high humidity. From the evidence presented, it seems that environmental conditions favorable for continued survival of *Nypa* were maintained and restricted to the northwestern part of Nigeria from Late Eocene to Early Miocene. This situation allowed for the continued presence of *Nypa*, other palms (*Elaeis guineensis*) and the mangrove swamp forest represented by *Zonocostites ramonae (Rhizophora* spp.) in that area. It should be noted that *Nypa* could have become extinct from Nigeria when climate deteriorated or became unfavorable. It has been suggested that this change, which was a global event, resulted in the reduction, extirpation and extinction of many African palms beginning from the Palaeogene onwards [29]. *Nypa* is currently endemic to the Indo-Malaysian mangrove swamp forests. Thus, the sediments in the study area in which *Nypa* was absent, are considered not older than the Late Eocene. Furthermore, *Retibrevitricolporites protrudens* was also recovered at this level. The occurrence and abundance of *Retibrevitricolporites protrudens*- a species with an age range of Oligocene to Pliocene- during this period supports this fact.

At 5,000ft, there was an occurrence of *Mauritidites crassiexinus*. This species, a palm currently extinct from Nigeria and the entire West Africa, has an age range of Paleocene to Eocene [30]. Its presence at this level of studied well raises some questions about the age of the sediments. In this case, the occurrence of *M. crassiexinus* is considered a contamination (a reworked form from older sediments). This conclusion was arrived at based on the following reasons: Firstly, if the presence of *M. crassiexinus* at 5,000ft indicates an Eocene age for that depth, other pollen and spores characteristic of the Eocene should have been recovered in association with it. But pollen and spores characteristic of, and with age range restricted to both the Palaeocene and Eocene were absent. Examples of such pollen and spores include *Spinizonocolpites baculatus/echinatus, Longapertites marginatus, Proxapertites operculatus, Margocolporites foveolatus,* and *Grimsdalea polygonalis* among others. Secondly, only a single grain of this species was recovered. [31: p.439) had cautioned that "one should be suspicious that spores/pollen/dinocysts occurrences may be reworked when they are relatively rare specimens occurring stratigraphically well above rather abundant counts of the same form". Therefore, from the above discussion, the sediments would have been deposited during Oligocene-Miocene times. *Striatocolpites catatumbus*, an Early-Mid Miocene form [32], first appeared at 4940ft and marked the top of this zone. The last appearances of *Perfotricolpites digitatus, Stiatotricolporites* sp. and *Psilatricolporites annuliporis* equally occurred here. Hence, a Late Oligocene-Early Miocene age is suggested for the sediments within this interval.

Zone II (4,940-4,760ft)

Proxapertites cursus, R. protrudens, and *Monoporites annulatus* are the characteristic species of this zone. The LAD of *Perfotricolpites digitatus, Striatotricolporites* sp. and *Psilatricolporites annuliporis* demarcate the base of the zone. The last appearance of *P. cursus* at 4,840ft- a species known to have occurred from Early Eocene to Early Miocene [33, 34] -suggests that these sediments are not older than Late Oligocene-Early Miocene age since this interval lies above 5,020-4,940ft interval. Other species here is *Striatocolpites catatumbus*, with age range of Early-Mid Miocene [8]. Therefore, these sediments are of Early-Mid Miocene age; this is because *P. cursus* has not been found in sediments younger than the Mid-Miocene in Nigeria.

Species Richness (5,020, 5,000, 4,880, 4,800ft)

At 5,020ft, 62 types of palynomorphs i.e. species diversity (SD), were recovered (Fig. 2). This was the highest number of pollen species recovered from a single level. Over fifty one percent (51.6%) of the 62 types of species are found in forest regions, while 4.9% was mangrove swamp forest (MSF) and Fresh water swamp forest (FWSF) was 9.6%. Considering the fact that the mangrove swamp MSF and FWSF are both edaphic varieties of lowland rain forest (LRF), the figures for the MSF and FWSF were added to that of forest i.e. 51.6%, making a total of 66.1% for the LRF alone. Afterwards, the species diversity began to decrease gradually from 62 through 54 (5,000ft), 48 (4,980ft), 33 (4,960ft) and finally to 30 (4,940ft). Climate, at 5,020ft would have been wet and the major tributaries of the Niger River would have been active and contributed to an increase in sea level. The abundance of FWSF species indicates the presence of fresh water swamps in the area, thus indicating that the vegetation was a "mosaic of mangrove swamp and seasonally flooded rainforest" [21: p. 9]. Though mangrove swamp forest constitutes 4.9% of the species diversity figure, it constituted 58% of the entire pollen sum. This figure i.e. 58% indicates a coastal environment and a probable high sea level. Savanna species is 8.3% of the total species recovered at 4,980ft. Species diversity was 30 at 4,940ft, but it increased to 38 (4,920ft), decreased slightly to 35 (4,900ft) and increased sharply to 48 at 4,880ft. At 4,880ft, 68.4% of the 48 species types encountered belong to the LRF, indicating clearly a proliferation of forest species and denseness of the forest vegetation. It is assumed the forest would have been quite extensive at this time. After this time, species diversity decreased sharply from 48 through 27 (4,860ft) and increased again to 49 at 4,800ft. At 4,800ft, the LRF (RF, MSF and

FWSF) constituted 75.5% of the number of species encountered. The presence of the Arecaceae (*Arecipites* sp., *Monocolpites* sp., and *Gemmamonocolpites* cf. *gemmatus*) indicates a warm and wet climate. The absence of *Elaeis guineensis* (a sun-loving, open vegetation species) is note worthy. It is also pertinent to note that the area at this time was LRF-dominated, with diverse forest plant species. Some of these forest species include *Dipterocarpus* sp., *Celtis* sp., *Retitricolporites irregularis*, *Flabellaria* cf. *paniculata*, *Diospyros* sp., *Triplochiton scleroxylon*, *Alstonia booneii*, *Hannoa* sp, *Calpocalyx dinklagei*, *Pachydermites didierixii*; pteridophytes such as *Laevigatosporites* sp., *Pteris* sp., *Verrucatosporites usmensis* and other pteridophytes represented by trilete spores, and the climber (*Securidaca* cf. *welwitschii*). Thus, the general environment was that of a dense rain forest, with palms and fresh water swamp forest.

No	Depth (ft)	Species Diversity
1	4,760	31
2	4,780	15
3	4,800	49
4	4,820	28
5	4,840	27
6	4,860	28
7	4,880	48
8	4,900	35
9	4,920	38
10	4,940	30
11	4,960	33
12	4,980	48
13	5.000	54
14	5,020	62

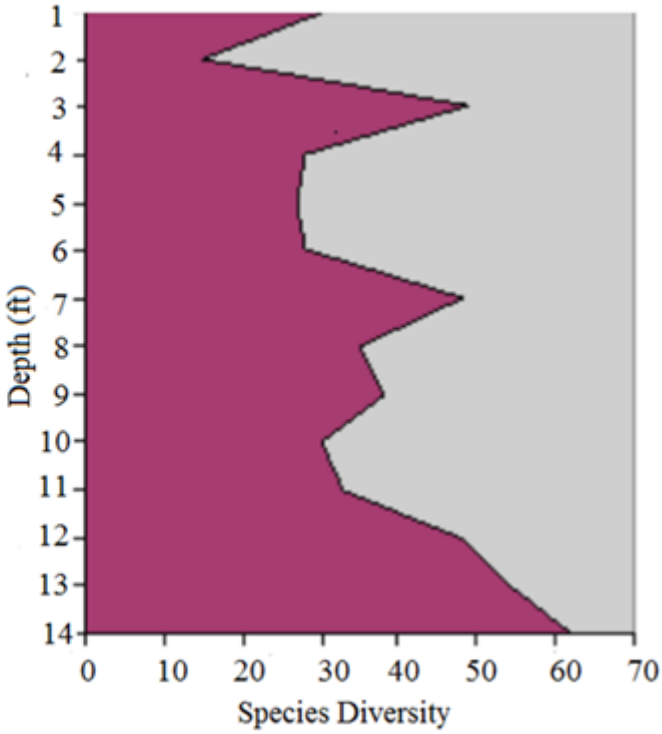


Fig 2: Species Diversity against Depth

Species Paucity (4,940, 4,860-4,820, 4,780ft)

At 4,940ft, the total number of species encountered is 30. This is a relatively high number. But considering the fact that the species diversity figure was once 62 at 5,020ft, and continually dropped to 30 at 4,940ft, it is regarded as a low SD index, indicating relative species paucity. At 4,940ft, the LRF was 73.2% but Guinea savanna species constituted 10%. The relatively high proportion for the Guinea savanna species indicates a slight change in climate from the hitherto wet to drier type or as a result of openings in the LRF. Though there was an increase in *Zonocostites ramonae* at this level, other LRF forest species (*Retibrevitricolporites protrudens*, *Psilatricolporites crassa*, *P. operculatus*, *P. annuliporis* and *Uapaca* spp.) decreased. On the other hand, *M. annulatus* increased from 3.4% (4,960ft) to 7.3% at 4,940ft, this being the highest figure recorded since 5,020ft. This corroborates the proliferation of grasses earlier noted in the Neogene [35] and [36]. The dominance of *M. annulatus* coincided with a reduction of forest species and FWSF which had hitherto been dominant (Table 1). Thus, indicating a slight change in climate, probably to a brief dry period.

The presence of *Verrucatosporites usmensis* (*Stenochleana palustris*), a fern commonly found in the wet forest seems to point to the persistence of some humid conditions. *V. usmensis* maintained a level of 15.2% at 4,940ft, its previous level being 15.3% at 4,960ft. At 4,840ft, SD was 27. Of this figure, LRF was 66.6% while savanna and grasses were 3.7% each. Though the species diversity was comparatively low (27), it was not significantly different from the preceding and successive levels which had 28 species each. At 4,780ft, SD dropped to 15, being the lowest figure recorded. This is significant because the preceding level, 4,800ft had 49 species suggesting a brief dry spell within this humid condition.

6. CONCLUSION

A total of 119 palynomorphs were identified out of 152 encountered. The palynological assemblage was dominated by pollen and spores. The studied sediments are of Late Oligocene-Mid Miocene age based on the recovery of *Zonocostites ramonae*, *Retimonocolpites pluribaculatus*, *Retibrevitricolporites protrudens*, *Psilatricolporites crassus*, *Circatricosisporites dorogensis*, *Retitricolporites irregularis* and *Pachydermites diederixi*. Species diversity of above 30 is regarded as rich while that of 30 and below poor. Except at few levels, there was a general occurrence of high species diversity. This diversity of the angiosperm palynoflora, which forms the bulk of the assemblage, suggests a dense lowland vegetation cover during the deposition of the studied sediments in a tidal swamp mangrove.

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