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PALAEOECOLOGICAL STUDIES OF QUATERNARY SEDIMENTS FROM THE UNIVERSITY OF LAGOS, NIGERIA

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ABSTRACT

The knowledge of changes in past ecological conditions during the Quaternary period of Nigeria is still incipient. This necessitated a palaeoecological investigation through drilled sediments of a 45 m borehole in a swampy area at the University of Lagos, in order to ascertain possible changes in the past ecological conditions of the study area over time. Sixteen sediment samples were collected at intervals of 3 m between the depth of 0.00 m and 45.00 m and subjected to palynological, lithological, pH and salinity analyses. In the palynological study, pollen of open forest types: *Alchornea cordifolia, Elaeis guineensis,* Asteraceae, among others were recovered, indicating human influence over time. Pollen of *Rhizophora* sp., Combretaceae/Melastomataceae*,* Poaceae, *Ceratopteris* sp., *Cyclosorus afer*, amongst others; were also represented. Spores of *Pteris* sp., *Nephrolepis* sp. and *Acrostichum* sp., charred Poaceae cuticles, epidermal cells and fungal spores were also recovered. From the lithological analysis of the samples, a considerable number of lithological types were recognized, which varied in grain-size, grain sorting and grain-texture. The pH and salinity values of the sediment samples also varied considerably at different depths. However, vegetation changes during this period could be attributed to an interplay between fluctuations in the wet-dry climatic phases and anthropogenic activities. The data obtained from lithological, pH and salinity analyses reveal a mosaic of sedimentary depositional environment in which the recovered palynomorphs were preserved. Parent plants of the recovered fossil palynomorphs are still found as extant plants till today, despite the ever increasing human activities at the study area. Absolute ages were extrapolated and these revealed the period at which paleoecological changes occurred but limited to some intervals.

Key words: palynomorphs, Quaternary period, climatic phases, anthropogenic, sediments.

INTRODUCTION

With increasing knowledge of the remarkable events that occurred during the late Quaternary period in several parts of the world, palynological evidence has become a veritable tool for the explanation of the vegetation changes over climatic history (Absy, 1985). Palaeoecology entails the study of periodic changes in the ecological conditions of an area over a geological time. These changes are most evidently reflected in the vegetation, which is part of the biological components of an environment. The distribution and composition of tropical West African vegetation is strongly linked to the prevailing climatic conditions (Holdridge *et al.*, 1971). Booth (1957) postulated that there were alternating periods of wet and dry climatic conditions in West Africa in Quaternary period. This consequently influenced the type of vegetation present in the prevalent climatic conditions.

Palynology is the study of both modern and fossil pollen grains and spores, as well as other types of microfossils (Sowunmi, 1987). Pollen and spores are micro-structures involved in the reproduction of plants and are dispersed from their parent vegetation types. It is based on the interdependence between climate and vegetation that palynology is employed in the reconstruction of past environments in the Quaternary period given its peculiar rapidity of climatic changes. Important palaeoecological studies on the late Quaternary changes in Nigeria and other African countries have been conducted (Sowunmi, 1986, 1991, 2002 and 2004; Adekanmbi, 2008; Adeonipekun, 2013). Davey (1971) carried out an assessment of palynomorph distribution in recent continental shelf sediments off the coast (offshore) of Southwest South Africa between Cape Town and Cape Agulhas. He reported that both marine and non-marine palynomorphs have their highest abundances relatively near the shore and both decreased gradually offshore, with a striking similarity in the distribution pattern of all both groups. Leroy and Dupont (1997) conducted a high-resolution pollen analytical study on ODP site 658, off Cape Blanc, Northwestern Africa. They noted a reduction in the extent of savanna vegetation from 2.8 Ma and attributed it to the development of desert in West Africa. Dupont *et al*., (1998) employed the use of sporomorphs and dinoflagellate cysts in documenting the vegetation history of the West African forest during the last 700 Ka in relation to changes in salinity and productivity of the eastern Gulf of Guinea from site GIK 16867 in the northern Angola Basin. They discovered that the Afromontane forest, rather than the open grass-rich dry forest expanded to lower altitudes partly and replaced the lowland rainforest of the borderlines east of the Gulf of Guinea, during most of the cool and cold periods. Lezine and Cazet (2005) carried out a high resolution pollen study of 69 samples collected from core KW31 off the mouth of Niger River from the Gulf of Guinea. They pointed out that the increase in forest diversity and the expansion of rain and secondary forests in the adjoining continent could have arisen from the post-glacial warming coupled with increase in monsoon fluxes over West Africa. They also reported that a vegetation response to the shift towards aridity occurred widely at the end of the African Humid Period around 4,000 Y.B.P.

In Nigeria, Sowunmi (1986) evaluated the impact of man on the natural vegetation of the Niger-Delta through a drilled core. She reported that anthropogenic influence became obvious from ca. 3000 Y.B.P as evidenced by a drop in rainforest pollen concomitantly with a sharp rise in *Uncaria africana* and *Elaeis guineensis* (open forest trees). Sowunmi (1987) took samples from four different communities of the Niger Delta, Nigeria: Onyoma, Ofuabo, Ogbolomabiri and Bassambiri. She attributed the reduction in forest and a concomitant expansion of savanna to adversely dry climatic conditions. She reported that farming activities prevailed in the rain forest zone and probably in the deltaic region from ca. 3,000 Y.B.P onwards. Sowunmi (2004) reported an abrupt decrease and a subsequent disappearance of *Rhizophora* pollen during the late Holocene in Ahanve creek, Badary, Lagos, Nigeria. Fresh water vegetation such as those of fresh water grasses, *Alchornea cordifolia* and *Elaeis guineensis* replaced *Rhizophora* sp. These events were attributed in part to anthropogenic effects, though climate and geomorphology remain the main factors that were said to have influenced Holocene vegetation changes in the area.

Most paleoecological studies in Nigeria have been carried out in the Niger Delta area and are restricted to the Tertiary period, hence data on Quaternary changes in Nigeria are still emerging. This necessitated the present study undertaken with a view to examining the past ecological changes that prevailed in the Quaternary period in a swampy area at the University of Lagos, Akoka, Yaba, Lagos.

MATERIALS AND METHODS

Description of the study area

The study location is situated within a swampy area at the University of Lagos, Akoka, Yaba, Lagos and lies between Latitude 6°31'0.70"N and Longitude 3°23'57.76"E (Figure 1). The University of Lagos is located on the western part of Lagos metropolis in Yaba Local Government Area of the state. The present vegetation is predominantly open vegetation, consisting of *Panicum maximum*, *Alchornea cordifolia*, *Tridax procumbens*, *Terminalia catappa*, *Elaeis guineensis*, *Chromolaena odorata*, *Gomphrena celosoides*, *Mariscus alternifolius*. and *Paspalum vaginatum*. Other represented plants include *Triumffeta cordifolia, Phyllantus* sp., *Drepanocarpus lunatus, Mimosa pudica, Luffa cylindrica, Saccolepis africana*, *Scoparia dulcis, Dalbergia castaphyllum, Vernonia cinera, Ficus* sp., *Alternanthera sessilis, Ipomea carica* and *Vernonia amygdalina* among others.

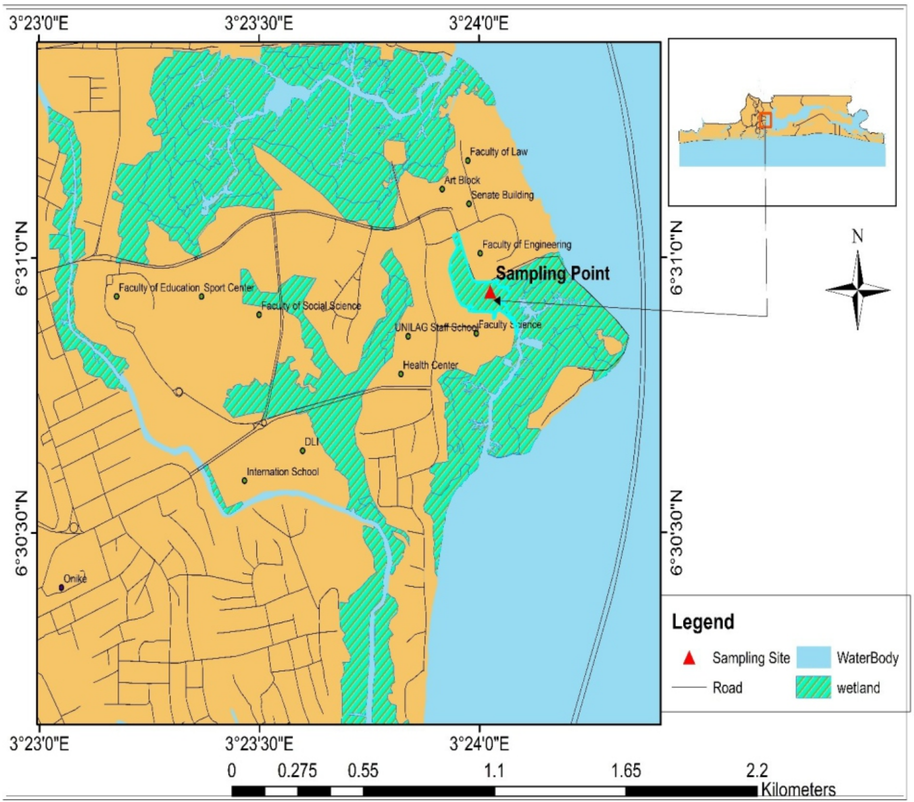


Figure 1: Map showing the sampling site at the University of Lagos, Nigeria.

Source of materials: 16 sediment sub-samples were collected at an interval of 3.00 m between 0.00 m and 45.00 m from a drilled bore-hole in the year 2013. The collected samples were subjected to palynological, lithological, pH and salinity analyses.

Lithological analysis

A lithological analysis of each sample was carried out and the textural characteristics (grain-size, grain shape and grain sorting) were determined using the standard grain size scale in the American/Canadian Stratigraphic Code. This was done in order to examine the physical properties of these samples.

Palynological analysis

Ten grams of each sediment sub-sample was weighed and subjected to standard palynological preparation techniques (Faegri and Iversen, 1966; Erdtman, 1969) in the Laboratory of Palynology and Palaeobotany, Department of Botany, University of Lagos. Pollen preparation of each sample passed through three different stages: demineralization using 40 % HF overnight and concentrated HCl to remove siliceous and calcareous materials respectively; heavy liquid separation using Zinc chloride and Hydrochloric acid solution (specific gravity 2.0) and finally acetolysis to dissolve cellulosic materials for easy identification of palynomorphs. Samples were then stored in 100% glycerin to prevent the palynomorphs from drying out. From stock mixture, samples were collected and mounted on slides and studied under x40 magnification using an Olympus CH2 light microscope. Identification was done using some pollen albums, relevant journals (Sowunmi, 1973; 1987; 1995 and Gosling *et al*., 2013) and pollen reference slide collection in the Laboratory of Palynology and Palaeobotany, Department of Botany, University of Lagos. Photomicrography of some of the identified palynomorphs were taken with the aid of a Motic 2300 digital camera. Pollen diagram was also constructed by deriving the percentage composition of each phytoecological group; total percentage of pollen counts produced by represented plants in each phytoecological group at each depth (Moore and Webb, 1978; Lezine and Vergnaud-Grazzini, 1973), using SPSS statistic version 17. Some of the identified taxa with important ecological limits were chosen for phytoecological groupings and classified into nine different groups. This was done based on known present day natural distribution of these plants, using the works of Keay (1959) and Sowunmi (1986 and 1987).

Soil salinity and pH test

Five grams of the soil samples were weighed and dissolved in 50 ml of distilled (deionized) water to form a suspension. The samples were thoroughly stirred using a stirring rod and allowed to stand for three hours to allow the dissolution of ions and salt content of the sediments in the water. A salinity probe (La Motte pH/Conductivity /TDS/Salinity Meter Tracer Pocketester Code 1766) was then used to measure the salinity (ppm) and pH values of each of the samples.

RESULTS

From the palynological analysis of the sediment samples, pollen and fern spores of different phytoecological groups were identified across depths (Table 1). Charred Poaceae cuticles, epidermal cells and fungal spores were also recovered.

Phytoecological groups

1. Mangrove swamp forest: *Rhizophora* sp., *Avicennia* sp. and *Acrostichum* sp.
2. Open Forest: *Elaeis guineensis*, Asteraceae, *Alchornea cordifolia* and *Commelina* sp. type.
3. Fresh water swamp forest: *Cyclosorus afer* and *Ceratopteris* sp.
4. Guinean Lowland Rainforest: *Senna* sp., Combretaceae/Melastomaceae, Bombacaceae and *Albizia* cf. *zygia*.
5. Fern spores: *Pteris* sp. and *Nephrolepis* sp.
6. Guinea Savanna: *Syzygium guineense*
7. Montane forest: *Podocarpus* sp.
8. Poaceae group
9. Cyperaceae group

Table 1: Composite spectra of identified pollen and spores across sample depths (in percentages) except at 12 m and 45 m with bareness of palynomorphs respectively

S.no	PARENT PLANTS OF PALYNOMORPHS	Sample depths (metres)															
		0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45
1.	*Rhizophora* sp.	3.1	5.4	22.4	22.1	0	0	0	0	13.7	6.4	0	0	23.6	29.1	5.9	0
2.	Poaceae	21	28.2	31.1	5.2	0	0	0	0	7.2	2.4	42.9	8.9	32.5	24.7	20.1	0
3.	*Acrostichum* sp.	0.8	0.8	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0
4.	*Avicennia* sp.	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.	*Alchornea cordifolia*	34.7	20.7	20.4	56.7	0	98.3	4.5	81.9	19.3	70.4	19	80.5	8.2	39.9	69	0
6.	*Pteris* sp.	0	0	8.0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.	*Nephrolepis* sp.	0	0	0	0	0	0	0	0	10.3	1.8	0	3.3	0	0	0	0
8.	*Ceratopteris* sp.	0	0	0	0	0	0	0	0	0	1.8	0	0	0	0	0	0
9.	*Cyclosorus afer*	11.7	26.5	0	2	0	0.5	0	0	8.3	0	0	0	0	0	0	0
10.	*Elaeis guineensis*	2.7	9.6	3.9	1	0	0.4	95.5	18.1	8.3	10.1	17.9	7.3	17.5	0	0	0
11.	Arecaceae	4.8	1	0	0	0	0.4	0	0	0	2.7	0	0	9.1	0	0	0
12.	Asteraceae	0.5	1.9	7.7	0	0	0	0	0	12.3	0	0	0	0	0	0	0
13.	Myrtaceae	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14.	*Podocarpus* sp.	0	0	0	0	0	0	0	0	0	0	0.6	0	0	0	0	0
15.	*Albizia* cf. *zygia*	0	0	0	0	0	0	0	0	8.3	0	0	0	9.1	0	0	0
16.	*Syzygium guineense*	0	0	0	0	0	0	0	0	0	0	0	0	0	6.3	4	0
17.	Apocynaceae type	0	1	0	3	0	0	0	0	0	1.8	0	0	0	0	0	0
18.	Anacardiaceae type	0	0	0	0	0	0	0	0	0	0	0.6	0	0	0	0	0
19.	*Commelina* sp. type	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20.	*Senna* sp.	0	2.9	0	0	0	0	0	0	0	0.9	0	0	0	0	0	0
21.	Euphorbiaceae	3.7	0	0	0	0	0	0	0	12.3	0	0	0	0	0	0	0
22.	*Rauvolfia vomitoria* type	0	0	0	0	0	0	0	0	0	0	0.6	0	0	0	0	0
23.	Bombacaceae	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.	Cyperaceae	8.5	0	11.5	3	0	0.4	0	0	0	0.9	13.4	0	0	0	0	0
25.	Acanthaceae	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26.	Combretaceae/ Melastomaceae	7	0	0	7	0	0	0	0	0	0	5	0	0	0	1	0

Table 2: Pollen spectra (percentage composition) of phytoecological groups and absolute ages of sediments across sample depths (except at 12 m and 45 m respectively)

Depth(m)	Extrapolated absolute ages after Sowunmi (2004)	PHYTOECOLOGICAL GROUPS								
		Fresh water swamp forest	Guinea savanna	Fern spores	Guinea lowland rainforest	Mangrove swamp forest	Montane forest	Open forest	Poaceae	Cyperaceae
0		0	0	11.7	11.7	4.4	0	42.7	21	8.5
3	< 6409 Y.B.P	0	0	26.5	5.9	6.2	0	33.2	28.2	0
6	ca. 7172 Y.B.P	0	0	8.0	0	22.4	0	32	26.1	11.5
9	< 8576 Y.B.P	0	0	2	10	22.1	0	57.7	5.2	3
12		0	0	0	0	0	0	0	0	0
15		0	0	0.5	0	0	0	99.1	0	0.4
18		0	0	0	0	0	0	100	0	0
21		0	0	0	0	0	0	100	0	0
24		0	0	18.3	20.9	13.7	0	39.9	7.2	0
27		1.8	0	1.8	2.7	7.2	0	83.2	2.4	0.9
30		0	0	0	6.2	0	0.6	36.9	42.9	13.4
33		0	0	3.3	0	0	0	87.8	8.9	0
36		0	0	0	9.1	23.6	0	34.8	32.5	0
39		0	6.3	0	0	29.1	0	39.9	24.7	0
42		0	4	0	1	5.9	0	69	20.1	0
45		0	0	0	0	0	0	0	0	0

Absolute ages of few intervals were extrapolated in this study (Table 2), owing to a limited correlation between the sampled intervals and those of Sowunmi (2004) and also rarity of radiocarbon dates in Lagos, Nigeria. It is noteworthy that the wet-climatic phase markers in this study include fern spores, as well as pollen of fresh water swamp forest, Guinea lowland rainforest, mangrove swamp forest and Cyperaceae group. The dry-climatic phase markers thus included pollen of savanna, Poaceae group, open forest and montane forest (Dupont and Agwu, 1991; Sowunmi, 1987; Tossou, 2002 and Ige, 2011). From the phytoecological groupings, the pollen spectra revealed seven main pollen zones (zones A to G). The zonation was done through the observation of marked changes in the relative percentages of all the ecological groups from the oldest to the topmost depth (Table 2) as shown below:

Zone A: (45 m)
There were no palynomorphs recovered from this depth.

Zone B: (42 m - 36 m)
Firstly, there was a relatively high representation of Poaceae coupled with the occurrences of open forest and Guinea savanna groups. Secondly, there was also an abrupt rise in the representation of mangrove group and a drastic increase in Guinean lowland rainforest group. An establishment of a coastal savanna vegetation is inferred for this zone.

Zone C: (33 m - 30 m)
In this zone, open forest increased drastically (27.3-87.8%). At first, there was a marked abrupt decline in Poaceae representation (32-8.9%) and again with a rise in its occurrence (8.9 % - 52.9 %). Guinean lowland rainforest also dropped drastically (27.3-2.8%) with a total absence of mangrove swamp forest. This zone also marked the first appearance of fern spores and Cyperaceae (2.4% and 13.4% respectively). A very significant event was the rare occurrence of a *Podocarpus* species, which is not native to Nigeria.

Zone D: 27 m - 24 m
This zone marked the restoration of the mangrove swamp forest together with an increase in Guinean lowland rain forest and a sharp drop in the percentage occurrence of Cyperaceae group. The first appearances of a fresh water swamp forest element: *Ceratopteris*, as well as *Nephrolepis* sp. were recorded. At this period, there was also a marked abrupt reduction in the percentage occurrence of Poaceae group. Open forest though fluctuated, remained greatly dominant in this zone.

Zone E: 21 m to 15 m
This was a period when open forest types reached a total dominance coupled with a feeble

occurrence of Poaceae, fresh water swamp group and Cyperaceae group at the end of the zone. Also, there was a total absence of other ecological groups. The predominant vegetation during this period was that of a great establishment of an open forest.

Zone F: 12 m

This zone was marked by barrenness of palynomorphs.

Zone G: 9 m to 0 m (Present)

Due to the complexity of this zone, it is sub-divided into two sub-zones.

Sub-zone G.I: 9 m to 6 m

This was a period of marked restoration from the total absence of mangrove and Guinean lowland rainforest. The Cyperaceae and Poaceae groups increased abruptly with a drastic drop in open forest representation, which was still greatly dominant in this zone. Fern spores and fresh water swamp forest group were feebly represented. A short-lived establishment of savanna vegetation is suggested for this zone.

Sub-zone G.II: 3 m to 0 m (Present)

This zone marked the establishment of an erstwhile-reduced freshwater swamp forest group, though with a total disappearance of fern spores and a low or none occurrence of the Cyperaceae group. The mangrove ecosystem and Guinean lowland rainforest seemingly diminished drastically to the base of the zone. There was a slight drop in the representation of open forest, coupled with a considerable decrease in the occurrence of the Poaceae group, though both groups still thrived over the other groups.

Lithology, pH and salinity of the sediment samples

The pH and salinity values of the sediment samples varied considerably across sample depths (Figure 2). The lithological study of the sediment samples also revealed four different lithological types of alternating sandy and clayey sediments (mudstones).

Lithologic type A (45 m, 36 m, 33 m, 30 m, 27 m, 24 m and 21 m)

Mudstones (>75 %): Light grey, soft and non-fissile.

Sand (<25 %): Light grey, fine grained, sub-angular and very well sorted.

Lithologic type B (42 m and 39 m)

Sand (>95 %): Light-grey, medium-coarse grained, pebbly, sub-angular to sub-rounded and moderately sorted.

Mudstones (<5 %): Light-grey, soft and sub-fissile/non-fissile.

Lithologic type C (18 m, 9 m, 6 m and 3 m)

Mudstones (>80 %): Brown to light grey, soft and non-fissile.

Sand (<20 %): Light-grey, very fine grained, sub-rounded and very well sorted.

Lithologic type D (12 m and 0.00 m)

Sand (>80 %): Light-grey, fine medium grained, sub-angular to sub-rounded and moderately sorted.

Mudstones (<2 %): Dark-grey to light-grey, soft and sub-fissile to non-fissile.

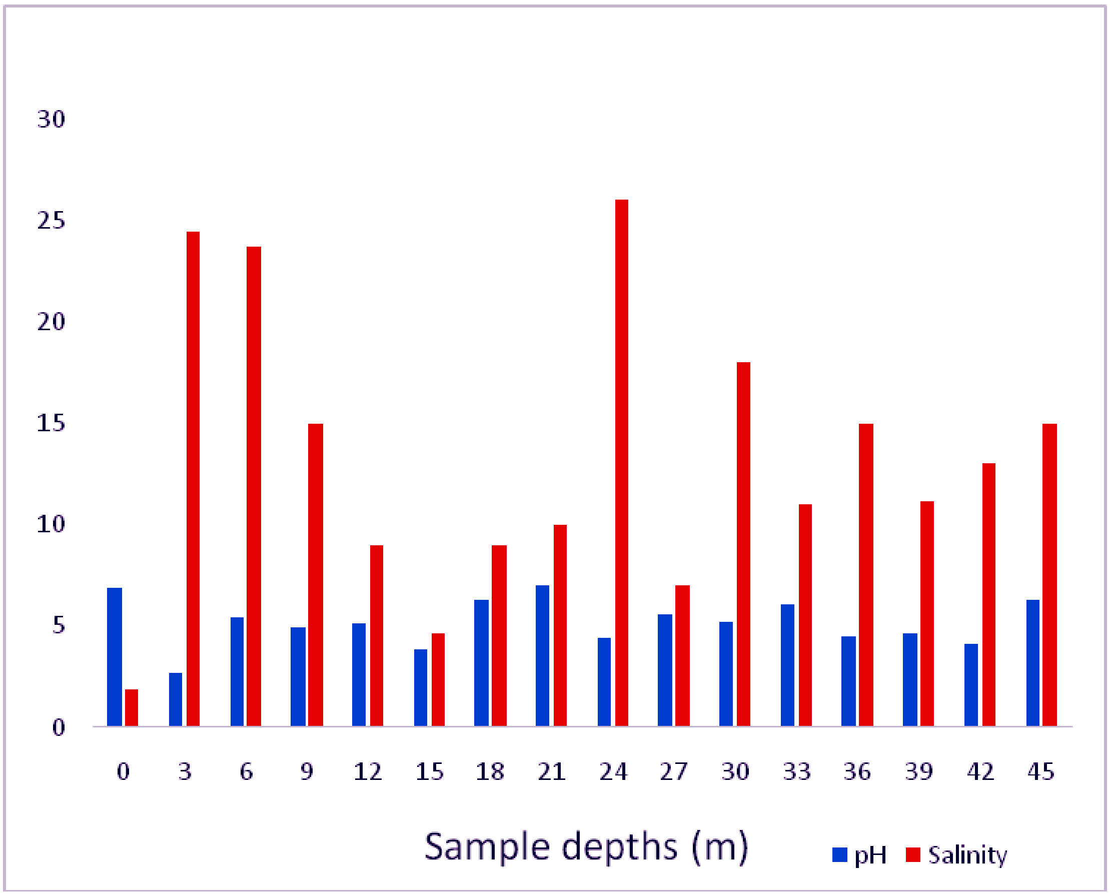
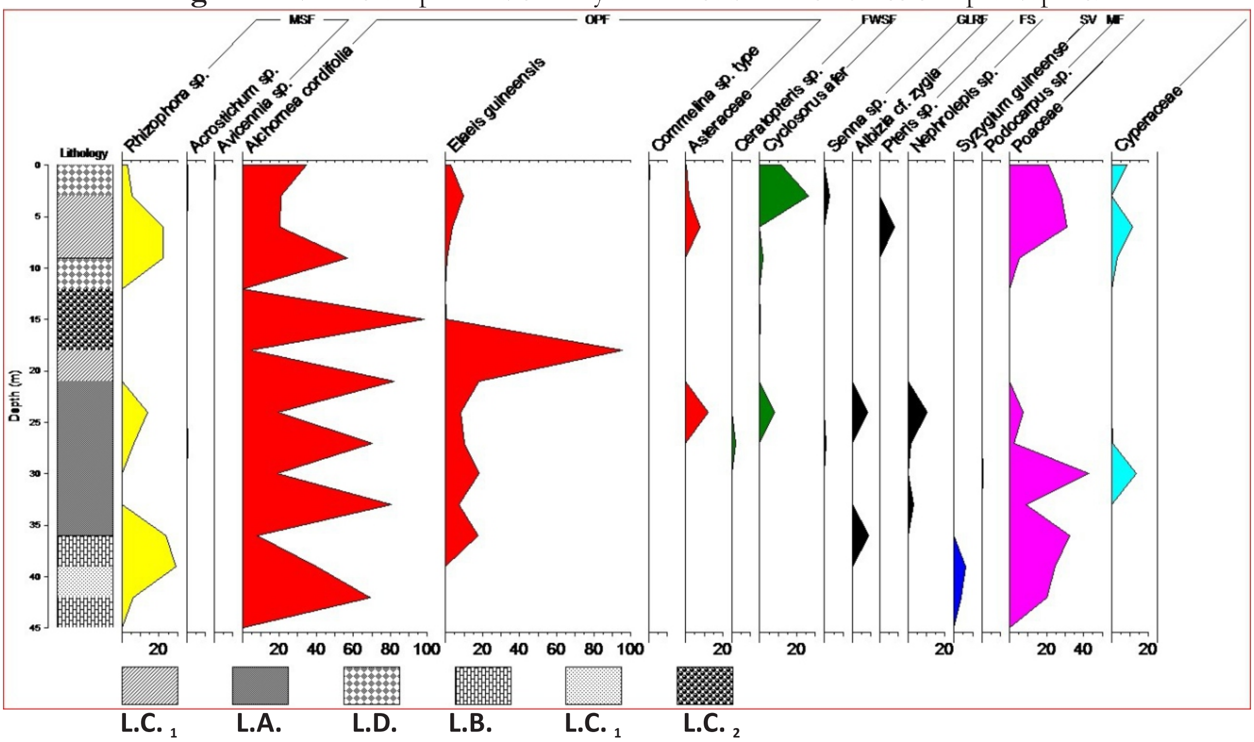


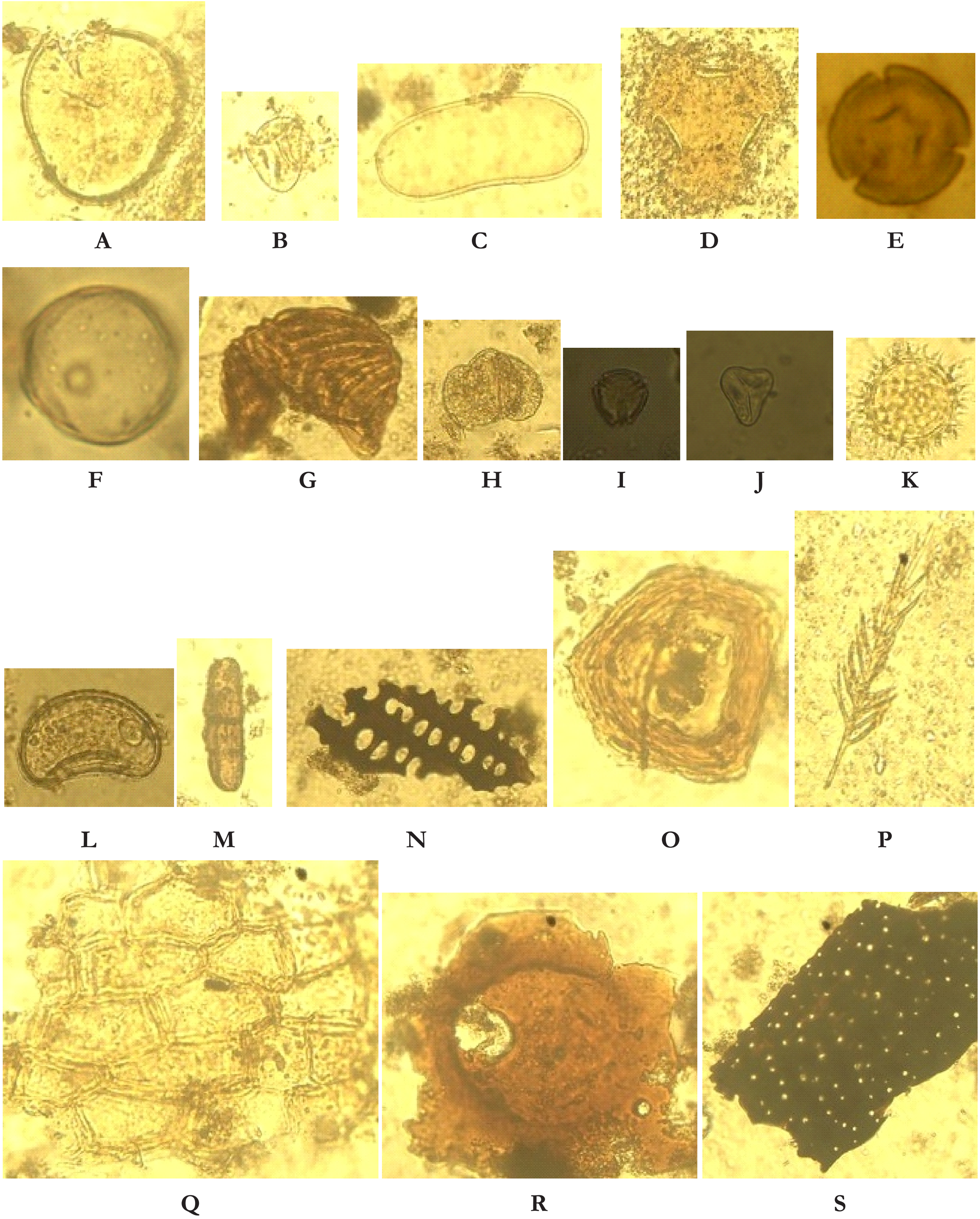
Figure 2: Values of pH and salinity of the sediments across sample depths.



KEY: L.A = Lithologic type A; L.B = Lithologic type B; L. C. $_1$ = Lithologic type C (3 m to 9m); L. C. $_2$ = Lithologic type C (15 m to 18 m); L.D = Lithologic type D.

Figure 3: Pollen diagram of a 45-m sample core at the University of Lagos.

PHOTOMICROGRAPHS OF SOME RECOVERED POLLEN GRAINS AND SPORES IN THIS STUDY



Photomicrographs of some recovered fossil forms: PLATE 1. A- *Acrostichum aureum*; B- Cyperaceae; C- *Cyclosorus afer*; D- *Senna* sp., E- *Rhizophora* sp., F- Poaceae; G- *Ceratopteris* sp., H- *Podocarpus* sp., I- *Alchornea cordifolia*; J- *Elaeis guineensis*; K- Asteraceae; L- *Nephrolepis* sp., M- Fungal spore; N and S- Charred Poaceae cuticles; O and R- Decayed plant parts P- Fossil plant leaf; Q- Epidermal cells; Q (All magnification: x400).

DISCUSSIONS

The results from botanical evidences revealed changes in the vegetation types that prevailed over time in this area. Zones A and F are attributed to a bareness of palynomorphs (Tables 1-2) which might have resulted from the poor preservation state of palynomorphs, typical of their predominantly sandy lithology (Figure 3). In Zone B, there was a relatively high abundance of Poaceae and open forest type, with the occurrence of Guinea savanna, in comparison with those of wet climatic phase markers such as Guinea lowland rainforest, riverine forest and mangrove groups. This is indicative of a secondary forest with a physiognomy similar to the southern Guinea savanna, rich in a mosaic of both forest and savanna components (Keay, 1959). In this study, mangrove reached its peak occurrence of 24.1 % at 39 m. Sowunmi (1981a and b) considered mangrove representation at a level below 40% of the pollen spectrum in sediments as low or poor. The mangrove ecosystem is responsive to sea level changes and is therefore unequivocally regarded as reliable indicator of sea-level fluctuations (Ige, 2011).

The recovery of charred Poaceae cuticle seemingly resulted from an anthropogenic bush burning during this period, typical of our present day Nigeria (Adeonipekun, 2012). Essien and Aniama (2014) also pointed out that the presence/abundance of charred Poaceae cuticle and fungal spores is indicative of anthropogenic activities on the local vegetation of an area. Osayi *et al*., (2012) recorded a high influx of charred Poaceae cuticles, attributed to increased bush burning activities in their study area. In addition, a sea regressive phase is inferred in this zone, as marked by a relatively high representation of dry climatic phase markers, coupled with a relatively low representation of wet climatic phase markers. This view is also supported by a relatively low pH (4.5-4.6) and salinity of the sediments, characteristic of a sea level fall. Another evidence to support this view is the lithology of this zone, comprising of fine/medium/coarse grained pebbly, sub-angular deposits, intercalated with some mudstones. According to Sowunmi (1987), this type of deposit is similar to that which is laid down in the present fresh water upper deltaic flood plains and is an indication that both coast and the mangrove swamp were farther south at the time of sediment deposition. The mudstone intercalations containing low quantities of *Rhizophora* sp. pollen are indicative of the presence of minor and short-lived salt-water swamp in the locality. Salinity values of the sediments (11-13 ppm.) found within the fresh water range, is indicative of likely varied levels of fresh water inundation into the study location at different periods of deposition. These low salinity values are suggestive of a regressive terrestrial influence, rather than that of a transgressive seawater incursion (Sowunmi, 1987).

In zone C, a more dominantly cool and dry climate is suggested. This is evidently supported by a very drastic rise in Poaceae with a concomitant sudden appearance of *Podocarpus* sp. and a remarkable representation of open forest group. These occurrences are coupled with the representation of fern spores, Guinea lowland rainforest and Cyperaceae, though feebly represented but indicative of a brief wetter condition. The occurrences of fern spores and Cyperaceae in sediments have been reported to be indicative of a brief humid condition (Dupont and Agwu, 1991; Tossou, 2002). This zone is suggested to be of a more sea regressive phase during the deposition of sediments.

The recovered Podocarpus pollen is bisaccate with air sacs, which aided its long dispersal to the experimental location during this period. It possibly could have been transported by either a strong wind or high-energy transport medium such as a river system. Knapp (1971) pointed out that the Pliocene age marked the beginning of the occurrence of *Podocarpus* sp. in West Africa because of the creation of suitable conditions for its establishment on the Cameroon mountains. He affirmed that the source of this bisaccate pollen is most likely the Cameroon mountain range or its extension to Nigeria. He adduced that Podocarpus pollen found in the offshore Niger Delta sediments was transported from this area. This is also in accordance with Keay (1959) who noted that *Podocarpus* species is found in mountainous areas. This zone is probably marked by a southward extension of the savanna.

In zone D, the botanical evidences are suggestive of a well-established mangrove surrounded by an extensive open forest. Here, the prevalent climatic condition is unequivocally that of a wetter type, as indicated by a good representation of wet-climatic phase indicators with a concomitant drastic reduction in the percentage occurrence of Poaceae group. In this study, this zone is the first transgressive phase to be recorded, following the preponderance of mangrove group as well as other wet-climatic phase markers, in relation to Poaceae group. The lithology of this zone with over 90% mudstones also supports this view, since clay-bearing mudstones are characteristic of a transgressive phase and may be attributed to the preponderance of *Rhizophora*, as remarked by Sowunmi (1987). The relatively low pH and low salinity of the sediments are also suggestive of a sea-transgressive high rainfall. This is because high rainfall could have possibly caused more fresh water entering the sea with its terrigenous sediments (Adegbie *et al*., 2003) which diluted the seawater. This probably resulted into a reduced salinity and a decrease in the pH values, followed by their subsequent landward transportation into the depositional environment, and may be attributed to a sea level rise.

In zone E, it seems that there was a minor and brief period of a wet condition, as seen in the feeble representation of both fresh water swamp and Cyperaceae groups and with the remarkable preponderance of open forest types. This is suggestive of a drier climate characteristic of this period. The botanical evidences in this zone may be attributed to a more regressive phase with the absolute dominance of open forest types. However, the characteristic mudstone lithology similar to that of the later zone does not correspond with the phenomenon of sea regression.

The topmost sub-zone characteristic of the present vegetation revealed an apparent establishment of a secondary forest and is similar to that which is today prevalent in the study area. Rhizophora was poorly represented in all the sections studied, as remarked by Sowunmi (1981). However, there was a marked restoration of the mangrove ecosystem at zones D and G respectively. These possibly were periods when conditions became more favourable for their establishment in the experimental location. In zone G, there was an observed reduction in mangrove representation until the end of the zone. This most likely occurred due to fluctuations in the extent and intensity of tidal flow during this period. In sections where mangrove thrived and savanna dominated in between, these are characteristics of probable wet conditions sandwiched among a predominantly dry climate.

Zone G was subdivided into two sub -zones due to well-defined boundary recognition of this zone. Botanical evidences in subzone G-I is suggestive of a vegetation similar to that of the southern Guinea savanna, rich in a mosaic of both forest and savanna components (Keay, 1959). Sowunmi (1987) also reported a peak in Rhizophora as well as a re-appearance or marked increase in other groups, notably the rainforest species at sub-section 9.80 m - 6.60 m of a sampled core in the Niger/Delta, Nigeria. In this zone, there was a good representation of wet-climatic phase markers, as well as that of dry climatic phase markers. An interplay of wet-dry climatic cycles, probably caused by an incidence of climatic instability could be inferred for this zone. There were likely fluctuations between transgressive and regressive phases, notable in the inferred climatic regime. The characteristic lithology of over 90% mudstone could have resulted from the transgressive stage during the transition between the two successive depositional phases.

In subzone G-II, the sandstone lithology of over 80%, notable in the present day freshwater upper-deltaic flood plains, also confirms the seaward extension of freshwater swamp to mangrove vegetation (Sowunmi, 1987). This might have been a transitional period between the rainforest and savanna representatives, associated with an apparent establishment of a secondary forest probably influenced by man. It is also remarkable to note that Sowunmi (1987) also recorded a similar decrease in mangrove pollen at the topmost sub-section of a sampled core in the Niger-Delta. The several vegetation changes prevalent during this period are indicative of a consequent climatic deterioration as affirmed by Sowunmi (1987), as found in our present day climate in Nigeria. This was a period of continual intermediate transgressive-regressive cycles, as evidently supported by the preponderance of both wet-dry climatic phase indicators.

One notable event in this study was the pollen recovery of *Elaeis guineensis* and *Alchornea cordifolia*, (Plate 1 and 2) which are ubiquitous in present day Nigeria. They were found in almost all the sections, indicative of an inferred secondary re-growth over time in the Quaternary period of this area.

CONCLUSION

This study has recorded the first incidence of related events at similar sections in the late Quaternary stratigraphy of both Lagos and Niger-Delta, Nigeria. This is the first reported recovery of *Ceratopteris* sp. from the Quaternary sediments of Lagos, Nigeria.

The fluctuations between wet-dry climatic phases and anthropogenic activities can be attributed to the vegetation changes during this period. The period at which paleoecological changes occurred at some intervals in the study location have been extrapolated through previously documented absolute ages in Lagos, Nigeria.

The palynological data reveals that parent plants of some of the recovered fossil palynomorphs are still present as extant plants in the study site until today. This indicates the extent of conservation of these plants in spite of the anthropogenic activities over time in this area.

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