

## Palynology of Recent Bottom Sediments from Shallow Offshore Niger/Cross River Delta Nigeria: A Preliminary Study

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**Abstract:** To assess the distribution and transport media of palynomorphs in the shallow offshore eastern Niger/Cross River Delta, recent bottom sediments from three locations (distal ABC, middle DEF and proximal GH) in the area were palynologically investigated. Records of highest abundance and diversity values of palynomorphs in middle location DEF indicate that the Cross River brings about seventy percent of the palynomorphs into the eastern Niger Delta. Wind only brings Charred Poaceae cuticles and *Podocarpus milanjanus* as well as aiding Poaceae for their higher records in distal ABC than others. The most abundant plants represented in the sediment source areas of the sites today as revealed by the palynomorphs recovered are Poaceae, *Elaeis guineensis*, *Acrostichum aureum*, *Pteris* spp., *Nephrolepis undulata*, *Cyclosorus afar* and *Stenochleana palustris* (*Verrucatosporites* spp.). Pollen of *Rhizophora* spp. and fresh water forest trees that are abundant in subsurface sediments have been reduced greatly and replaced by Poaceae and *Elaeis guineensis* pollen due to anthropogenic activities. Proximity to shore and shallow depth determine the abundance of pollen and spores, fungal elements and to an extent *Concentricytes*. *Protoperidinium* spp. and other dinoflagellates prefer the deeper ABC location with lowest temperature and high salinity. Microforaminiferal wall linings were however recovered mostly in the shallowest proximal site. Recovered diatoms show useful ecological trends. These results further confirm the usefulness of these palynomorphs and diatoms for paleoenvironmental and paleovegetational reconstruction. The degradation the Nigerian coastal ecosystems had undergone as well as presently undergoing due to anthropological activities is also revealed.

**Key words:** Niger delta, recent bottom sediments, vegetation reconstruction, palynomorphs, diatoms

### INTRODUCTION

Several works abound in literature on the palynology of subsurface Niger Delta sediments (Germeraad *et al.*, 1968; Evamy *et al.*, 1978; Sowunmi, 1981a; Sowunmi, 1981b; Sowunmi, 1986; Sowunmi, 1987; Poumot, 1989; Morley and Richards, 1993; Ige, 2009, 2011; Durugbo *et al.*, 2010; Adebayo *et al.*, 2012). Details of the occurrences and distribution of different palynomorphs and palynological groups have been highlighted and their uses for biostratigraphy, paleoecology and paleoenvironmental study have been variously discussed. These studies on palynomorphs have made excellent contributions to oil exploration in Nigeria particularly in the clastic dominated areas where traditional marine fossils such as foraminifera and calcareous nannofossils are poor to being absent. Most of the studies on the palynology of Niger Delta sediments have drawn heavily from the findings of Muller (1959) on the Orinoco Delta wherein he studied recent sediments to investigate the

distribution of various palynomorphs and palynodebris in its deltaic and shelf sediments. Muller (1959) showed that pollen transport and deposition depend partly on the topography and altitude of source area relative to the depositional site. Also highlighted is the fact that transport of pollen and spores is climatically controlled by the strength and direction of the wind and rainfall pattern.

There is no much published work on the distribution of these palynomorphs in the recent Niger Delta sediments known to the authors except (Williams and Sarjeant, 1967; Sowunmi, 1987) despite the high level of oil exploration activities going on and the degradation of the vegetation of the area. While Williams and Sarjeant (1967) reported abundant sporomorphs and rare dinoflagellates in the modern sediments offshore area, Sowunmi (1987) worked on a 36 m core drilled at low tide and surface samples from the central Niger Delta onshore. Palynomorphs in surface sediments were compared with existing vegetation and the data were related to past changes in vegetational compositions over the studied

core. The palynomorph composition of the surface sediments is similar to that of the present vegetation and it compares well with the fossils (Sowunmi, 1987). Though not offshore, the data obtained from the core shows the abundance of open vegetation plants-*Elaeis guineensis* and *Uncaria africana*-from about c.3000 BP till the present while *Rhizophora* spp. still remained high up to the topmost sample. The Rainforest group fluctuated and nose-dived from this depth. This finding made Sowunmi (1987) to infer commencement of anthropogenic activities from this time. Sowunmi (1987) reveals that the palynomorph assemblages reflect all the vegetation types traversed by the Niger river. Abundance of *Rhizophora*, fresh water swamp forest, open vegetation plant pollen and fern spores in the topmost samples with corresponding low occurrences of rainforest and Poaceae (Gramineae) groups reflected the present vegetation then.

As part of the contributions of the authors to the knowledge of the present vegetation dynamics and palynology of the eastern Niger Delta offshore, bottom sediments of shallow offshore eastern Niger/Cross River Delta were sampled for palynological investigation. Augmentation with sedimentology was also carried out to substantiate and corroborate deductions from palynology. The relative proportions of palynomorphs are expected to reflect vegetation composition of sediment source areas and indirectly current climatic regime on integration with sedimentology. From this study, published inferred changes in the delta vegetation over millions of years can be compared with the present for an assessment of the threat to its biodiversity. The significance of recovered palynomorphs and diatoms for palynostratigraphy and palaeoenvironmental reconstruction in the shallow part of Niger Delta will be evaluated.

**Vegetation of southeast/south-south Nigeria:** Since Asu and Ivo rivers which are part of the eroding subsystems of the Cross River drainage traverse the Southeast across to the South-South Nigeria into the Atlantic, insight into the vegetation types of these geo-political zones is needed as background information. Keay (1959) remarked that the vegetation zones in Nigeria are determined mainly by the mean monthly relative humidity and rainfall distribution rather than the mean annual rainfall and temperature. Edaphic or ecological factors override the climatic influence as obtains in freshwater swamp, saltwater (mangrove) swamp and beach vegetation types. The vegetation of Southeast Nigeria is also guided by the same factors hence made up of Guinea savanna, Lowland rainforest, Freshwater swamp, Saltwater swamp and Strand of herbs and shrubs in a pseudo-parallel

fashion as well as montane vegetation type which is found in the Cameroun mountain range extension to Nigeria.

## MATERIALS AND METHODS

Sediment samples for this study were sourced from the easternmost part of the Niger Delta/Cross River Delta during an Environmental Impact Assessment (EIA) project. Using a Day Grab (0.125m<sup>3</sup>), three locations-GH (~15 km from coast), DEF (~25 km from coast) and ABC (~43 km from coast) at 15 m, 33 m and 53 m water depths, respectively were sampled in a Survey Vessel-M V Aleutian-contracted by Mobil Producing Nigeria Unlimited/Mak Mera Nigeria Limited, Lagos, Nigeria Fig. 1a-c. The longitudes and latitudes of the locations are GH-7°38'39.815"E 4°14'11.591"N, DEF-7°58'40.567"E 4°6'30.876" and ABC-7°29'35.467"E 4°0'50.973"N. Sediments within 4 km radius of each location were sampled. Location ABC has four sites, DEF has five and GH has two. The top most part of the sediments (0.0-1.0 cm) collected by the grab was scraped, collected and properly labeled for this investigation (Rochon *et al.*, 1999).

For laboratory work, 10 g of each sample was weighed and subjected to standard palynological preparation techniques to free the palynomorphs from the embedding rock. Treatments with HCl, HF and acidified ZnCl<sub>2</sub> solutions were carried out and known volume of glycerine was used to ascertain the volume of the final residue. This was used to calculate the pollen percentage per gram of sediments. Upon the preparation of microslides using glycerine jelly with a gentle lowering of cover slip, microscopic analysis was carried out with the use of Olympus Microscope Model CHD/CH-2 (40 objective lens). Identification of recovered palynomorphs and diatoms was done through the use of published atlases (Fox, 1957; Hendey, 1958; Caratini and Guinet, 1974; Rochon *et al.*, 1999), journals (Sowunmi, 1987, 1973, 1995; Hooghiemstra *et al.*, 1986) and Palynomorph Reference Slide Collection of the Laboratory of Palaeobotany and Palynology, University of Lagos, Akoka, Lagos Nigeria.

Data for salinity, depth and temperature during the sample collection were obtained from a Seabed Profiler, model SBE 19 Plus (with a CTD probe). Lithological inferences on the sediments were visually made so as to decipher the type of rock they are made up (Table 1). Photomicrographs of many important palynomorphs and diatoms as well as other accessory microfossils were taken and displayed in the album section (Fig. 2-15).

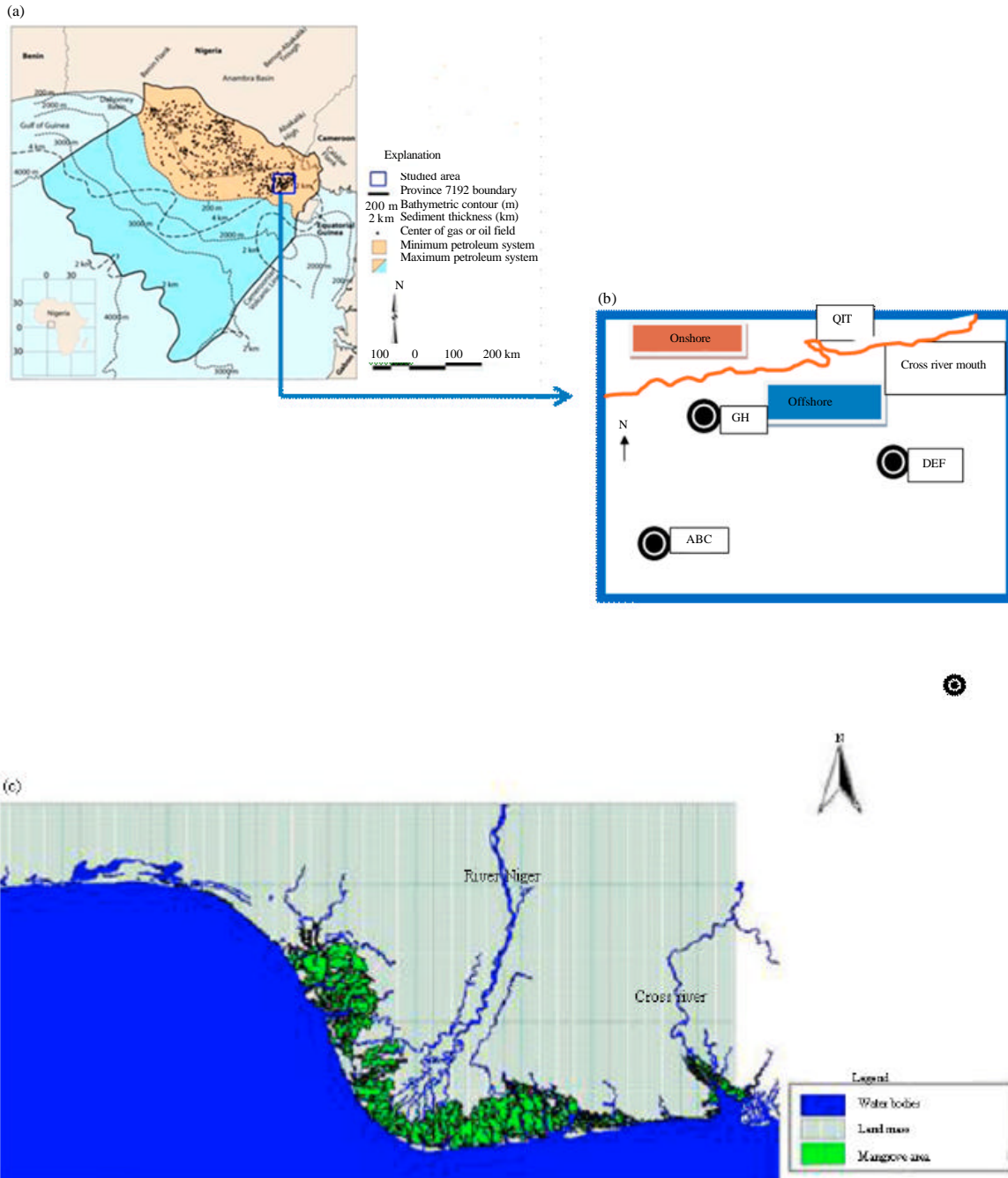


Fig. 1(a-c): (a) Location map of study area (Adapted from Petroconsultants, 1996; Michele *et al.*, 1999; Adebayo *et al.*, 2012). (b) The three locations of study area enlarged and (c) Niger Delta Map showing River Niger and Cross River positions. From Agbola and Olurin (2003) and Amosu *et al.* (2012)

Table 1: Lithology, salinity, depth and temperature values of the three studied locations

Location	Average water depth (m)	lithology	Average salinity (ppt.)	Average temperature (°C)	Distance from shore (km)
ABC	52.60	Soft fine clay	35.08	19.40	≈43
DEF	33.00	Soft fine clay	35.53	22.20	≈35
GH	14.50	Sticky fine clay	29.62	29.28	≈17

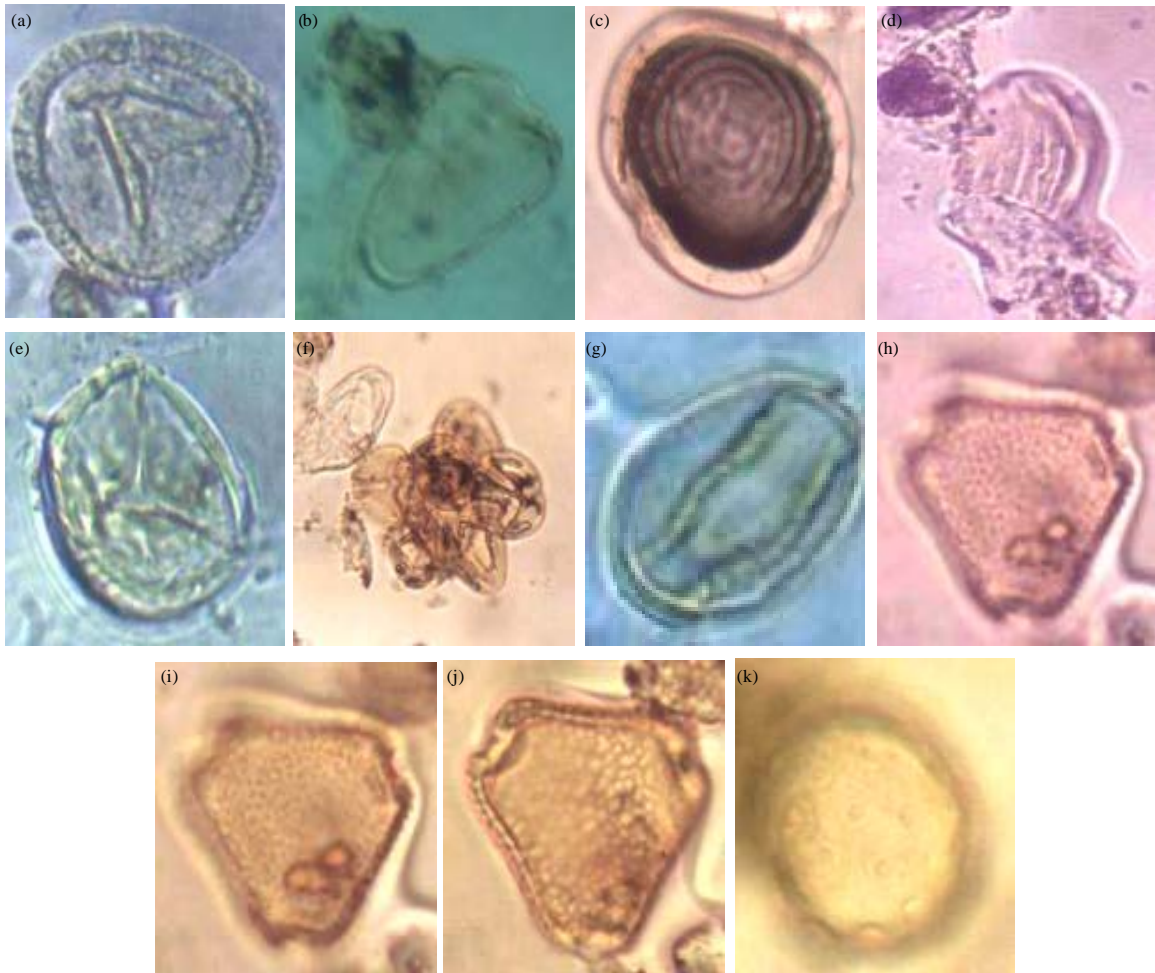


Fig. 2(a-k): (a) *Sphagnum* sp. 1, (b) *Cyperus* sp., (c) *Concentricytes*, (d) *Ephedra* sp., (e) *Lycopodium* sp., (f) Aggregated Myrtaceae pollen, (g) cf. *Cleome* sp., (h) *Deinbollia pinnata*, (i) *D. pinnata* and (k) *Cheno/Am. Mag.* X400

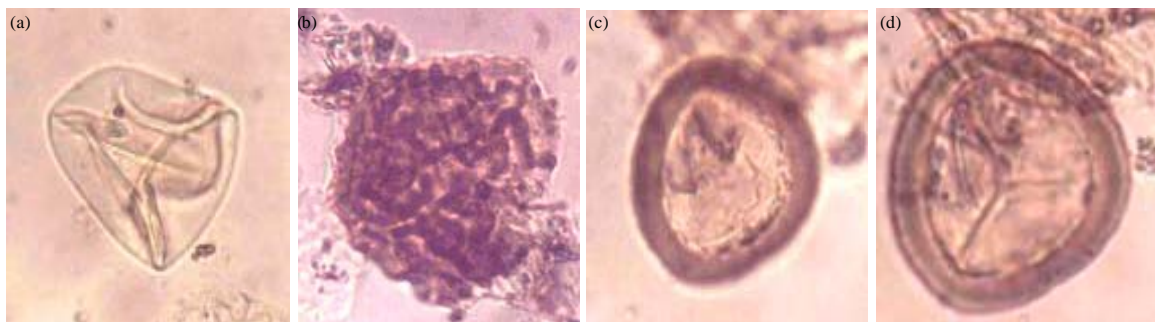


Fig. 3(a-k): Continue

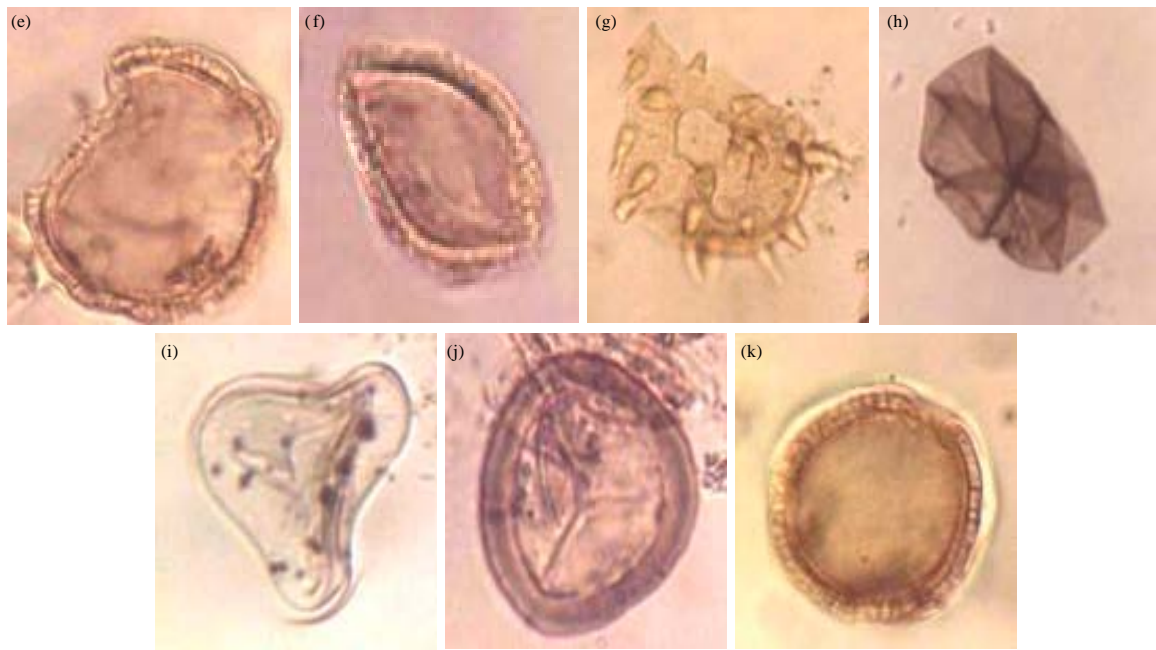


Fig. 3(a-k): (a) Poaceae, (b) *Crassoretiriletes* sp., (c) *Pteris* sp. 1, (d) *Pteris* sp. 1, (e) *Borreria* sp., (f) Arecaceae (*Raphia* sp.), (g) *Echiperiporites* (Malvaceae), (h) Indet. Alga (Acritarch) (i) *Cyathae* sp., (j) *Pteris* sp. 1 and (k) *Canthium* sp. Mag. X400

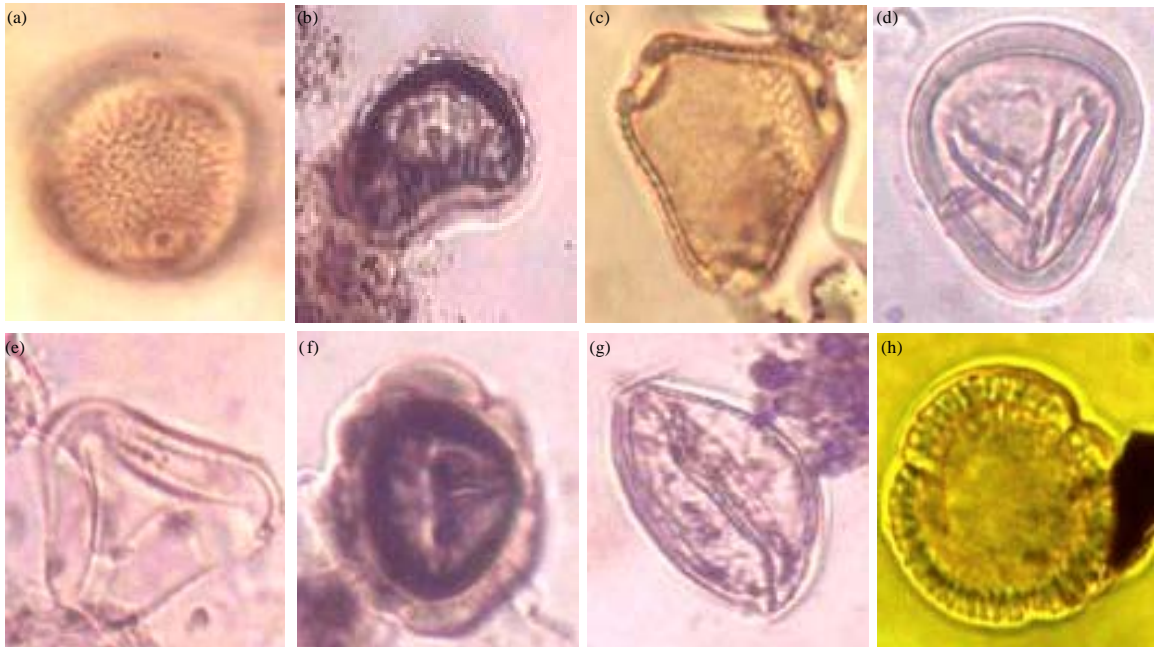


Fig. 4(a-p): Continue

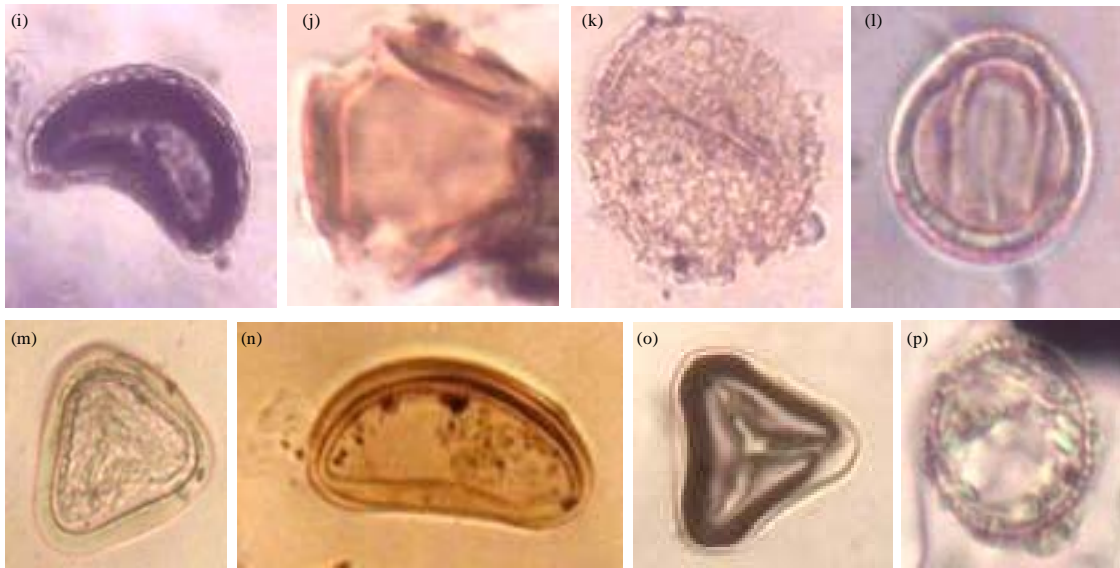


Fig. 4(a-p): (a) *Canthium* sp., (b) *Nephrolepis undulata*, (c) *Deibollia pinnata*, (d) *Pteris* 1, (e) *Elaeis guineensis*, (f) *Pteris* 1, (g) *Oncocalamus* sp., (h) *Avicemia nitida*, (i) *Nephrolepis undulata*, (j) Papilionaceae, (k) Cf. *Amanoa* sp., (l) Cf. *Cleome* sp., (m) Cf. *Pteris* sp., (n) Laevigate spore (small), (o) Trilete Spore and (p) Cf. *Berlinia grandifolia*. Mag. X400

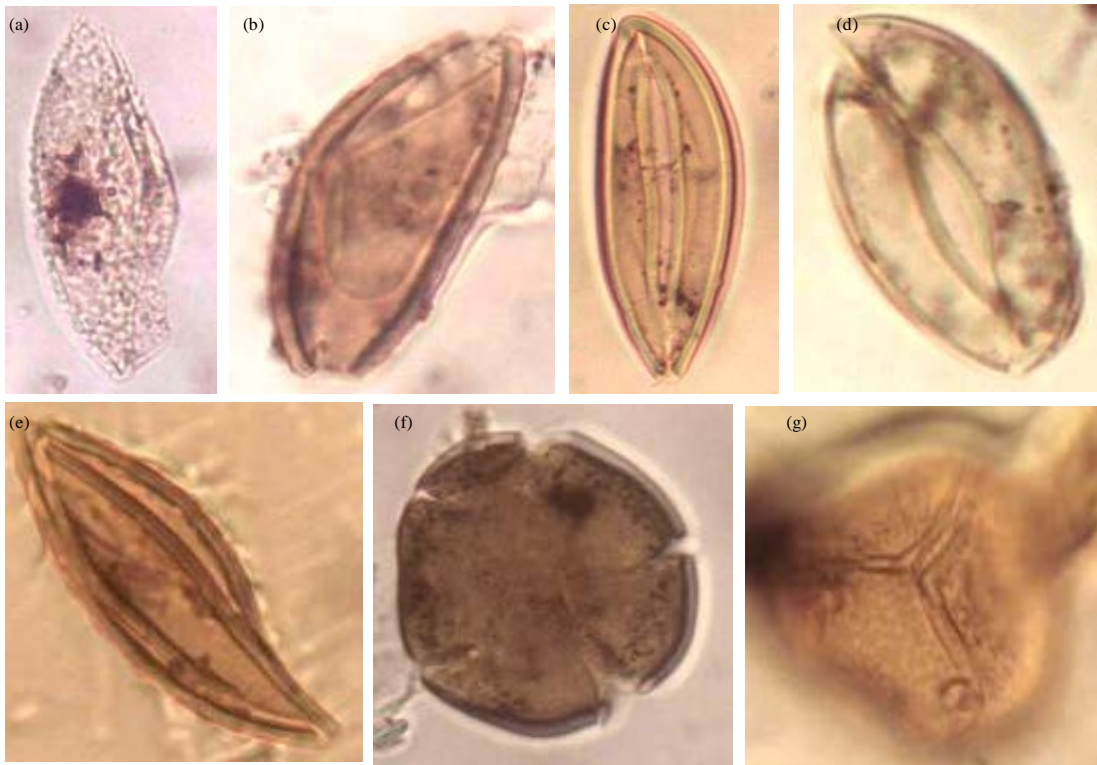


Fig. 5(a-j): Continue

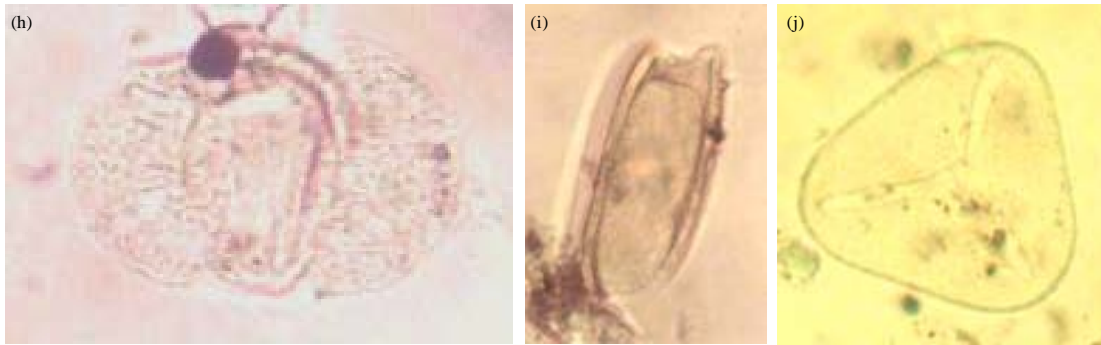


Fig. 5(a-j): (a) Arecaceae 1, (b) Arecaceae 2 (c) Arecaceae 3, (d) Arecaceae 4; (e) Arecaceae 5, (f) *Pentadesma* sp., (g) *Pteris* sp., (h) *Podocarpus milanjanus*, (i) Aracaceae 6 and (j) *Elaeis guineensis*. Mag. X400

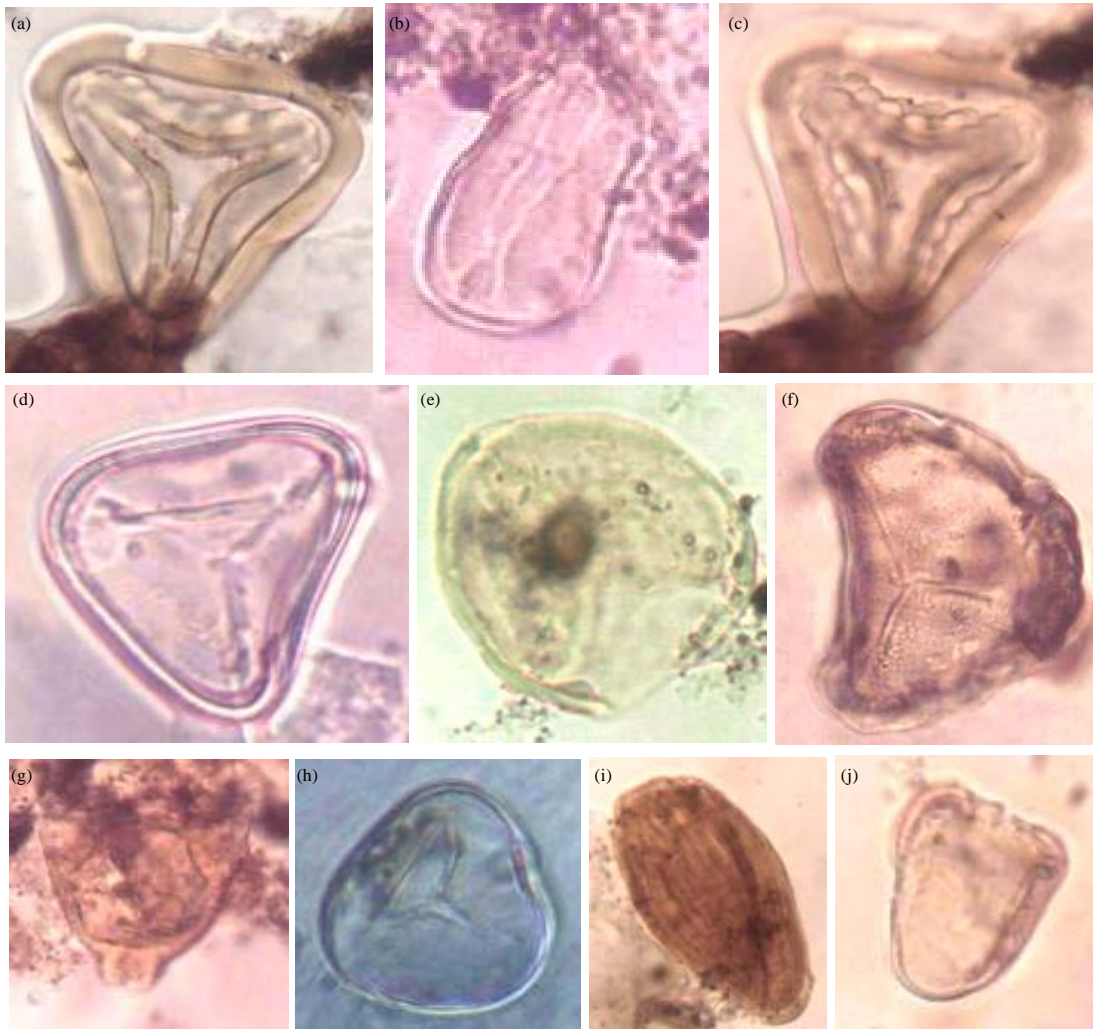


Fig. 6(a-j): (a) Polypodiaceae 1, (b) *Podocarpus barteri*, (c) Polypodiaceae 1, (d) Cyathaceae 1, (e) *Sterisporites* sp., (f) *Dryopteris* sp., (g) *Retibrevitricolporites ibadanensis/protundens*, (h) Cyatheaceae 2, (i) *Ephedra* sp. and (j) *Cyperus*. Mag. X400 except a, c, f and d×1000

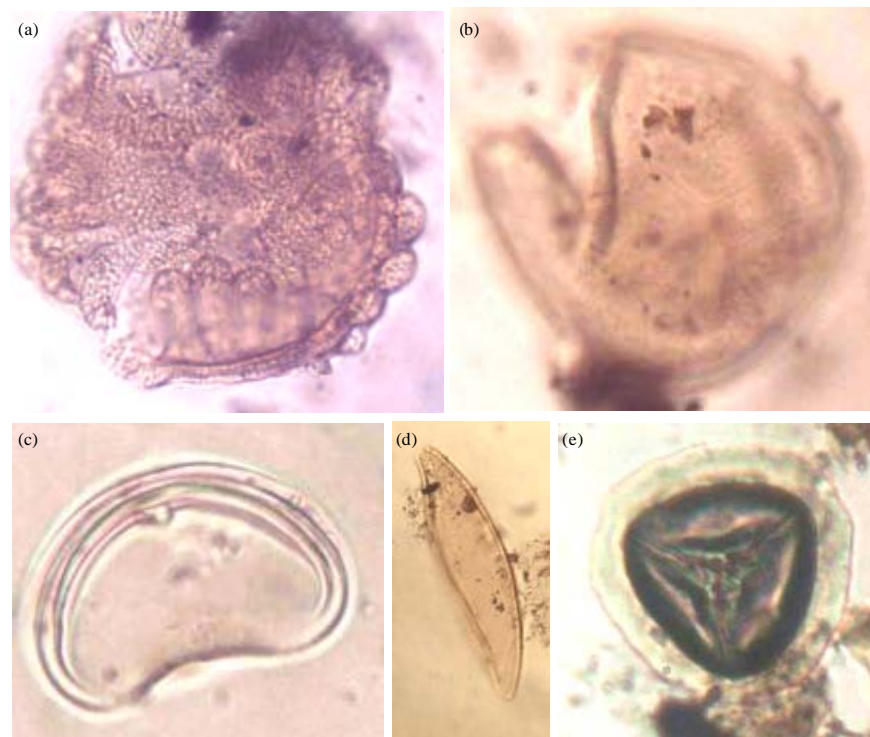


Fig. 7(a-e): (a) Acanthaceae, (b) Indet.Spore, (c) *Cyclosorus afer*, (d) Arecaceae 7 and (e) *5-Pteris* sp., 2. Mag. X400 except a X1000

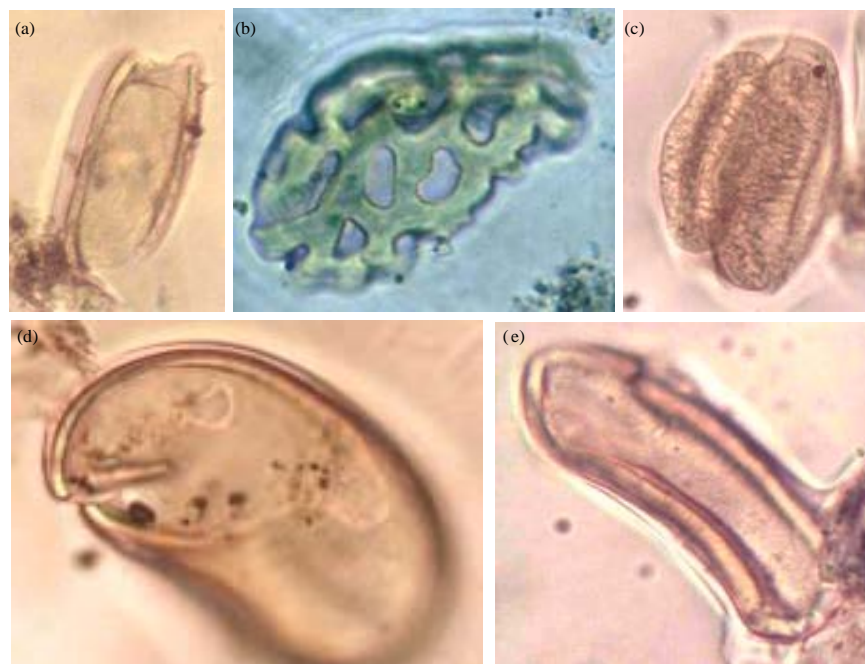


Fig. 8(a-e): (a) Arecaceae, (b) *Spirosyncolporites bruni*, (c) *Podocarpidites*, (d) *Cyclosorus afer* and (e) Arecaceae 8. Mag. X400



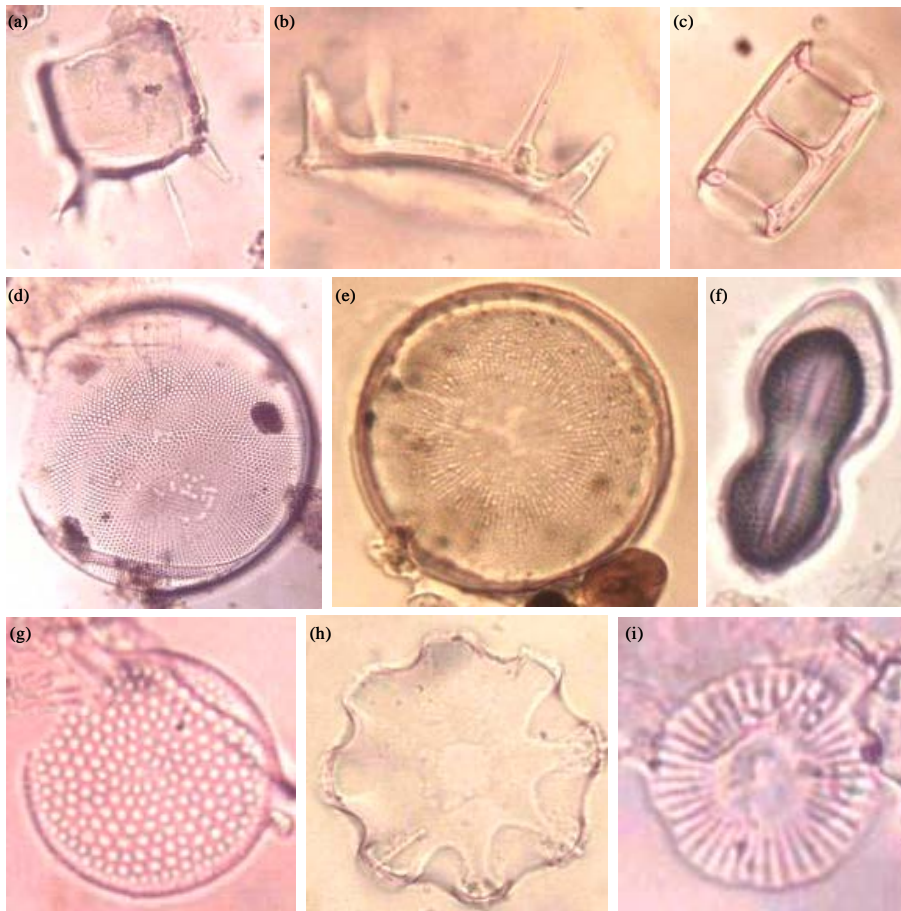


Fig. 9(a-i): (a-b) *Bidduphia* cf. *mobiliensis*, (c) *Aulacasiera granulata*, (d) *Coscinodiscus subtilis*, (e) *Coscinodiscus* sp., (f) *Surirella* sp., (g) *C. concinnus*, (h) *Euastrum* sp. and (i) *Cyclotella* sp. Mag. X400 except e and h×1000

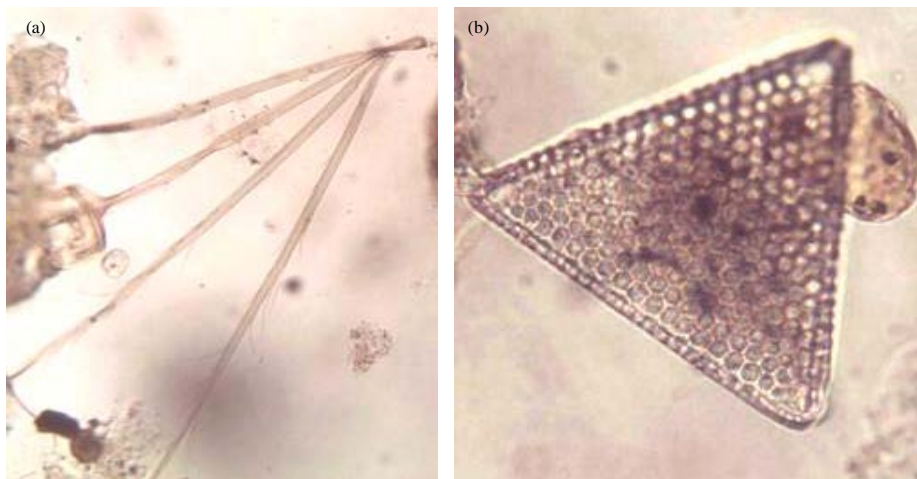


Fig. 10(a-e): Continue

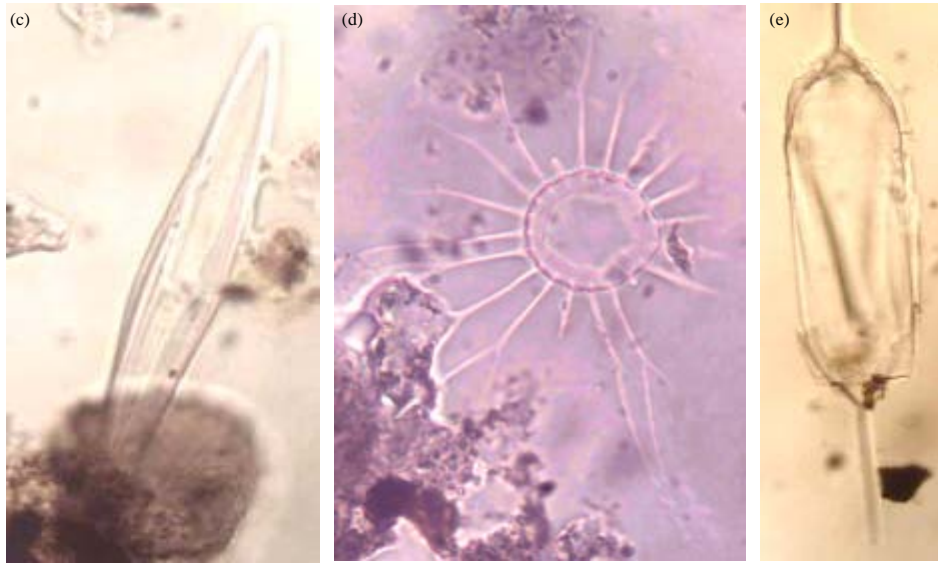


Fig. 10(a-e): (a) Indet Alga, (b) *Biddulphia* cf. *favus*, (c) *Frustulia* sp., (d) cf. *Golenkinia* sp. and (e) *Ditylum* cf. *brightwellit*. Mag. a, 4 and 5×400; b and c×1000

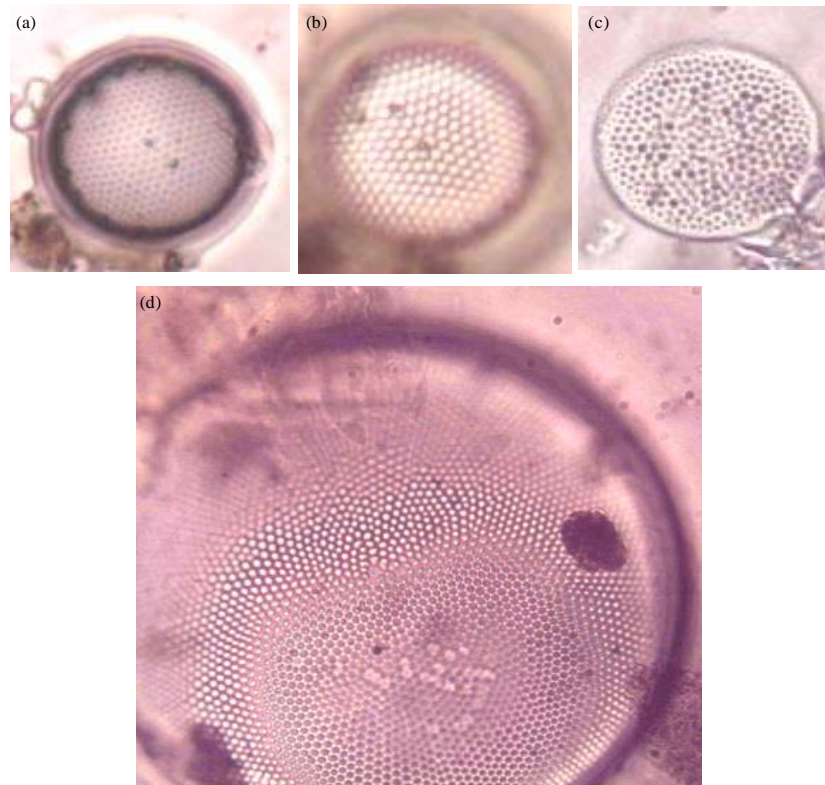


Fig. 11(a-d): (a-b) *Stellarima* cf. *microtarias*, (c) *Coscinodiscus concinnus* and (d) *C.* cf. *morsianus*. Mag. X400, except d×1000

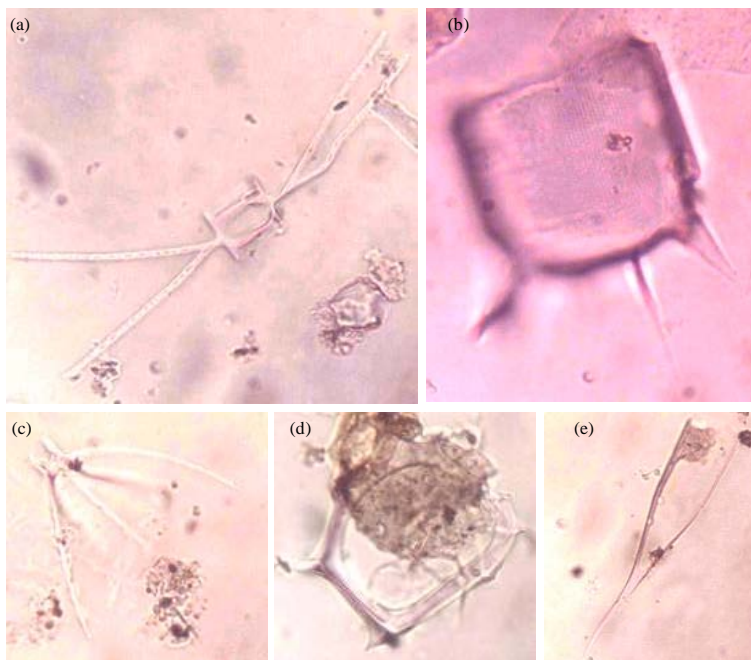


Fig. 12(a-e): (a) *Chaetoceros* sp., (b) *Biddulphia mobiliensis*, (c) *Bacteriastrum* cf. *elongatum*, (d) *Dictyocha* sp. (Silicoflagellate) and (e) *Rhizosolenia* sp. Mag. a and b×1000, c, d and e×400

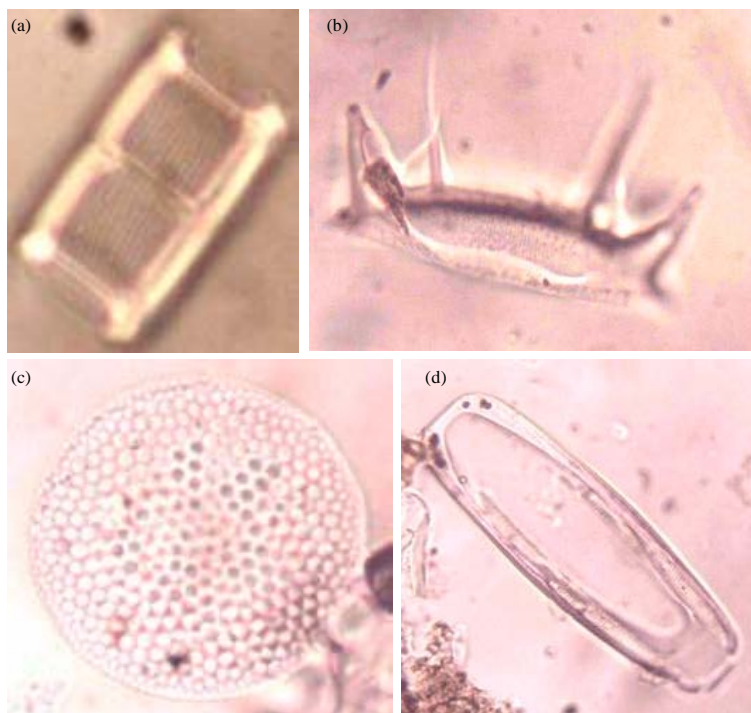


Fig. 13(a-d): (a) *Aulacasiera granulata*, (b) *Biddulphia mobiliensis*, (c) *Coscinodiscus* cf. *marginatus*, (d) Indet. Diatom. Mag. x1000

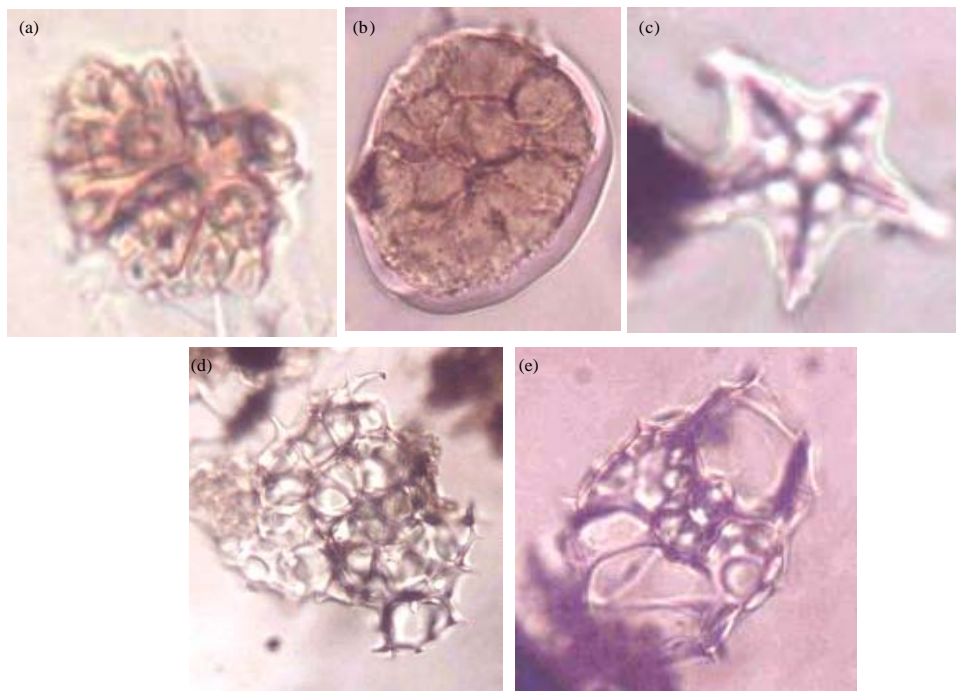


Fig. 14(a-e): (a) *Botryococcus brauni*, (b) *Peridinium* sp., (c) Endoskeletal dinoflagellate (*Actiniscus* sp.), (d-e) Silicoflagellate. Mag. x1000 except a and c x400

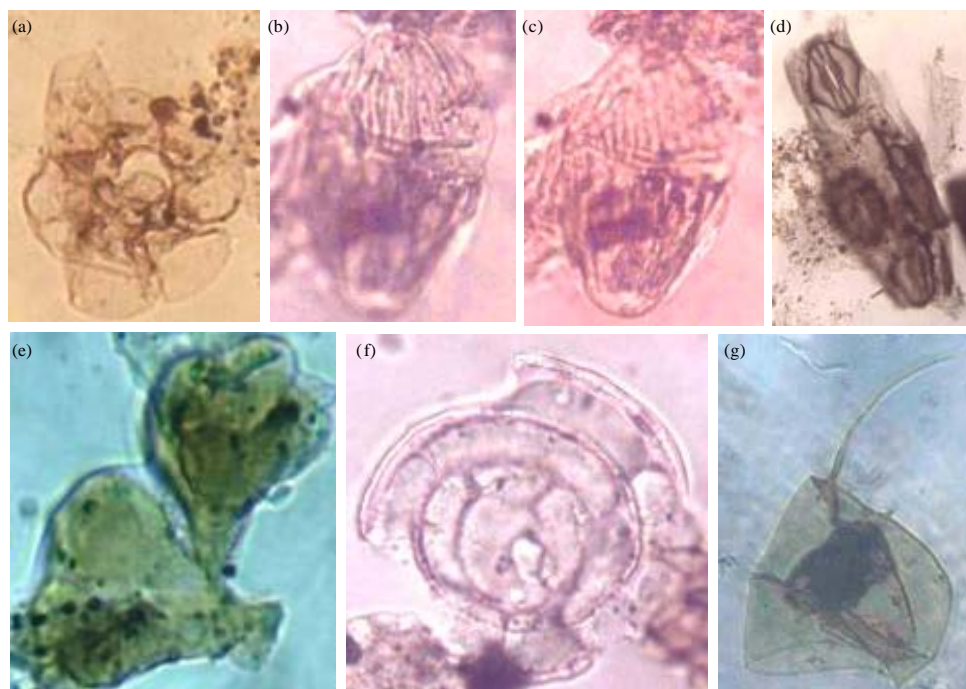


Fig. 15(a-i): Continue

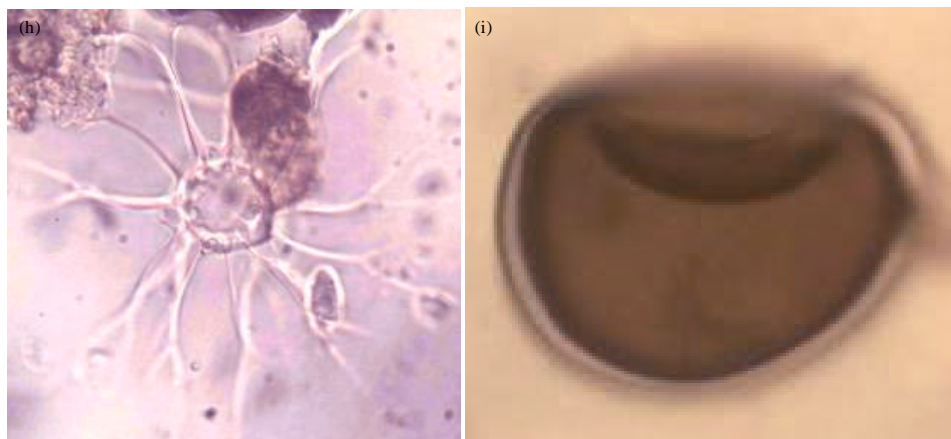


Fig. 15(a-i): (a) Microforaminifera wall lining, (b-c) *Dinogymnium* sp. (Cretaceous), (d) Charred Poaceae cuticle, (e) Foraminifera, (f) *Botryococcus brauni*, (g) cf. *Peridinium* sp., (h) *Cladopyxis* sp., (i) *Protoperidinium* sp. Mag. 400 except e, h and i with x1000

## RESULTS

Pollen grains and spores dominate the palynoflora in the three locations. From the recovered miospores in 1 gram sediment, pollen of Poaceae (53-152 grains, 32%) and *Elaeis guineensis* (14-61 grains, 11%) are dominant while *Pteris* spp. 8%, cf. *Cyclosorus afar* (*Laevigatosporites* spp.) 10%, *Stenochleana palustris* (*Verrucatosporites* sp.) 10%, *Acrostichum aureum* 8% and *Nephrolepis undulata* 3% are the dominant pteridophyte spores. *Rhizophora* spp. (3-6 grains, 0.9%)—the characteristic mangrove plants of the Niger Delta—are poorly recovered as against subsurface sediments that are in excess of 15% (Sowunmi, 1987; Adeonipekun, 2006; Adebayo *et al.*, 2012) Table 1-3. Typical rainforest tree pollen-Sapotaceae 0.2%, *Canthium* sp. 0.2%, *Khaya* spp. 0.02% and Combretum/Melastomaceae 0.3%—are poorly recovered while *Symphonia globulifera* (*Pachydermites diderixi*), *Pentaclethra macrophylla* (*Brevitricolporites guineetii*), *Bombax*, *Ceiba*, *Calpocalyx*, *Acacia* and *Albizia* and *Triplochiton* spp are absent (Table 2-4). These are common pollen of subsurface Niger Delta sediments.

Location DEF has the highest diversity of palynomorphs including diatoms and this is followed by the proximal GH location while the distal ABC has the lowest (Fig. 16a, b). This is due to the greater impact of the Cross River system discharge in DEF than the other two locations as well as the shallow depth and favourable salinity (Fig. 1b). The Cross River receives sediments from several rivers from the southeast and drains into the

Atlantic Ocean. Wind current seems to be effective mainly on Charred Poaceae cuticles for having poor record in shallow DEF and GH locations while having high and regular occurrences in the distal and deeper ABC location (Table 2-4). Also of significant wind impact is the transport of winged gymnosperm pollen-*Podocarpus milanjanus* with an average 4 grains (2%) and 6 grains (1%) in ABC and DEF, respectively as against GH with 3 grains (0.5%) Table 2-4, Fig. 16e, f. The record of pollen of Poaceae (Grass) seems enhanced significantly by wind as observed in this work.

Apart from river current, proximity to shore and shallowness are other determinants involved in the recovery of fungal elements. This is shown by the highest proportion in the proximal and shallowest GH (2.0-5.0) as against 1.0-2.0 grains in the deeper and distal DEF and ABC locations (Table 2, 3).

Freshwater alga-*Botryococcus* (Averaging 44 grains) was recovered in abundance together with *Concentricytes* (28 grains) in the shallow location DEF. Shallow water dinoflagellates recovered are more in the distal deeper location ABC (Fig. 16c). Diatom species are also abundantly recovered from all the locations with a clear demarcation between marine and freshwater forms in their record. Occurrence of charred Poaceae cuticles is highest in the distal location ABC (Fig. 16e, f).

Diversity of dinoflagellates is generally poor with the few recovered being more in ABC location and lowest in GH. *Protoperidinium* spp. are the main dinoflagellates (Fig. 16d) found and their occurrence is highest at the ABC location (18 grains) as against GH (7 grains).

Table 2: Recovered palynomorphs from sediments of shallow Niger/Cross River Delta (per 1 g sediment)

Palynomorphs	ABC					DEF				GH	
	A	B	C	C0	C1	D1	D2	E2	F3	G1	H2
Poaceae	62	25	60	74	44	126	150	275	56	103	35
<i>Elaeis guineensis</i>	5	13	28	3	23	47	68	65	63	27	16
<i>Podocarpus milanjanus</i>	5	1	3	3	6	9	13	-	1	4	1
<i>ChenoAms</i>	2	-	3	-	-	5	-	1	-	1	-
<i>Uapaca staudtii</i>	1	-	-	-	-	3	1	3	-	-	1
<i>Laguncularia racemosa</i>	1	-	-	-	1	-	2	-	-	-	-
<i>Nymphaea lotus</i>	2	4	-	1	-	4	2	3	3	-	-
<i>Longapertites</i> sp.	-	1	-	-	-	-	-	-	-	-	-
Arecaceae	-	1	-	3	1	1	3	7	-	1	2
Indet. Pollen	1	4	8	2	2	19	3	21	4	21	9
<i>Alchornea cordifolia</i>	-	2	1	-	1	2	-	5	-	7	-
Cf <i>Nuclea latifolia</i>	-	-	4	-	-	-	-	-	-	-	-
Psilate Arecaceae small	-	-	5	1	1	1	-	1	2	11	4
Euphorbiaceae	-	-	1	-	-	1	1	-	-	-	-
Umbelliferae	-	-	1	-	-	-	-	-	-	-	-
<i>Ephedra</i> sp.	-	-	1	-	-	1	-	-	-	-	-
Arecaceae (Thick and psilate)	-	-	1	2	-	4	6	-	4	7	-
Asteraceae	-	-	1	-	-	3	-	-	-	-	1
Arecaceae (Large and granulate)	-	-	-	-	1	-	10	-	-	-	-
<i>Retibrevitricolporites obodoensis</i>	-	-	1	-	1	-	-	-	-	-	-
<i>Oncocalamus mannii</i>	-	-	-	-	-	3	1	-	-	-	-
Combretum/Melastomaceae	-	-	1	-	-	2	-	-	1	-	1
Arecaceae (Reticulate)	-	-	-	-	-	5	-	-	-	2	-
<i>Rhizophora</i> sp.	-	-	-	-	-	12	1	9	-	1	4
Cf. <i>Borrassus</i> sp.	-	-	-	-	-	2	-	-	-	-	-
<i>Parinari</i> sp.	-	-	-	-	-	1	-	1	-	1	-
<i>Podococcus barterii</i>	-	-	-	2	-	4	1	3	-	-	-
Psilatecolpate 'minutes'	-	1	-	-	-	-	-	-	-	4	-
<i>Cyperus</i> spp.	-	1	2	-	-	-	-	-	-	-	1
Acanthaceae	-	-	-	-	-	1	-	-	-	-	-
Cf. <i>Crudia</i> sp.	-	-	-	-	-	1	-	-	2	-	-
<i>Canthium</i> sp.	-	-	-	-	-	1	1	1	-	2	-
Sapotaceae	-	-	-	-	1	-	-	2	-	2	-
<i>Verrutriporetates</i> (cf. <i>Celtis</i> )	-	-	-	-	-	-	-	-	-	-	1
<i>Tetrochidium</i> sp.	-	-	-	-	-	-	-	4	-	-	-
<i>Psilatecolporites 'zonocostites'</i> cf. <i>Alchornea</i>	-	-	-	1	-	-	1	3	-	2	-
Cf. <i>Aubrevillea kerstingii</i>	-	-	-	-	-	-	-	1	-	-	-
<i>Commelina</i> sp.	-	-	-	-	-	-	-	1	-	-	-
<i>Berlinia grandifolia</i>	-	-	-	1	-	-	-	2	1	-	-
<i>Protea</i> sp.	-	-	-	-	-	-	-	2	-	-	-
<i>Pandanus candelabrum</i>	-	-	-	-	-	-	-	2	-	-	-
<i>Longapertites</i>	-	-	-	-	-	-	-	2	-	-	-
<i>Pentadesma</i> type	-	-	-	-	-	-	-	-	1	-	-
Cf. <i>Cleistopholis patens</i>	-	-	-	-	-	-	-	-	-	1	-
<i>Gaertnera paniculata</i>	-	-	-	1	-	-	-	-	-	1	-
<i>Avicennia</i> sp.	-	-	-	-	-	-	-	-	-	1	-
<i>Polygala</i> sp.	-	-	-	-	-	-	2	-	-	-	-
Cf. <i>Perforitricolpites digitatus</i>	-	-	-	-	-	-	-	-	-	1	-
Arecaceae reticulate	-	-	-	-	-	-	-	-	-	2	-
<i>Echiperiporites icacinoides</i> (Icacinaeae)	-	-	-	-	-	-	-	-	-	1	-
<i>Borreria</i> sp.	-	-	-	-	-	-	-	-	-	1	-
<i>Retimonocolpites</i> 'pandanus shaped'	-	-	-	-	-	-	-	-	-	3	-
Podocarpidites (large Bissacate)	-	-	-	-	1	-	-	-	-	2	-
<i>Verrutricolporites minutus</i>	-	-	-	-	1	-	-	-	-	2	-
<i>Deibolla pinnata</i>	-	-	-	-	-	-	2	-	-	-	-
<i>Psidium guajava</i>	-	-	-	-	-	-	5	-	-	-	-
<i>Raphia</i> sp.	-	-	-	-	-	-	1	-	-	-	-
Meliaceae	-	-	-	-	-	-	1	-	-	-	-
<i>Verrumonocolpites</i> 'palmae'	-	-	-	-	-	-	2	-	-	-	-
<i>Retiverrutricolporites 'crassus'</i> (Acanthaceae)	-	-	-	-	-	-	1	-	-	-	-
<i>Ipomoea</i> sp.	-	-	-	-	-	-	1	-	-	-	-
<i>Amanoa</i> sp. ( <i>Retitricolporites irregularis</i> )	-	-	-	-	1	-	-	-	-	-	-
<i>Allophylus africanus</i>	-	-	-	-	1	-	-	-	-	-	-
<i>Calamus</i> sp.	-	-	-	1	-	-	-	-	-	-	-

Table 2: Continue

	ABC					DEF				GH	
	A	B	C	C0	C1	D1	D2	E2	F3	G1	H2
<b>Palynomorphs</b>											
<b>Pteridophyte spores</b>											
<i>Verrucatosporites</i> spp.	31	11	22	12	3	61	90	42	49	17	10
<i>Verrucatosporites usmensis</i>	-	-	-	-	-	-	4	-	-	-	-
<i>Laevigatosporites</i> spp.	20	6	15	8	7	54	50	45	69	25	17
<i>Stereisporites</i> sp.	1	1	-	-	-	-	-	-	-	2	-
<i>Leotritiletes</i> sp.	3	1	5	1	-	4	4	2	5	-	4
<i>Pteris</i> 1	11	4	15	6	3	12	14	-	6	19	4
<i>Pteris</i> 2	9	2	5	3	18	30	22	25	1	2	6
Trilete spore	1	7	-	2	-	-	-	-	5	1	-
<i>Cyathea</i> sp	1	3	9	5	1	1	6	4	2	-	1
<i>Acrostichum aureum</i>	-	-	2	6	2	46	100	34	63	33	13
Indet. Spore	-	-	-	-	1	2	-	4	3	1	3
Retitriteles	-	-	-	-	-	-	-	1	-	-	-
<i>Polypodiaceisporites</i> sp	-	-	-	-	-	-	-	2	1	-	-
Cf. <i>Atirium</i> spore	-	-	-	-	-	-	-	4	-	-	-
<i>Lycopodium</i> sp.	-	-	-	-	1	-	-	-	5	-	-
<i>Nephrolepis undulata</i>	-	-	-	-	13	-	31	-	-	6	13
' <i>Verrutriteles crassus</i> '	-	-	-	-	-	-	3	-	-	-	-
<i>Echitriteles pliocenicus</i>	-	-	-	-	-	-	1	-	-	-	-
<i>Spirosyncolporites bruni</i>	-	-	-	1	-	-	1	-	-	-	-
<b>Diatoms</b>											
Cf <i>Planktoniella</i> sp.	-	-	-	-	-	-	-	-	1	-	-
<i>Aulacasiera</i> spp.	14	17	27	10	18	43	4	12	21	19	4
<i>Cyclotella</i> spp	--	3	1	-	4	1	7	-	10	1	1
<i>Peridiniopsis rotundata</i>	-	1	-	-	-	-	-	-	-	-	-
Cf. <i>Cladopyxis brachiolata</i>	-	7	-	-	-	-	-	-	-	-	-
<i>Coscinodiscus</i> cf. <i>sub-bulliens</i>	-	7	-	-	-	-	-	-	9	-	-
<i>Coscinodiscus</i> cf. <i>kutzingeri</i>	-	-	-	-	-	-	1	-	-	-	1
<i>Coscinodiscus</i> spp.	-	-	-	-	-	-	20	-	30	6	4
<i>Coscinodiscus</i> cf. <i>subtilis</i>	-	-	-	-	-	-	10	-	13	-	-
<i>Golenchinia</i>	-	1	-	-	-	-	-	-	-	-	-
<i>Chaetoceros</i> spp.	-	6	1	-	-	1	-	-	-	-	-
<i>Peridiniopsis rotundata</i>	-	1	-	-	-	-	-	-	-	-	-
<i>Centritractus</i>	-	1	-	-	-	-	-	-	-	-	-
Cf. <i>Navicula</i> sp.	-	1	-	-	-	-	-	-	-	-	-
Cf. <i>Bacteriastrum elongata</i>	-	1	-	-	-	-	-	-	-	-	-
<i>Ecastrum</i> sp.	-	-	-	-	-	-	-	-	1	-	-
<i>Diatom</i> spp.	-	6	-	1	-	-	3	-	-	-	1
* <i>Silicoflagellate</i>	-	3	-	-	-	-	-	-	-	-	-
<i>Surreirella</i> sp.	-	1	-	-	-	-	-	-	-	-	-
<i>Coscinodiscus</i> (small)	-	3	10	-	-	10	14	-	3	-	-
<i>Coscinodiscus</i> cf. <i>marginatus</i> (small)	-	1	-	-	4	-	2	-	3	-	-
<i>Stephanodiscus</i> sp.	-	-	-	-	-	2	-	-	-	-	-
*Endoskeletal dinoflagellate	-	1	-	-	-	-	-	-	-	-	-
<b>Dinoflagellates</b>											
<i>Selenopemphix armata</i>	-	1	1	-	-	-	-	-	-	-	-
<i>Peridinium</i> spp.	-	7	-	-	-	-	1	2	3	6	3
<i>Leosphaeridium</i>	-	-	-	-	-	1	-	-	-	-	-
<i>Impagidinium</i> sp.	-	-	1	-	-	-	-	-	-	-	-
<i>Dinogymnium</i> sp	-	1	-	-	-	-	-	-	-	-	-
* <i>Discoaster</i> sp.	-	1	-	-	-	-	-	-	-	-	-
<i>Protoperidinium</i>	14	33	21	15	7	28	7	13	17	8	5
<b>Fresh water algae</b>											
<i>Botryococcus</i>	37	1	-	3	8	10	90	9	70	3	-
<i>Pediastrum kajaite</i>	-	1	1	-	-	-	-	-	-	-	-
<i>Pediastrum bifidite</i>	-	-	-	-	-	-	-	-	1	-	-
Algae indet.	-	3	3	-	-	-	-	-	-	-	-
<b>Fungal elements</b>											
<i>Concentricytes</i>	9	5	3	3	4	22	28	5	46	8	1
Fungal spore	4	1	-	-	2	2	2	2	-	6	3
Fungal hyphae	3	-	-	-	2	-	1	2	1	4	-
Fungal conidium	2	-	-	-	-	-	-	-	-	-	-
Charred poaceae cuticles	4	2	5	-	3	-	-	-	-	-	-
Foraminiferal wall linings	-	-	-	-	1	-	1	-	-	12	10

Table 3: Statistics of palynomorphs and diatoms from the studied sites

Palynomorphs	ABC					DEF				GH	
	A	B	C	C0	C1	D1	D2	E2	F3	G1	H2
<b>Pollen grains</b>											
Diversity	8.00	10	16	13	15	24.00	24	22	11	25.00	12
Average diversity	12.40					20.25				18.50	
Abundance	84.00	107	121	95	86	257.00	279	404	138	209.00	76
Average abundance	98.60					269.50				142.50	
<b>Spores</b>											
Diversity	8.00	8	7	9	9	8.00	12	10	11	10.00	9
Average diversity	8.20					10.25				9.50	
Abundance	77.00	35	75	54	49	210.00	237	167	203	108.00	71
Average abundance	58.00					204.25				89.50	
<b>Diatoms</b>											
Diversity	1.00	16	4	2	3	5.00	8	1	7	3.00	5
Average diversity	5.20					5.25				4.00	
Abundance	14.00	60	39	11	26	56.00	61	12	89	26.00	11
Average abundance	30.00					54.50				18.50	
<b>Dinoflagellates</b>											
Diversity	1.00	3	2	1	1	2.00	2	2	3	2.00	3
Average Diversity	1.50					2.25				2.50	
Abundance	14.00	41	23	15	7	29.00	8	14	19	11.00	7
Average abundance	20.00					17.50				9.00	
<b>Freshwater algae</b>											
Diversity	1.00	3	2	1	1	1.00	1	1	2	2.00	0
Average diversity	1.60					1.25				1.00	
Abundance	37.00	5	4	3	8	10.00	90	9	71	12.00	0
Average abundance	11.40					45.00				6.00	
<b>Fungal elements</b>											
Diversity	4.00	2	1	1	3	2.00	3	3	2	3.00	2
Average diversity	2.20					2.50				2.50	
Abundance	18.00	6	4	4	11	24.00	31	9	47	18.00	6
Average abundance	8.60					27.75				12.00	
Charred poaceae cuticles	4.00	2	5	2	-	3.00		-	-	-	-
Microforaminiferal wall linings				-	1		1			12.00	10

Table 4: Percentages of recovered sporomorphs from bottom sediments offshore shallow Niger/Cross River Delta

Sporomorphs	Pollen (%)			
	ABC	DEF	GH	Average
Poaceae	37.00	30.00	28.0	32.00
<i>Elaeis guineensis</i> (Jacq.)	10.00	13.00	10.0	11.00
<i>Podocarpus milanjianus</i> (Thumb.)	2.00	1.00	0.5	1.00
<i>Chenopods</i>	0.60	0.40	0.2	0.40
<i>Uapaca staudtii</i> Pax	0.10	0.30	0.5	0.30
<i>Laguncularia racemosa</i> Gaertn.	0.70	0.10	0.0	0.30
<i>Nymphaea lotus</i> L.	1.00	0.70	0.0	0.60
<i>Longapertites</i> sp.	0.20	0.00	0.0	0.08
Arecaceae	0.80	0.50	0.9	0.70
Indet pollen	3.00	3.00	7.0	4.00
<i>Alchornea cordifolia</i> (Schumach. et Thonn.) Mull. Arg.	0.70	0.50	1.0	0.80
Cf. <i>Nuclea latifolia</i>	0.40	0.00	0.0	0.10
Arecaceae (Psilate and small)	0.90	0.30	3.0	1.00
Euphorbiaceae	0.10	0.10	0.0	0.07
Apiaceae	0.10	0.00	0.0	0.03
<i>Ephedra</i> sp. L.	0.10	0.05	0.0	0.05
Arecaceae (Thick and psilate)	0.40	0.80	1.1	0.80
Asteraceae	0.50	0.20	0.0	0.20
Arecaceae (Large granulate)	0.20	0.50	0.0	0.20
<i>Retibrevitricolporites obodoensis</i>	0.30	0.00	0.0	0.08
<i>Oncocalamus mannii</i> (H. Wendl.) H. Wendl.	0.00	0.30	0.0	0.10
Combretum/Melastomaceae	0.10	0.20	0.5	0.30
Arecaceae (Reticulate)	0.00	0.20	0.3	0.20
<i>Rhizophora</i> sp. L.	0.00	1.20	1.5	0.90
Cf. <i>Borrassus</i> sp.	0.00	0.10	0.0	0.030
<i>Parinari</i> sp. Aubl.	0.00	0.10	0.2	0.080
<i>Podococcus barberii</i> G. Mann et H. Wendl.	0.30	0.40	0.0	0.200
Psilatricolpate 'minutus'	0.20	0.00	0.7	0.070



Table 4: Continue

Sporomorphs	Pollen (%)			
	ABC	DEF	GH	Average
<i>Cyperus</i> spp. L.	0.40	0.00	1.0	0.500
Acanthaceae	0.00	0.05	0.0	0.020
Cf. <i>Crudia</i> sp.	0.00	0.20	0.0	0.070
<i>Canthium</i> Lam.	0.00	0.20	0.3	0.200
Sapotaceae	0.20	0.10	0.3	0.200
Verrutripurites (cf. <i>Celtis</i> )	0.00	0.20	0.4	0.200
<i>Tetrochidium</i> sp. Poepp.	0.00	0.20	0.0	0.060
Psilatricolporites 'zonocostites' cf. <i>Alchornea</i> sp.	0.10	0.20	0.3	0.200
Cf. <i>Aubrevillea kerstingii</i>	0.00	0.05	0.0	0.020
<i>Commelina</i> sp. L.	0.00	0.05	0.0	0.020
<i>Berlinia grandifolia</i> (Vahl et Dalziel)	0.10	0.20	0.0	0.010
<i>Protea</i> sp. L.	0.00	0.20	0.0	0.070
<i>Pandanus candelabrum</i> P. Beauv.	0.00	0.10	0.0	0.030
<i>Longapertites</i>	0.00	0.10	0.0	0.030
<i>Pentadesma</i> type	0.00	0.08	0.0	0.030
Cf. <i>Cleistopholis patens</i>	0.00	0.00	0.2	0.050
<i>Gaertnera paniculata</i> Benth.	0.10	0.00	0.2	0.080
Cf. <i>Avicennia</i> sp.	0.00	0.00	0.2	0.050
<i>Polygala</i> sp. Tourn.	0.00	0.10	0.2	0.100
Cf. <i>Perforicolpites digitatus</i>	0.00	0.00	0.3	0.100
Arecaceae (reticulate)	0.00	0.00	0.3	0.100
<i>Echiperiporites icacinoides</i>	0.00	0.00	0.2	0.050
<i>Borreria</i> sp. G. Mey.	0.00	0.00	0.2	0.050
<i>Retimonocolpites</i> 'pandanus shaped'	0.00	0.00	0.5	0.200
<i>Podocarpidites</i> (large bisaccate)	0.00	0.20	0.3	0.200
Verrutricolporites 'minutus'	0.00	0.20	0.3	0.200
<i>Deinbollia pinnata</i> (Poir. et Thonn.) Schumach. et Thonn.	0.00	0.10	0.0	0.030
<i>Psidium guajava</i> L.	0.00	0.30	0.0	0.100
<i>Raphia</i> sp. P. Beauv.	0.00	0.05	0.0	0.020
Meliaceae ( <i>Khaya</i> sp. A. Juss.).	0.00	0.05	0.0	0.020
<i>Verrumonocolpites</i> 'palmae'	0.00	0.10	0.0	0.030
Acanthaceae (' <i>Retiverrutricolporites crassus</i> ')	0.00	0.05	0.0	0.020
<i>Ipomoea</i> sp. L.	0.00	0.05	0.0	0.020
( <i>Amanoa</i> sp. Aubl.) <i>Retitricolporites irregularis</i>	0.00	0.20	0.0	0.070
<i>Allophylus africanus</i> Radlk.	0.00	0.20	0.0	0.700
<i>Calamus</i> sp. Auct. ex L.	0.20	0.00	0.0	0.700
<i>Spirosyncolporites bruni</i>	0.10	0.04	0.0	0.050
<b>Spores</b>				
<i>Verrucatosporites</i> spp.	11.00	13.00	6.0	10.000
<i>Verrucatosporites usmensis</i> (cf. <i>Stenochleana palustris</i> )	0.00	0.20	0.0	0.070
<i>Laevigatosporites</i> spp.	8.00	12.00	10.0	10.000
<i>Stereisporites</i> sp.	0.04	0.00	0.3	0.100
<i>Leotriletes</i> sp.	1.40	0.90	1.4	1.200
<i>Pteris</i> 1	5.00	2.00	4.4	4.000
<i>Pteris</i> 2	5.00	4.00	2.0	4.000
Trilete spore	2.00	0.40	0.2	0.900
<i>Cyathea</i> sp. Sm.	3.00	0.70	0.4	1.000
<i>Acrostichum aureum</i> L.	1.30	14.00	10.0	8.000
Indet. Spore	0.20	5.40	1.2	2.000
Retitritele spore	0.00	0.05	0.0	0.020
<i>Polyodiaceisporites</i> sp.	0.00	0.20	0.0	0.060
Cf. <i>Atirium</i> spore	0.00	0.20	0.0	0.060
<i>Lycopodium</i> sp. L.	0.20	0.40	0.0	0.200
<i>Nephrolepis undulata</i> (Afzel. ex Sw.)	2.00	2.00	6.0	3.000
Verrutriteles 'crassus'	0.00	0.20	0.0	0.050
<i>Echitriteles plicocenicus</i>	0.00	0.05	0.0	0.020

Microforaminiferal wall linings were poorly recovered from the distal locations (1 grain) while fairly abundant in the shallow GH location (11 grains) Table 2 and 3.

It was observed that an inverse relationship exists between *Protoperidinium* spp. and fungal elements (Fig. 16c) as well as diatom and fungal elements (Fig. 16g).

While *Protoperidinium* increases towards the distal and deeper location, fungal elements and *Botryococcus* nose-dived. *Pediastrum bifidites* relates inversely to *P. kajaites* thus while *P. kajaites* prefers distal and deeper location (Table 3), *P. bifidites* seems to prefer higher energy fluvial setting to low energy areas. As diatom

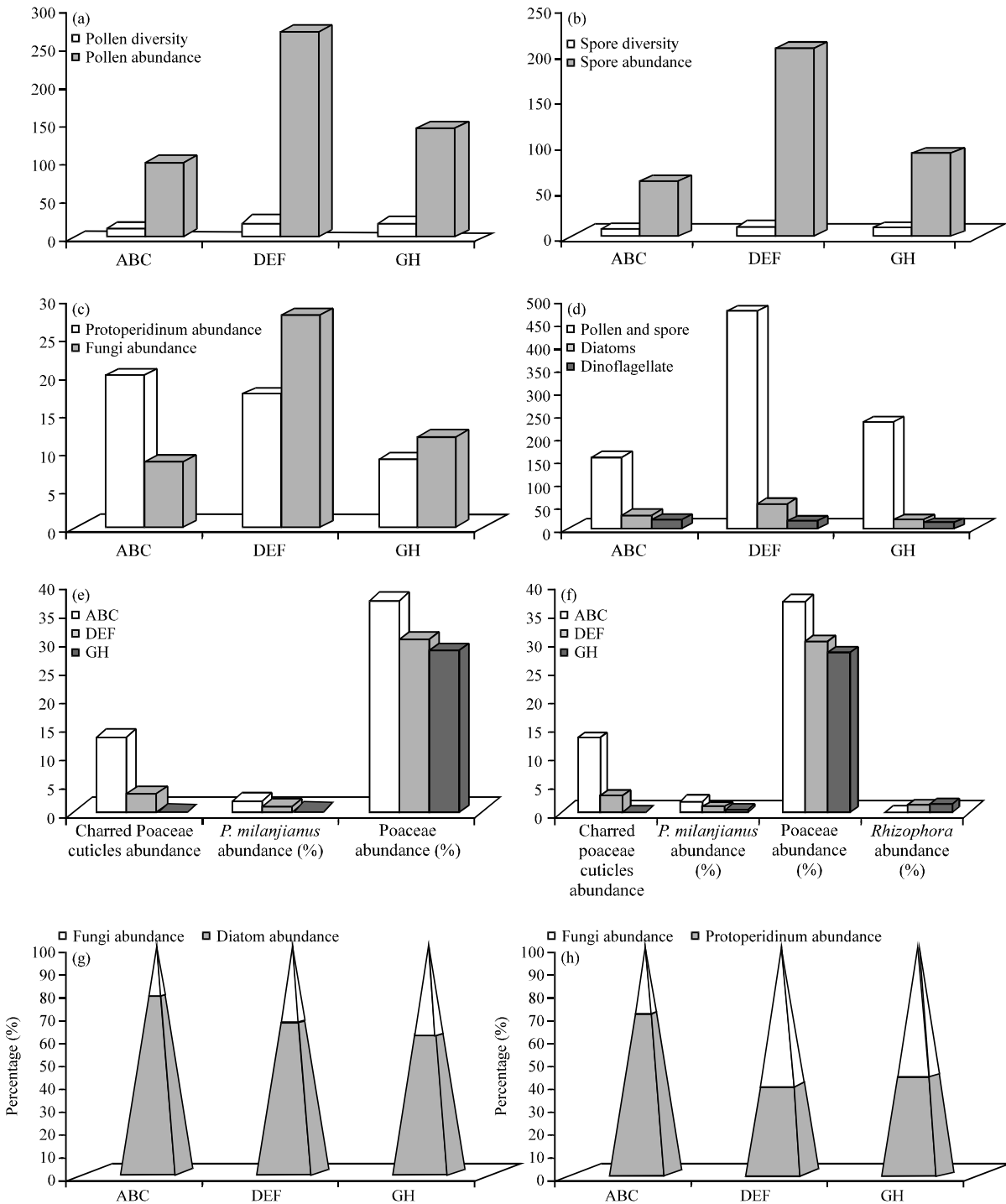


Fig. 16(a-h): (a) Pollen diversity and abundance compared, (b) Spore diversity and abundance compared, (c) *Protopteridinium* and Fungi abundance compared, (d) Relationship in the abundance of pollen and spores, diatoms and dinoflagellates, (e) Relationship in the abundance of charred Poaceae cuticles, *P. milanjanus* and Poaceae, (f) Relationship in the abundance of charred Poaceae cuticles, *P. milanjanus*, Poaceae and *Rhizophora*, (g) Comparison of fungi and diatom abundance and (h) Comparison of fungi and Protopteridinium abundance

proportions increase towards the offshore, fungi reduce in proportion. These observed trends may prove to be useful in sequence stratigraphy particularly in shallow bathymetry with poor recovery of traditional marine fossils.

Highest diversity and abundance of diatoms were recorded for location DEF followed by ABC while GH has the least values. The shallow water of DEF and its closeness to higher nutrient cycling being along the fluvial channel discharge together with the highest salinity of 35.55 ppt most probably favoured the co-existence of more species (Table 1, 2). Battarbee (1986) remarked that salinity is probably the strongest environmental factor influencing the distribution of diatoms. Centric diatoms dominate over pennate particularly in DEF and ABC locations. This reflects the openness of these areas relative to the GH. Centric diatoms are planktonic in character while pennates are more benthic in nature (Battarbee, 1986; Li *et al.*, 2010). Marine diatom species are restricted to the ABC and DEF locations. These marine dwellers include *Coscinodiscus* spp, *Chaetoceros* spp, *Surirella* sp., *Asterionella japonica*, *Mallomas* and cf. *Cladopyxis brachiolata* (Table 1). Typical freshwater diatoms recovered include *Euastrum* sp.cf. *Diploneis estuarii*, cf. *Planktoniella* sp., *Amphora* sp. and *Bidduphia* spp.

## DISCUSSION

**Loss of biodiversity:** The vegetation represented by the recovered miospores is different from what the Niger Delta was noted for. It however, truly reflects what is present today in the delta and the Southeast with Guinea savanna in the northernmost part and Lowland rainforest in the south. Many parts of the southern rainforest are now secondary forest/derived savanna. Pollen of Poaceae and *E. guineensis* populate the pollen spectra along with fern spores. Sowunmi (1999) had stressed the significance of *E. guineensis* as a good indicator of environmental condition in the late Holocene of West and West Central Africa. Poaceae on the other hand has always been a major component of the Niger Delta subsurface sediments since the Eocene when it evolved (Germeraad *et al.*, 1968; Sowunmi, 1986). This high occurrence also has always been recorded along with high mangrove pollen-*Rhizophora* since its evolution at the Oligocene end (Germeraad *et al.*, 1968). Surprisingly, the occurrence of *Rhizophora* in the study area is extremely low to absent (Table 1, 2). This scenario shows the danger of extinction this mangrove is exposed to presently. The abundance of *Rhizophora* in subsurface sediments of the Niger/Cross River Delta is so high that it is commonly

excluded from Pollen Sum computation (Sowunmi, 1987; Adeonipekun, 2006; Adebayo *et al.*, 2012). For it to record low occurrence to being absent in this recent sediments shows the decimation *Rhizophora* has undergone. Sowunmi (2004) in a study of an 11 m terrestrial core from Ahanve, Badagry in coastal South-Western Nigeria as part of Dahomey Gap Project (derived savanna) reported that prior to ca. 3109±26 BP, proportion of *Rhizophora* pollen recorded an abrupt decrease and subsequently disappeared. According to Sowunmi (2004), freshwater grasses, *Alchornea cordifolia* and *E. guineensis* replaced *Rhizophora* and this phenomenon was adduced to anthropogenic effects though climate and geomorphology remain the main factors in Holocene vegetation changes. *Rhizophora* spp are disappearing at a fast rate that must be checked to save the delta vegetation.

Natural and anthropogenic causes have also been adduced by non palynologists for the loss of mangrove. Human influence has been cited as chief among these causes through damming which has caused sediment starvation Abam (2001), dredging (Ohimain *et al.*, 2010) and bush clearing for oil and gas exploitation as well as agriculture. Abam (2001) cited recent works of Ibe (1988), Beets (1988) and Awosika *et al.* (1990) whose findings contrast those of previous works by Allen (1965) and Whiteman (1982) that the Niger Delta coastline had been accreting sediments. Sediment starvation, coastal erosion, over-exploitation of the area for oil, urbanization and farming contributed along with global warming-caused flooding and sea level rise, to the loss of mangrove, freshwater and rainforest vegetation types as revealed from this present study. Ohimain *et al.* (2010) in a study of abandoned dredged canal spoils due to oil exploration activities in the lower reaches of Benin River in the Niger Delta concluded that the spoils changed the topography of the area by 95 cm. This micro-topographic change impacted the soil chemistry and eventually led to change in vegetation pattern from a dominantly mangrove to open vegetation sand-witched mangrove with non-saline plants taking advantage of the favourable soil chemistry.

In this present study, pollen of rainforest trees such as Sapotaceae and *Canthium* are also poorly recorded and typical freshwater/rainforest trees such as *Symphonia globulifolia*, *Ceiba*, *Bombax*, *Calpocalyx* and *Pentaclethra macrophylla* are absent in the recovered palynomorphs. This further shows the openness and decimation of the forest of the source area mainly caused by anthropogenic activities. The abundant occurrence of pollen of an open vegetation dweller-*E. guineensis*, averaging 61 grains/g (11%), shows the degree of exposure the source area vegetation is subjected to. In subsurface sediments of older ages even within the

Holocene, *E. guineensis* never reached such abundance. Today in the Southeast Nigeria, the Low-land rainforest has been decimated into derived savanna with *E. guineensis* forming what is now called the “Oil Palm bush” for its ubiquity. The freshwater vegetation has been taken over by saltwater vegetation types hence, the absence of typical freshwater trees such as *Amanoa* sp. (*Retitricolporites irregularis*) and *Symphonia globulifera* (*Pachydermites diderixi*). Ironically, the slow rates of mangrove regeneration and edaphic re-adaptation have impeded its recovery despite the current increasing sea level rise.

**Transport media:** The dominating power of the fluvial systems of the Niger Delta over wind has been reported by several workers such as Pastouret *et al.* (1978), Sowunmi (1981a, b, 1986), Adeonipekun (2006) and Adeonipekun and Ige (2007). The Cross River system has a dominating influence on the sediments of the eastern part of the Niger/Cross River Delta with the highest abundance and diversity of palynomorphs in the shallow middle DEF location compared to the shallowest GH and deepest ABC locations (Table 1-3). Location DEF being closer to the Cross River mouth receives more sediment from the Cross River than the Niger River and its tributaries. The Cross River is of steeper gradient than the low-relief gradient Niger River (Zabel *et al.*, 2001) and hence dominates the eastern part sedimentation. Apart from this, Abam (2001) identified upstream damming of the Niger River and other close rivers as one of the factors that have led to reduction in sediment loads and freshwater into the western Niger delta in recent times compared to the eastern part. The abundant occurrences of freshwater alga-*Botryococcus* and *Concentricytes* in the middle DEF location also reflect the dominating power of the fluvial system in the Cross River Delta. The recovery of fungal elements is highest in the most proximal and shallowest GH location which agrees with the findings of Muller (1959) that they were found mostly closer to the deltaic dense swamp vegetation where they are involved in the decay of organic matter.

Wind current seems to be effective mainly on charred Poaceae cuticles and Poaceae for having low records in shallow DEF and GH locations while having high and regular occurrences in the distal and deeper ABC location (Table 1 and 2; Fig. 16e). The transport of winged gymnosperm pollen-*P. milanjanus*-is also by wind for having an average 4 and 6 grains  $g^{-1}$  in ABC and DEF, respectively as against GH with 3 grains  $g^{-1}$ . *Rhizophora* spp. however has a distribution pattern opposite those of Poaceae, charred Poaceae cuticles and *P. milanjanus* (Fig. 16f). The *Rhizophora* pattern is the

same with spores and other water-borne plants' pollen. These wind-borne pollen and cuticles recorded low proportions in the proximal locations GH and DEF while recording highest abundance in the distal ABC. All the locations studied in this present study are within the continental shelf, less than 100 m water depth and hence greatly influenced more by the river system and less by the wind according to the report of Muller (1959). The rainfall system of the Niger Delta puts it permanently under the effect of the Atlantic South West monsoon winds that hardly allow much of wind transportation except during the one to two month(s) harmattan (Adeonipekun, 2006).

**Paleoecology/proximity:** The high record of Marine indices' (dinoflagellates) in the distal locations of ABC and DEF relative to that of location GH agrees with the report of Muller (1959). Though much of the dinoflagellates are *Protoberidinium* and other Beridinioids undifferentiated, that recorded highest abundance in DEF, the few open water species (*Impagidinium* sp. and *Selenopemphix armata*) are restricted to the ABC distal and deep location. Findings here further support the use of these shallow marine dinoflagellates by paleoecologists as good marine indicators.

The observed inverse relationship between *Protoberidinium* spp. and Fungal elements (Fig. 16h) and Diatoms and Fungal elements (Fig. 16g) may prove useful in sequence stratigraphy in the Niger/Cross River Delta. This is shown in this work with the proportion of *Protoberidinium* increasing in the distal and deeper location while fungal elements nose-dived and vice-versa in the proximal and shallow location. The increasing salinity values from the shore to offshore favour increasing diatom abundance and diversity and this has an inverse relationship to that of fungal elements.

**Sequence stratigraphic significance:** Sequence stratigraphy in shallow bathymetry with poor traditional marine fossils like nannofossils and foraminifera in the Niger Delta has always been very challenging due to the clastic dilution that impaired preservation. With high abundance and the regularity of occurrences of shallow marine dinoflagellate-*Protoberidinium* spp., freshwater alga-*Botryococcus* and fungal elements as well as diatoms across stratigraphic columns, utilizing them cannot be difficult. Apart from these, they are also easy to identify which also reduces the degree of error due to wrong identification.

Recovery of freshwater *Pediastrum* is very poor in the studied marine locations of this present work, although they are frequently recovered abundantly from

marine sediments in tropical areas having been washed in by rivers Brenac and Richards (2001). Brenac and Richards (2001) reported the usefulness of this alga as a good guide in sequence stratigraphy where maximum abundances are usually associated with late highstand and lowstand systems tracts. However, the poor recovery in this work precluded a general deduction for their significance as a guide fossil. Meanwhile, from the few recovered, *Pediastrum bifidites* seems to prefer higher energy fluvial setting to low energy areas as found in this work while *P. kajaites* is in the contrary with occurrence only in the distal and deeper location ABC (Table 3).

**Recovered diatoms:** Diatoms are microscopic algae commonly encountered in palynological preparation. Even though there is practically no published work on Niger Delta diatom stratigraphy known to the authors, their recovery from palynological preparations necessitates that attention should be given to them not only for their stratigraphic values but paleoecological and paleoclimatic interpretation significance of which several publications abound. Some of the popular works in Nigeria on diatoms of marine and coastal ecosystems in recent sediments include (Nwankwo, 1990, 1996; Nwankwo and Kasumu-Iginla, 1997; Nwankwo and Onyema, 2003; Adesalu and Nwankwo, 2005; Adesalu and Olayokun, 2011). The highest abundance and diversity were recorded for the DEF location followed by ABC. This shows that their occurrences in a stratigraphic column may be used to differentiate between open and closed basins in the delta. Battarbee (1986) reported that the centrales (centric) are dominant in open basins while the Pennales (pennate) are more of benthic in character and thus dominate in closed basins. The Centric and Pennate ratio is thus an important indicator of planktonic and benthonic relationship which indirectly gives information on bathymetry as well as proximity to shore. That diatoms were recovered from the studied sediment palynological treatment is not new. They are commonly recovered in palynological treatment. Sun *et al.* (1999) also reported their abundant recovery from palynological preparation in spite of the Hydrofluoric acid treatment in their work offshore China.

Although these findings from the present work are preliminary, the restriction of some typical marine diatoms to the deeper and distal site ABC is an indication of the usefulness of these diatoms as marine indices in palynological preparations. These typical marine diatoms are *Chaetoceros* spp, *Surirella* sp., *Asterionella japonica*, *Coscinodiscus* spp., *Mallomas* and cf. *Cladopyxis brachiolata* (Table 1, 2). Inferences from the

distribution of these diatoms will be useful in augmenting deductions from dinoflagellates and microforaminiferal wall linings.

**Reworked palynomorphs:** Of palynostratigraphic significance is the recovery of older aged palynomorphs from these recent sediments. Such reworked forms are dinoflagellate-*Dinogymnium* sp., pollen-*Ephedra* sp. and *Retibrevitricolporites ibadanensis* (Rubiaceae) as well as spore *Stereisporites* sp. (Anthocerosporites). They sometimes create problems in stratigraphic studies. Caution must be exercised therefore in the interpretation of data in deltaic area and high gradient river emptying its sediments into the sea since some older sediments along the river course might be reworked due to erosion. Adeonipekun and Ige (2007) reported the occurrence of some older aged pollen *Verrutricolporites rotundiporus* and *Psilamonocolpites* sp.1 (cf. *Cleistopholis patens*) from younger sediments in the eastern Niger/Cross River Delta. They adduced this phenomenon to the high incidence of orogeny and volcanic activities of the area Reijers (1996) that exposed some of these older sediments to erosion.

## CONCLUSION

The Palynology of recent sediments from offshore shallow Niger/Cross River Delta has revealed the magnitude of decimation of the vegetation of the Niger Delta and the Southeast Nigeria. This is due mainly to anthropogenic activities of oil exploration, agriculture and urbanization apart from the uncontrollable global warming-induced sea level rise and flooding. High abundant subsurface proportions of *Rhizophora* are different from its extreme low proportion in the recent surface sediments. Several rainforest and freshwater tree plants have been reduced to an extent that their pollen were absent from studied surface samples. Poaceae and *E. guineensis* as well as opportunistic herbs have taken over from the traditional mangrove plants.

The Cross River system dominates in the transportation of sediments into the eastern Niger Delta. Wind only carries Poaceae, charred Poaceae cuticles and *P. milanjanus*. The inverse relationships between *Protoperidinium* spp. and fungal elements as well as diatoms and fungal elements have good potential for application in sequence stratigraphy particularly in clastic dominated basins like the Niger Delta. The dichotomous grouping of diatoms into planktic (Centric) and benthic (Pennates) as well as the separation into marine, brackish and freshwater ecosystems dwellers may prove useful in paleoenvironmental reconstruction in the Niger Delta.

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