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PALYNOLOGICAL, PALEOENVIRONMENTAL AND PALEOCLIMATE ANALYSES OF EMI-5-WELL, OFFSHORE NIGER DELTA, NIGERIA

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ABSTRACT

Palynological, Paleoenvironmental and Paleoclimatic investigations of Emi-5 well Offshore, Niger Delta, Nigeria was conducted to established palynozones, determine age, reconstruct paleoenvironmental conditions and paleoclimatic conditions to permit stratigraphic correlation, provide insights into the depositional settings and changes overtime within the basin. Fifty one (51) shaly ditch cutting samples were subjected to standard palynological method involving sample maceration with 10 % HCl and 40 % HF acids to remove carbonates and siliceous components, neutralization with distilled water and sieving through 5-micron sieve, followed by separation of palynomorphs from residue prior to mounting of the grains on glass slides for further analysis. The palynological composition is marked by dorminance of pollen and spores over dinoflagellate cysts. The intercalation of the sandy and shaly intervals across the section evidenced from lithologic, textural, and wire line log data suggested that the entire studied interval belong to the Agbada Formation. Three interval range zones were delineated using the international stratigraphic guide for the establishment of biozones, they are *Stereisporites* sp – *Verrutricolporites rotundiporus; Verrutricolporites rotundiporus* – *Gemmemonoporites* sp. and *Retistephanocolpites gracilis* – *Pachydermites diederixi* Zones and based on the aforementioned zones the interval is assigned middle Miocene to late Miocene. Coastal-deltaic environment of deposition is inferred for the studied interval on the basis of occurrence and dominance of diagnostic forms such as *Zonocostites ramonae,Rhizophora*, *Psilatricoloporites crasssus* and *Acrostichum aureum* while good representation of these forms and the identified palyno-ecological groups placed the interval on a wet climatic zone.

Keywords: Niger Delta, Emi-5-Well, Palynological zones, Paleoenvironment, Paleoclimate

INTRODUCTION

Palynofacies has been described to mean the total organic matter recovered from a rock or unconsolidated sediment by the standard palynological processing technique of digesting samples in HCl and/or HF as well as their distribution and associations and whose composition reflect particular sedimentary environment (Powell et al. 1990; Batten and Stead, 2005). The integration of palynofacies and sedimentological analyses significantly contribute to environmental reconstruction, basin evaluation and resource exploration and exploitation (Oyede, 1992). A few research papers have been published on the palynology and sedimentary environment of deposition of the Niger Delta basin (e.g., Ige *et al*., 2011; Ajaegwu *et al.*, 2012; Ojo and Adebayo, 2012;, and Olajide *et al*., 2012). These works were undertaken at discrete locations and at different stratigraphic intervals most of which are in the onshore Niger Delta basin. As a result, some zones have not been accounted for between the identified zones. The present work is undertaken in order to reduce exploration uncertainties created by these missing zones. The aim of this work is therefore to conduct palynofacies studies of the strata penetrated by Emi-5 well, offshore Niger Delta in order to establish the palynostratigraphic zonation in line with the international stratigraphic guidelines as well as establish biochronology, palaeoenvironment of deposition as well as the paleoclimate of the strata penetrated by the well for the purpose of petroleum exploration. The use of the standard stratigraphic guideline is to provide common language that allows for global correlation of events.

The most comprehensive contribution to the knowledge on the palynology of the Niger Delta was made by Germeraad *et al.* (1968). The study was based on the palynomorph assemblages of the Tertiary sediments of three tropical areas: parts of South America, Asia and Africa (Nigeria). They established nine pantropical zones using quantitative base and top occurrence (numeric method) of diagnostic species such as *Echitricolporite spinosus, Crassoretitriletes vanradshoveni, Magnastrites howardi, Verrucatosporites usmensis, Monoporites annulatus,* and *Proxapertites operculatus*. Evamy *et al*. (1978) established twenty-nine informal palynological zones of the Niger delta using alphanumeric coding method, which seems to form the background information for in-house zonal scheme of Shell Petroleum Development Company. Palynological studies of sediments from North Chioma-3 Well, Niger Delta and its palaeoenvironmental interpretations were carried out by Ige *et al*. (2011). They recognized four pollen zones (I-IV), using pollen diagram method. They further established both wet and warm climate using percentage occurrence of mangrove forest taxa and interpreted the palaeoenvironment as mangrove swamp environment because of high occurrence of *Rhizophora* sp. palynology of Bog-1 well, south-eastern Niger Delta was studied by Olajide *et al*. (2012). They noted that dominance occurrence of the mangrove species, *Zonocostites ramonae* (*Rhizophora*) and *Foveotricolporites crassiexinus* (*Avicennia*), suggests a tidal swamp shoreline inhabited by mangroves. Ajaegwu *et al.* (2012) discussed the Late Miocene to Early Pliocene palynostratigraphy and palaeoenvironments of Ane-1 well, Eastern Niger Delta, Nigeria. They adopted the alpha-numerical method (Evamy *et al*., 1978; Morley, 1997) to identify eight palynological zones, dated Late Miocene to Early Pliocene. Ojo and Adebayo (2012) carried out palynostratigraphy and palaeoecology of Chev-1 well, south-western Niger Delta basin. They identified nine palynozones and suggested that the studied sediments were deposited during Miocene-Pliocene period in which there was predominance of a high sea level and wet-humid climatic conditions because of the recovered palynomorphs were mainly made up of mangrove swamp floras. Osokpor *et al*. (2015) carried out palynozonation and lithofacies cycles of Paleogene to Neogene age sediments in PML-1 well, Northern Niger Delta Basin. They established two palynozones (*Ephedra claricristata* and *Auricupollenites echinatus* range zones) of Oligocene (Late Rupelian and Chattian stage) and three palynozones (*Verrutricolporites laevigatus/Verrutricolporites scabratus* range zone; and *Verrutricolporites rotundiporus* and *Margocolporites* sp. Abundance zones) of Early–Late Miocene.

Study area

Location

The studied well (Emi-5), is found within the Emi Field, which is located in the offshore depobelt, Niger Delta, southeastern Nigeria (Fig. 1) and covers an area of 58.24 km². The Niger Delta Basin is located on the continental margin of the Gulf of Guinea in the equatorial west Africa and lies between Latitudes 4 and 7ºN and Longitudes 3 and 9º E (Whiteman, 1982).

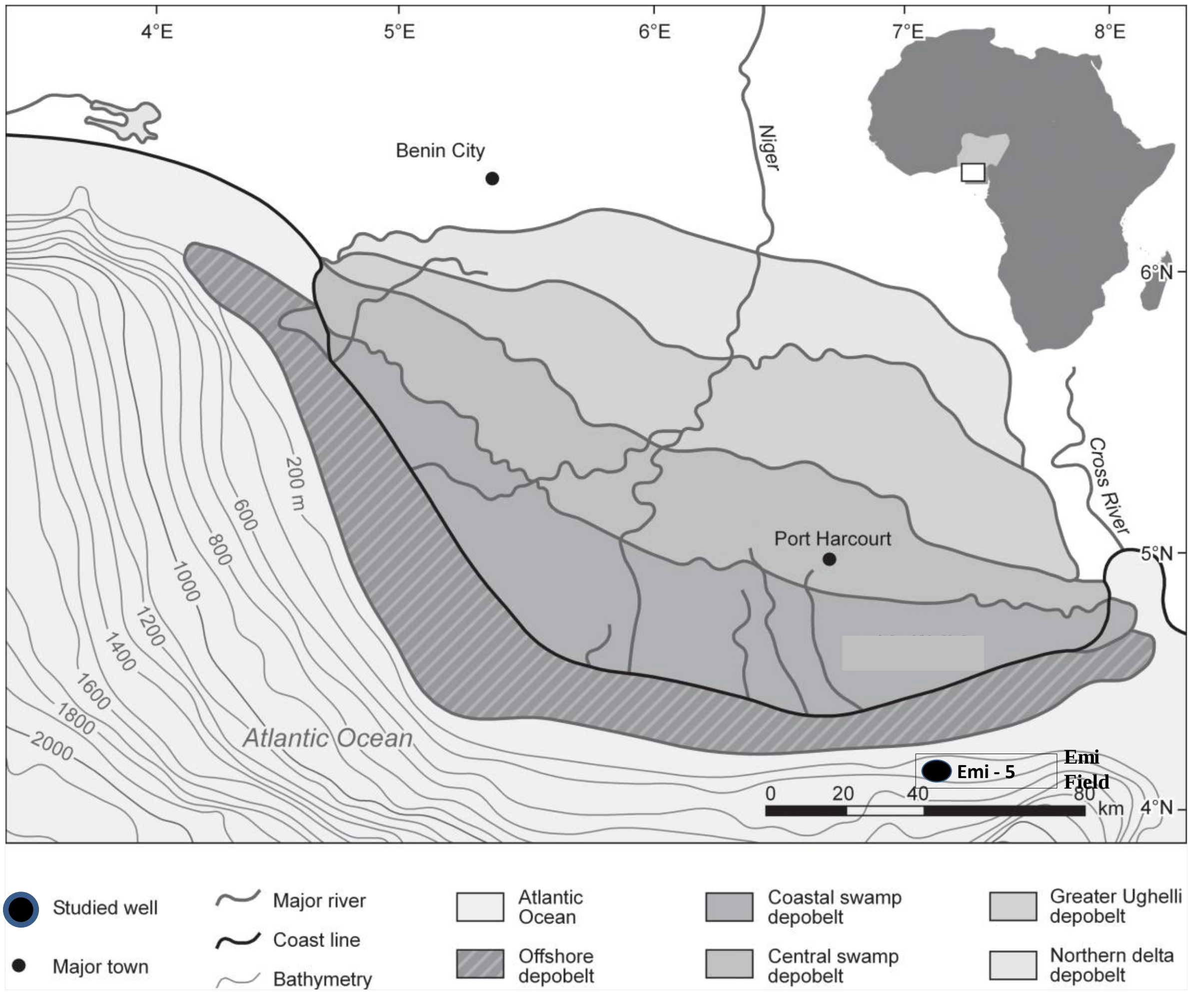

Figure 1: Depobelt map of the Niger Delta and location of the studied well (modified after Okosun and Chukwuma-Orji, 2016).

Geology of the Niger Delta

The Niger Delta Basin is located in the Gulf of Guinea, on the West African continental margin. The basin contains Cenozoic marine to fluvial deposits overlying oceanic crust and fragments of the African continental crust (Doust and Omatsola, 1990; Ojo and Adebayo, 2012). The lithology or sedimentary deposit of the Niger Delta Basin ranges from the facies of the first major Cenozoic transgression to the depositional products of the present day, as well as materials eroded from subsurface and outcropping formations.

The Delta began developing in the Paleocene. From the Eocene to the present, the delta has prograded southwest ward forming depobelts, each depobelt represent the most active portion of the delta at each stage of development (Doust and Omatsola, 1990; Ojo and Adebayo, 2012). The sedimentary sequence of the basin consists in ascending order of three diachronous formations, namely: Akata (marine beds), Agbada (transitional sandshale beds) and Benin (continental sediments) formations (Figure 2). These formations together form an overall thick, progradational passive-margin wedge (Short and Stauble, 1967; Ola and Adewale, 2014**).**

The Akata Formation consists of prodelta and open marine dark grey shale with lenses of siltstone and sandstone. Some sand beds considered to be of continental slope channel fill and turbidite are present (Weber and Daukoru, 1975). An estimated maximum thickness of the Akata Formation is in the range of 600m to probably greater than 6000m in the northern part of the delta where the formation has been drilled through into the Cretaceous (Weber and Daukoru, 1975; Avbovbo, 1978; Durugbo and Uzodimma, 2013).The age of the Akata Formation ranges from Paleocene in the proximal parts of the delta to Recent in the distal offshore.

The Agbada Formation consists of cyclic coarsening-upward regressive sequences composed of shales, siltstones, and sandstones units of delta front and lower delta plain deposits (Weber, 1971). The Agbada Formation has been described as paralic (cyclic) lithofacies sequence of marine and fluvial deposits consisting of alternation of sand/sandstone shale/mudstone units (Bankole *et al*., 2014). The thickness of the Agbada Formation is highly variable (from 300m up to about 4500m). The oldest deposits of the Agbada Formation are of Eocene age in the north and are presently being deposited in the nearshore shelf domain. The Benin Formation consists predominantly of cross-bedded, coarse, pebbly continental sands, with clay lenses and lignites. Marine shale breaks have been identified within the formation. The bulk of the sediments were deposited in the upper delta plain as freshwater, backswamp, and meander belt facies and lower flood (delta) plain setting (Whiteman, 1982). Short and Stauble (1967) designated a type section for the Benin Formation in Elele-l. The Benin Formation first occurs in Oligocene times in the northern delta sector (Reijers *et al*., 1996). The Benin Formation is up to 2,000m thick in the central onshore part of the delta and thins towards the delta margins (Bustin, 1988). Reijers (2011) has proposed elevation of the Benin, Agbada and Akata lithostratigraphic units classified as formations to group level.

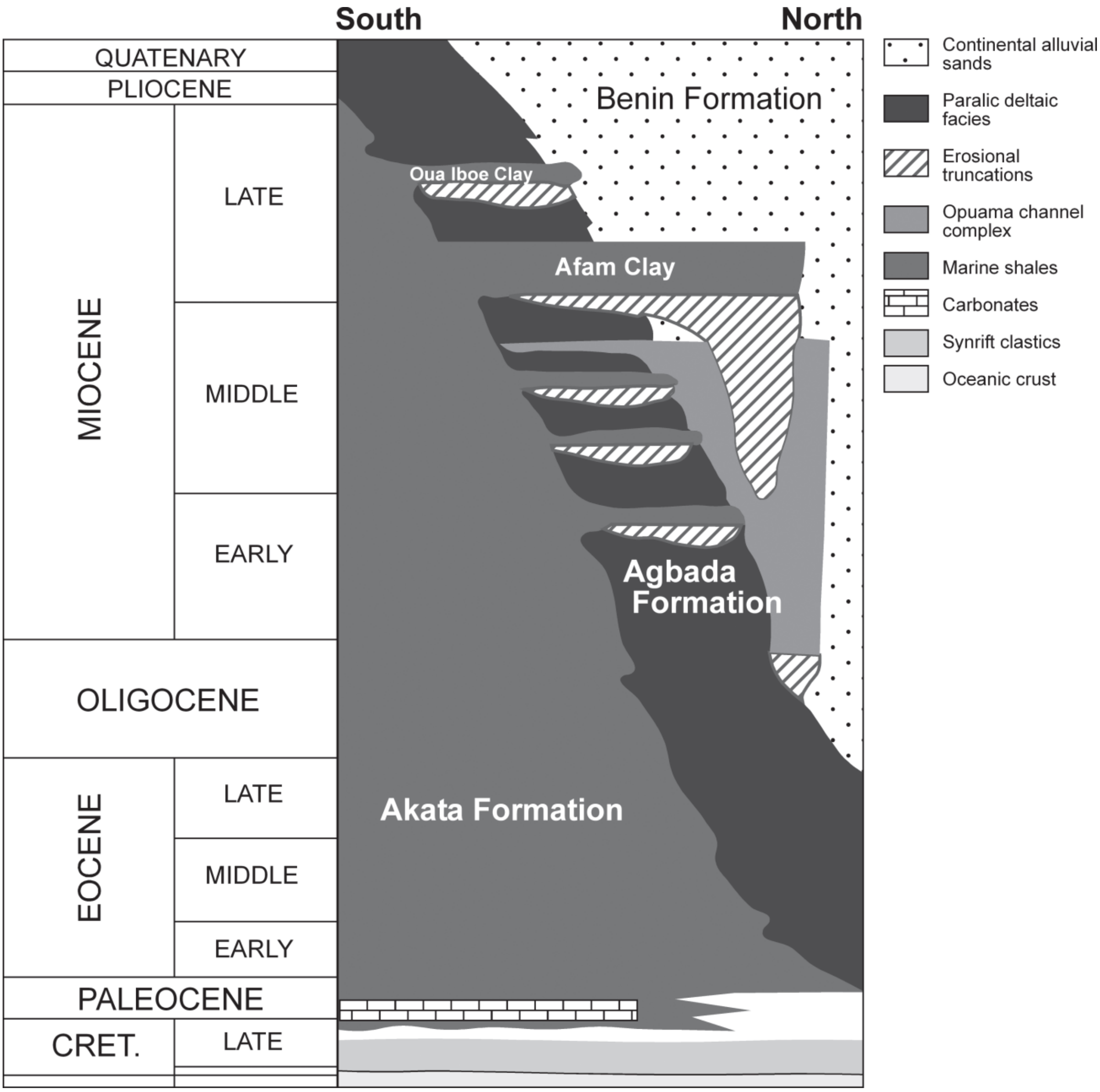

Figure 2: Stratigraphy of the formations of the Niger Delta (Ige, 2010).

MATERIALS AND METHODS

The ditch cutting samples and wireline logs of Emi-5 well were provided by ExxonMobil Producing Nigeria Unlimited. The sample preparation and analysis were carried out in Mosunmolu Laboratory Nigeria Limited, Lagos.

The standard acid palynological preparation method was followed. Fifty-one ditch cutting samples from Emi-5 well were subjected to analysis. Ten grams of each sample were treated with 10 % HCl under a fume cupboard for the complete removal of carbonates. This was followed by neutralization with distilled water before the next procedure. Then 40 % HF was added to the sample which was placed on a shaker until complete dissolution of the silicates and the particles settled. Thereafter, the HF was carefully decanted, followed by neutralization with distilled water. Distilled water was added and decanted three times at 60 minutes interval, in order to remove fluoro-silicate compounds usually formed from the reaction with HF. Sieving and separation were performed using Brason Sonifier 250, where the residues were then transferred into a centrifugal tube and centrifuged at a speed of 2500 revolutions per minute for five minutes. Brason Sonifier is an electric device used with the aid of 5-micron sieve to filter away the remaining inorganic matter (silicates, clay and mud) and heavy minerals to recover organic matters. The sieved residue was given controlled oxidation using concentrated nitric acid (HNO_3). The level of oxidation required by each sample was closely monitored under a microscope. The same procedure for sample preparation for palynomorphs recovery was followed for the palynomacerals, except that the oxidation process with HNO_3 was omitted in order not to bleach the palyno debris. The recovered organic matters were uniformly spotted on arranged cover slips of 22 / 32 mm and were then allowed to dry for mounting. The mounting medium used for permanent mounting of cover slip onto glass slide was Loctite (Impruv), which reduce the risk of loosening and leaks in the slide and was dried with natural sunlight for five minutes. The slides were then stained with safranin-O in order to enhance the study of dinoflagellate cysts.

Both palynology and palynofacies slides were examined under the Olympus Binocular light transmitted microscope. Palynomorph morphological description is centered on feature recognized at 600 µm and photographs taken with the CIX 41 Olympius binocular transmitted light microscope. Identification of palynomorph was done through the use of palynological albums and the published works of previous researchers (Germeraad *et al*., 1968; Ajaegwu *et al*., 2012; Bankole, 2010; Durugbo and Aroyewun, 2012; Ige, 2009; Ige *et al*., 2011).

RESULTS AND DISCUSSION

Palynofacies

The charts in Figures 3 below show the different palynomorph taxa encountered at the different depth intervals. The palynological composition is marked by dominance of pollen and spores over dinoflagellate cysts. The diversity yielded sixty six forms, dinoflagallete cyst account for 7.5% while spores and pollens account for the remaining 92.5% forms encountered in the Emi-5 well.

The abundance shows that, Mangrove taxa (68%), Freshwater (25%), Rainforest (2%), Montane (4%), Savanna (0.6%) and dinoflagellate cyst (0.9%).

At the upper part of the Emi-5 well (5079-6283 ft), show complete absence of dinoflagelatte cyst, which may infer the absence of marine influence. While at the lower part of the Emi-5 well (623-8484 ft) there we find the dinoflagellate cyst (7.5%), which shows the presence of marine influence. There is also an increase in coastal miospores to minimal representation of hinterland miospores downward the sequence.

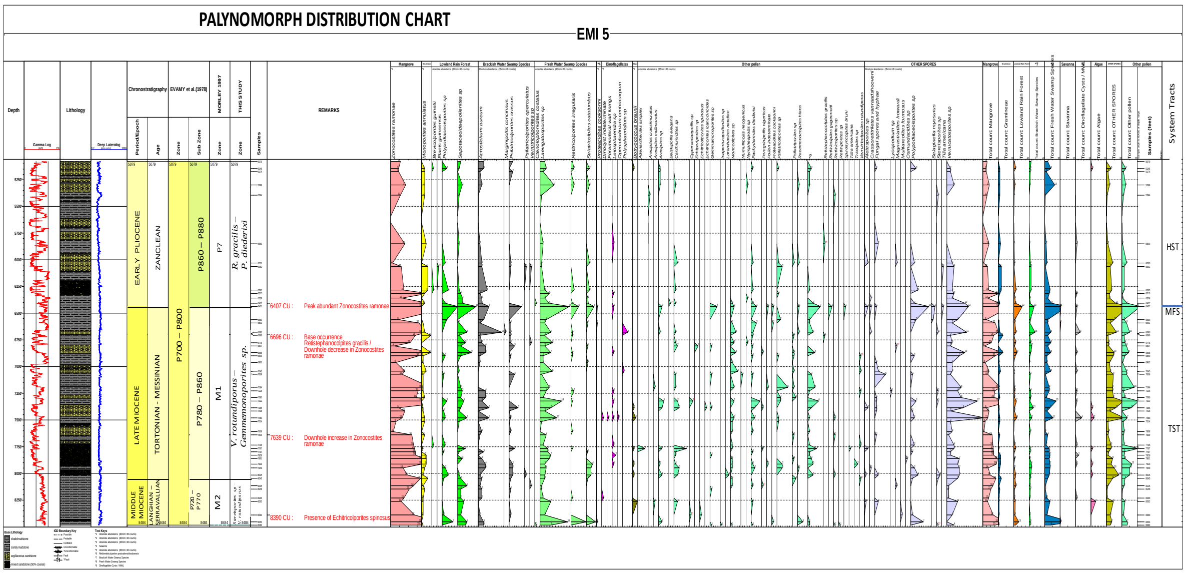

Figure 3: Palynomorph distribution chart of Emi-5 well

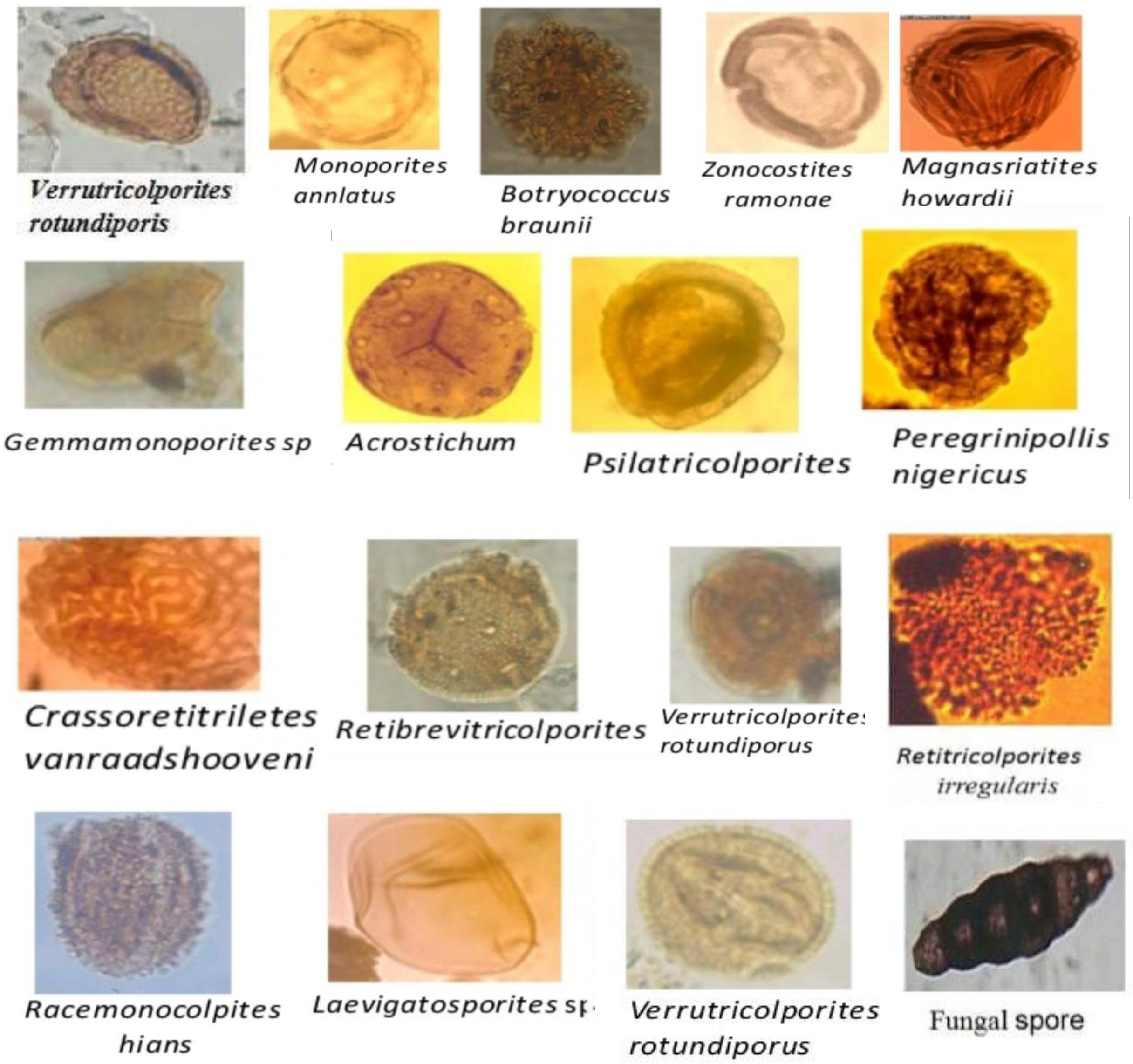

Plate 1. Palynomorphs recovered from the studied well (x 400).

Palynostratigraphic zonation and biochronology of Emi-5 Well

The palynostratigraphic zones proposed in Emi-5 are *Stereisporites* sp – *Verrutricolporites rotundiporus; Verrutricolporites rotundiporus* – *Gemmemonoporites* sp. and *Retistephanocolpites gracilis* – *Pachydermites diederixi* Zones

***Stereisporites* sp – *Verrutricolporites rotundiporus* Zone (Interval Zone) Stratigraphic interval**: 8484 – 8045 ft

Definition: The top of the zone is defined by the Last Downhole Occurrence (LDO) of *Stereisporites* sp at 8484 ft, while the base is marked by the Last Downhole Occurrence (LDO) of *Verrutricolporites rotundiporus* at 8045 ft.

Characteristics: The assemblages of palynomorphs taxa that characterise this zone include *Monoporites annulatus*, *Sapotaceoidapollenites* sp., *Ctenoloponidites costatus*, *Acrostichum aureum*, *Zonocostites ramonae*, *Laevigatosporites* sp., *Verrucatosprites* sp., Other taxa occurring within the zone are *Psilatricoloporites crasssus*, *Peregrinipollis nigericus*, *Aletesporites* sp., *Polypodiaceoisporites* sp. and *Magnastriatites howardi*.

Age: The zone is dated middle Miocene (Langhian – Serravallian stage) because of the presence of the record of first appearance of *Stereisporites* sp., *Cyperaceaepollis* sp., *Aletesporites* sp., *Verrutricolporites rotundiporus* and *Gemmamonoporites* sp. The presence of these speces within the marked interval are strong indication that the interval occurred between middle Miocene and Pleistocene (Bankole *et al*., 2014; Chuckwu-Orji, 2023).

Remark: The zone is equivalent to P720 – P770 subzone of Evamy *et al*. (1978).

***Verrutricolporites rotundiporus* – *Gemmemonoporites* sp. Zone (Interval Zone) Stratigraphic interval**: 8045 – 6437ft

Definition: The top of the zone is defined by the First Downhole Occurrence (FDO) of *Gemmemonoporites* sp at 6437 ft, while the base is marked by the Last Downhole Occurrence (LDO) of *Verrutricolporites rotundiporus* at 8045ft.

Characteristics: The assemblages of palynomorphs taxa that characterise this zone include *Monoporites annulatus*, *Sapotaceoidapollenites* sp., *Ctenoloponidites costatus*, *Acrostichum aureum*, *Zonocostites ramonae, Laevigatosporites* sp., *Verrucatosprites* sp., Other taxa occurring within the zone are *Psilatricoloporites crasssus, Peregrinipollis nigericus, Aletesporites* sp., *Polypodiaceoisporites* sp. and *Magnastriatites howardi*. This zone is characterised by peak abundance and downhole increase of *Zonocostites ramonae.* Dinocysts recovered within this zone are dinocyst indeterminate, *Leiosphaeridia* sp, *Operculodinium cantrocarpum* and *Polyspaeridium* sp.

Age: The zone is dated late Miocene (Tortonian – Messinian stage) because of the presence of the record of first appearance of *Stereisporites* sp., *Cyperaceaepollis* sp., *Aletesporites* sp., *Verrutricolporites rotundiporus* and *Gemmamonoporites* sp. The presence of these species within the marked interval are strong indication that the interval occurred during late Miocene (Bankole *et al*., 2014; Chuckwu-Orji, 2023).

Remark: The zone is equivalent to P780 – P860 subzone of Evamy *et al*. (1978).

Retistephanocolpites gracilis – Pachydermites diederixi **Zone (Interval Zone) Stratigraphic interval**: 6437 – 5079 ft

Definition: The top of the zone is defined by the First Downhole Occurrence (FDO) of *Pachydermites diederixi* at 5079 ft, while the base is marked by the First Downhole Occurrence (FDO) of *Retistephanocolpites gracilis* at 6437ft.

Characteristics: There are few recoveries of palynomorphs taxa within this zone. However, the assemblages of palynomorphs taxa that characterise this zone include *Verrucatosprites* sp., *Psilatricoloporites* sp., *Laevigatosporites* sp., *Pachydermites diederixi, Monoporites annulatus*, *Sapotaceoidapollenites* sp., *Ctenoloponidites costatus*, *Acrostichum aureum* and *Zonocostites ramonae,* Other taxa occurring within the zone are *Psilatricoloporites crasssus, Peregrinipollis nigericus, Aletesporites* sp., *Polypodiaceoisporites* sp., *Magnastriatites howardi* and *Leiosphaeridia* sp.

Age: The zone is dated early Pliocene (Zanclean stage) because of the presence of *Retistephanocolpites gracilis*, *Cyperaceaepollis* sp., *Aletesporites* sp., *Verrutricolporites rotundiporus* and *Gemmamonoporites* sp. The last appearance of *Retistephanocolpites gracilis* at base of the zone is strong evidence that the interval occurred during early Pliocene (Bankole *et al*., 2014; Chuckwu-Orji, 2023).

Remark: The zone is equivalent to P860 – P880 subzone of Evamy *et al*. (1978).

Palaeoenvironmental conditions of deposition

The Palaeoenvironment during the deposition involves the periodic changes in the depositional environment over geological time. Evaluation of the palaeoenvironment of deposition is essential because different depositional environments give rise to reservoirs with different qualities and characteristics such as porosity, permeability, heterogeneity, and architecture. Inference of the palaeodepositional environments of the studied wells was made based on the following criteria:

The palynoecological groupings of the recovered palynomorphs and the association of environmentally restricted diagnostic species such as *Zonocostites ramonae, Psilatricoloporites crasssus* (mangrove), *Monoporites annulatus* (montane), *Pachydermites diederixi* (fresh water swamp), *Laevigatosporites* sp., and *Botryococcus braunii* (rainforest) is shown in Table 1. Generally, the palynoecological groupings of the recovered palynomorph taxa indicate that the mangrove taxa have highest representation of the total recovery, followed by freshwater and rainforest swamps taxa in the well. Montane and savanna taxa have the lowest representation (Figure 3). Some authors (Adojoh *et al*., 2015; Olayiwola and Bamford, 2016; Chukwuma-Orji *et al*., 2017) agree that landward shifting of coastlines during sea level rise result in deposition of marine sediments in the subaerial delta plain. This period is also associated with shifting of the mangrove and other coastal swamp plant belts due to their preference for saline water. Therefore, the subaerial delta plain depositional environment is characterized by high representation of mangrove, other coastal swamp plants (from beach, brackish, freshwater swamp, rainforest, and palm) miospores, fungal elements, freshwater algae, and marine species (Adojoh *et al*., 2015; Olayiwola and Bamford, 2016).

Similarly, during sea level fall, the coastline is shifted basinward and the shelf area initially covered by marine water become exposed and probably incised due to erosion by fluvial activities. This result in deposition of terrestrial sediments in the subaqueous delta plain, which then become characterised by widespread savanna and montane vegetation belts. This depositional environment is characterised by maxima spectra of savanna and montane pollen (Adojoh *et al*., 2015; Olayiwola and Bamford, 2016; see also Germeraad *et al*., 1968; Jennifer *et al.*, 2012; Olajide *et al.*, 2012 and Chuckwu-Orji, 2023).

Based on these criteria, the lower delta plain to delta front and prodelta (subaerial delta to subaqueous delta plains) environments within coastal-deltaic environment of deposition have been inferred for the sediments encountered in the analysed intervals of Emin-5 well. The interval is characterised by high occurrences of mangrove taxa (*Zonocostites ramonae–Rhizophora*, *Psilatricoloporites crasssus* and *Acrostichum aureum*), followed by freshwater swamp (*Laevigatosporites* sp., and *Botryococcus brannii*) and rainforest swamp taxa (sapotaceae and *Pachydermites diederixi*). This interval has also little representation of savanna (*Retibrevitricolporites protudens, Pteris* sp., and fungal spore) and montane taxa (*Monoporites annulatus—Poacaea*) (Table 1). The prevailing climatic conditions supported the flourishing of the mangrove, rainforest, and fresh water vegetations.

This deduction agrees with that of some previous researchers in the Niger Delta (Durugbo *et al*., 2010; Ige *et al*., 2011; Ola and Adewale, 2014; Bankole *et al*., 2014; Chuckwu-Orji, 2023). They utilised high percentage occurrences of mangrove taxa (Rhizophora), fresh water and rainforest taxa to delineate wet climatic zones, which were also an indication of rise in sea level.

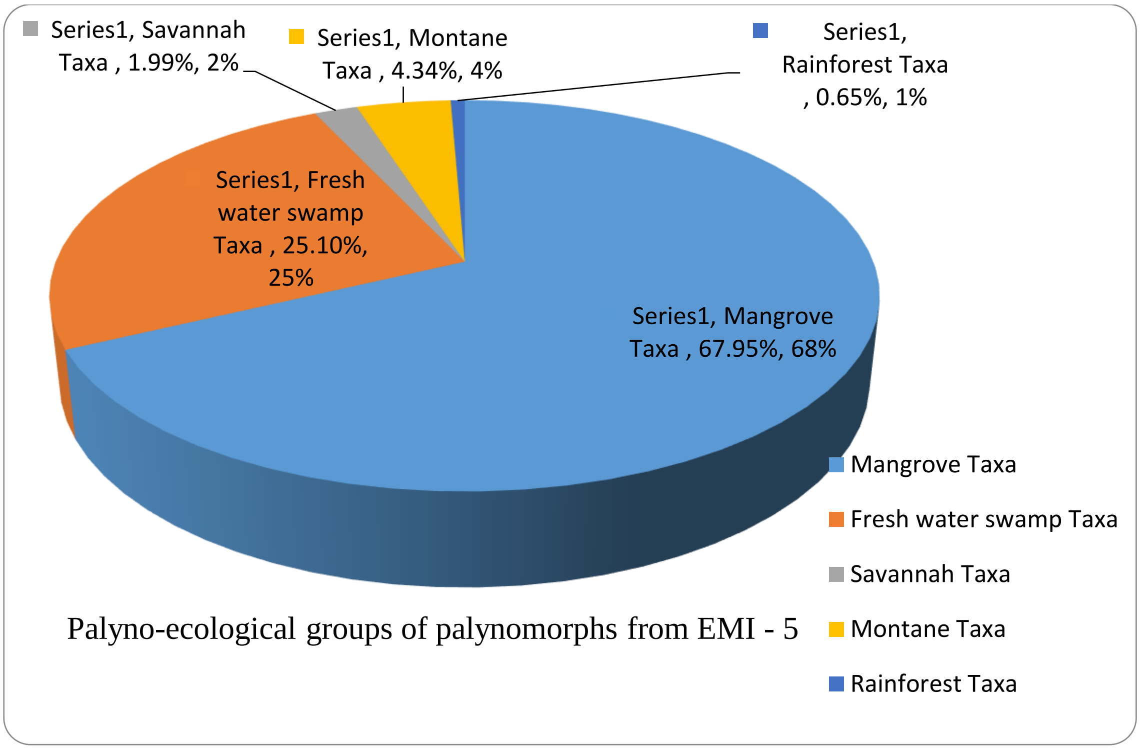

Figure 4: Palynoecological groups (%) of the recovered palynomorph taxa

Table 1: Palynoecological groupings of palynomorph taxa recovered from Emi-5 well

		Mangrove Taxa				Fresh water swamp Taxa										Rainforest Taxa					Montane Taxa				Savannah Taxa		
S/NO	Depth	Zonocostites ramonae	Psilatricolporites crassus	Acrostichum aureum	total mangrove Taxa	Verrutricolporites rotundiporus	Gemmamonoporites sp.	Magnestriatites howardi	Racemonocolpites hians	Multiareolites formosus	Crassoretitriletes vanraadshooveni	Laevigatosporites sp.	Botryococcus brauni	Verrucatosporites sp.	Total Freshwater swamp taxa	Elaeis guineensis	Pachydermites diederixi	Peregrinipollis nigericus	Sapotaceae	total Rainforest taxa	Praedapollis flexibilis	Aletisporites sp.	Monoporites annulatus	Total Montane Taxa	Cyperaceaepollis sp.	Retribrevitricolporites protrudens	Total Savannah Taxa
1	5636	71		4	75									5	5												
2	5803	1		3	4							1		1	2											2	2
3	6065	5			5							3		3	6												
4	6080	1			1							9		1	10								38	38			
5	6355	36		6	42							5		8	13								21	21		3	3
6	6430	19		9	28		1					1		7	9		3	2		5			28	28			
7	6540	30		7	37							3		1	4		2			2			1	1		5	5
8	6640											2	1		3				1	1			1	1		6	6
9	8062	3			3																		6	6			
10	8082	6			6							3		11	14		2			2							
11	8091	17		7	24		2				2	18		3	25										1	1	2
12	8154	10		10	20							10		2	12		2			2			10	10	1	5	6
13	8179	9			9		2		1			1			4								7	7			
14	8461	5	3	1	9							7	1		8			1		1			8	8	1		1
15	8607	6	1	2	9						1	3		5	9		1		1	2			15	15			
16	8974	13		2	15							8		5	13								10	10	1		1
17	9053	5	1	3	9							7		5	12								19	19		2	2
18	9152	18	1	2	21		2					4		6	12	1		1		2			20	20		1	1
19	9261	5	1	4	10		2					3		2	7								18	18	1	1	2
20	9272	8	2	4	14						1	2		3	6		2	1		3			1	1	3	3	6
21	9346	16		4	20		2			1		5		3	11		2			2			7	7			
22	10009	16	1	5	22		2					3		3	8		1			1			5	5	1	2	3
23	10056	8	1		9	1	1					1		3	6								5	5			
24	10150	12	1	7	20		1		1		1	3		3	9												
25	10249	14	2	5	21		1				1	7		5	14								8	8			
26	10313	3		0	3						1	8		2	11												

27	10335	13	1	2	16					1	5		4	10	1	1	2		1	4	5			
28	10378	6	1		7						1		2	3	1	1	2							
29	10502	1			1						1		2	3						2	2			
30	10517	6			6						1			1										
31	10563	4	1	5	10				1		11		1	13						1	1		1	1
32	10656	8	1	1	10	3	1				2		22	28						3	3			
33	10718	1		1	2			1			4		1	6										
34	10735	4		4	8						1			1						1	1			
35	10826	4	1		5						2		5	7										
36	10907	4			4						1		2	3										
37	11001	5		3	8						1	1	1	3										
38	11046	40	3	1	44						7		4	11						1	1	1	1	2
39	11187	10		1	11						1			1						4	5			
40	11236	6	5	4	15	3					1		1	5	1		2	1		5	6		3	3
41	11236	1	1	7	9	1					2		2	5	1		2			5	5		3	3

Paleoclimatic conditions

Paleoclimatic changes delineated in the studied wells have been determined from the relative abundance of microfloral elements of the palyno-ecological groups established in the well (Figures 5). The wet climatic zones inferred indicate the fluctuation of the climate and sea level change during the Miocene. The wet climatic zone suggests highstand/transgressive systems tracts (Adojoh *et al.*, 2015).

In Emi-5 well, the intervals show increased and good representation of mangrove taxa (*Zonoccostites ramonae, Psilaticolporites crassus* and *Acrostichum aureum),* freshwater taxa (*Striatricolporites catatumbus, Levigatosporites* sp., *Botryococcus braunii, Verrucatosporites* sp. and G*emmamonoporites* sp.) and rainforest taxa such as *Pachydermites diederixi* and *Sapotacea*. This is also supported by none to rare occurrences of montane and savannah taxa within the intervals such as *Monoporites annulatus, Coryius* sp., *Pteris* sp., fungal spores and *Cyperaceapollis* sp. High representation of coastal miospores (mangrove, beach, brackish and rainforest taxa) compared to minimal representation of hinterland miospores (savannah and montane taxa) are characteristics of transgressive sediments that were deposited during sea level rise and wetter climate, while the opposite represents sea level fall and drier climate (Morley, 1995; Ige, 2009; 2011; Adojoh *et al*., 2015; Olayiwola and Bamford, 2016; Chuckwu-Orji, 2019). The maximum occurrences of mangrove, rain forest and freshwater taxa are indications that the prevailing climatic conditions supported the flourishing of the mangrove, rain forest and fresh water vegetations. The wet climatic zones of this study agree with that of some previous researchers in the Niger Delta (Durugbo *et al*., 2010; Ige, 2011; Ola and Adewale, 2014 as well as Bankole *et al*., 2014; Chuckwu-Orji, 2019). The author utilised high percentage occurrences of mangrove taxa (*Zonoccostites ramonae* - Rhizophora), fresh water and rainforest taxa to delineate wet climatic zones which were also indication of rise in sea level.

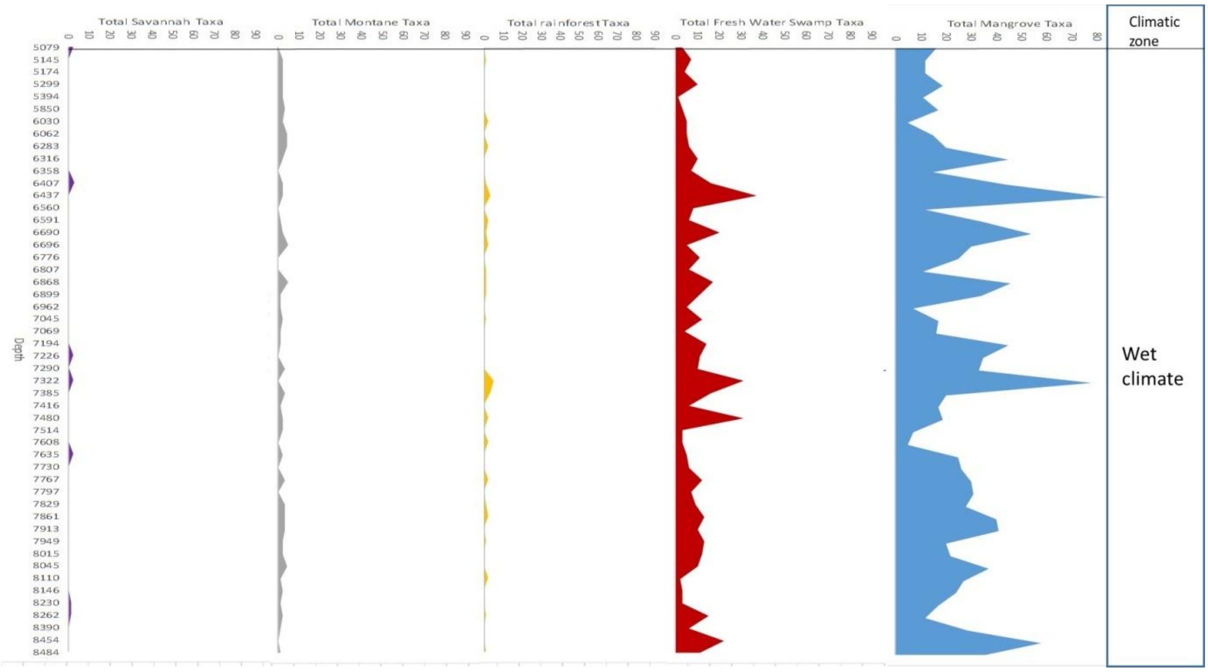

Figure 5: The abundance (population count) of the palyno-ecological groups and paleoclimatic zones of Emi-5 well

CONCLUSION

Palynological, Paleoenvironmental and Paleoclimatic investigations of Emi-5 well Offshore, Niger Delta, Nigeria was conducted to established palynozones, determine age, reconstruct paleoenvironmental conditions and paleoclimatic conditions to permit stratigraphic correlation, provide insights into the depositional settings and changes overtime within the basin. Fifty one (51) shaly ditch cutting samples were subjected to standard palynological method of palynomorph recovery. The palynological composition is marked by dorminance of pollen and spores over dinoflagellate cysts. The intercalation of the sandy and shaly intervals across the section evidenced from lithologic, textural, and wire line log data suggested that the entire studied interval belong to the Agbada Formation. Three interval range zones were delineated using the international stratigraphic guide for the establishment of biozones (Murphy and Salvador, 1999), they are *Stereisporites* sp – *Verrutricolporites rotundiporus; Verrutricolporites rotundiporus* – *Gemmemonoporites* sp. and *Retistephanocolpites gracilis* – *Pachydermites diederixi* Zones and based on the aforementioned zones the interval is assigned middle Miocene to late Miocene. Coastal-deltaic (lower delta plain to prodelta) environment of deposition is inferred for the studied interval on the basis of the palynofacies association and palynomorphs/palyno-ecological abundance. The variations in the relative abundance of the recovered palynomorphs (hinterland versus coastal/lithoral) taxa are characteristics of different palaeoenvironments of prograding paralic succession. The higher occurrences of mangrove, rainforest, and fresh water taxa (lithoral/coastal vegetation) with few savanna and montane taxa within the interval are indications that the interval was deposited in lower delta plain during sea level rise and wet climate. The ecological groupings of the recovered palynomorph taxa revealed that the studied intervals were deposited under the maximum occurrences of mangrove, rain forest and freshwater taxa are indications that the prevailing climatic conditions supported the flourishing of the mangrove, rain forest and fresh water vegetations, which were also indication of rise in sea level. This studies is both useful in the study of the paleogeography and petroleum potential because they can contribute to the identification of depositional environments, thus aiding the general evaluation of the hydrocarbon potential of a sedimentary basin.

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REFERENCES
Adojoh, O., Lucas F.A. and Dada, S., 2015, Palynocycles, Palaeoecology and Systems Tracts Concepts: A Case Study from the Miocene Okan-1 Well, Niger Delta Basin, Nigeria. *Applied Ecology and Environmental Sciences*, 3, pp. 66–74. doi: 10.12691/aees-3-3-1.

Ajaegwu, N.E., Odoh, B.I., Akpunonu, E.O., Obiadi, I.I. and Anakwuba, E.K., 2012, Late Miocene to Early Pliocene Palynostratigraphy and Palaeoenvironments of ANE-1 Well, Eastern Niger Delta. *Nigeria Journal of Mining and Geology,* 48, pp. 31–43.

Avbovbo, A.A., 1978, Tertiary lithostratigraphy of Niger Delta. *American Association of Petroleum Geologists Bulletin*, 62, pp. 295–300.

Bankole, S.I., 2010, *Palynology and stratigraphy of three deep wells in the Neogene Agbada Formation, Niger Delta, Nigeria. Implications for petroleum exploration and paleoecology*, PhD thesis, Technische Universität Berlin, pp. 1–190.

Bankole, S. I., Schrank, E. & Osterloff, P. L. (2014). Palynostratigraphic, palaeoclimates and palaeodepositional evironments of the Miocene aged Agbada Formation in the Niger Delta, Nigeria. Journal of African Earth Sciences, 95, 41 - 62.

Batten, D.J. and Stead, D.T., 2005, Palynofacies analysis and its stratigraphic application. In *Applied stratigraphy*, edited by Koutsoukos, E.A.M., (Dordrecht: Springer), pp. 203–226.

Bustin, R.M., 1988, Sedimentology and characteristics of dispersed organic matter in Tertiary Niger Delta: Origin of source rocks in a deltaic environment. *American Association of Petroleum Geologists, Bulletin,* 72, pp. 277–298.

Chukwuma-Orji, J. N., Okosun E. A., Goro, I. A., & Waziri, S. H. (2017). Palynofacies, sedimentology and palaeoenvironment evidenced by studies of IDA-6 well, Niger Delta, Nigeria. Palaeoecology of Africa, 34, 87-105.

Chuckwu-Orji, J. N. (2019). Paleoclimatic reconstruction of Middle to Late Miocene strata evidenced from palynological study of Ida-4 well, Eastern Niger Delta, Nigeria. Nigeria journal of engineering and applied science, vol. 6 (2) pp 82-93.

Chuckwu-Orji, J. N. (2023). Sedimentological Analysis, Depositional Environment and Sequence Stratigraphic study of Ida 4, 5, 6 Wells Niger Delta basin, Nigeria. FUDMA Journal of Sciences (FJS), vol 7 No. 5, pp 296-317.

Doust, H. and Omatsola, E., 1990, Niger Delta Divergent/Passive Margin Basins. *American Association of Petroleum Geologists, Memoir*, 48, pp. 201–238.

Durugbo, E.U. and Aroyewun, R.F., 2012, Palynology and Paleoenvironments of the Upper Araromi Formation, Dahomey Basin, Nigeria. *Asian Journal of Earth Sciences,* 5, pp. 50–62. doi: 10.3923/ajes.2012.50.62.

Durugbo, E.U. and Uzodimma, E., 2013, Effects of lithology on palynomorph abundance in wells X1 and X2 from the Western Niger Delta, Nigeria. *International Journal of Geology, Earth and Environmental Sciences,* 3, pp. 170–179.

Evamy, B.D., Haremboure, J., Karmerling, P., Knaap, W.A., Molloy, F.A. and Rowlands, P.H., 1978, Hydrocarbon habitat of the Tertiary Niger Delta. *American Association of Petroleum Geologists, Bulletin,* 62, pp. 1–39.

Germeraad, J.J., Hopping, G.A. and Muller, J., 1968, Palynology of Tertiary sediments from tropical areas. *Review of Palaeobotany and Palynology,* 6, pp. 189–348. doi: 10.1016/003667(68)90051-1.

Ige, O.E., 2009, A Late Tertiary Pollen record from Niger Delta, Nigeria. *International Journal of Botany,* 5, pp. 203–215. doi: 10.3923/ijb.2009.203.215.

Ige, O.E., Datta, K., Sahai, K. and Rawat, K.K., 2011, Palynological Studies of Sediments from North Chioma-3 Well, Niger Delta and its Palaeoenvironmental Interpretations. *American Journal of Applied Sciences,* 8, pp. 1249–1257.

Jennifer, Y.E., Mebradu, S.M., Okiotor M.E. and Imasuen, O.I., 2012, Palaeoenvironmental studies of well "AX", in the Niger Delta. *International Research Journal of Geology and Mining,* 2, pp. 113–121.

Morley, R.J., 1997, Offshore Niger Delta palynological zonation, prepared for the Niger Delta Stratigraphic Commission. *Palynova*, 1, pp. 1–6.

Murphy, M.A. and Salvador, A., 1999, International Stratigraphic Guide—An abridged version, International Subcommission on Stratigraphic Classification of IUGS, International Commission on Stratigraphy, *Special Episodes,* 22, 4, pp. 255–272.

Okosun, E.A. and Chukwuma-Orji, J.N., 2016, Planktic Foraminiferal Biostratigraphy and Biochronology of KK-1 Well Western Niger Delta, Nigeria. *Journal of Basic and Applied Research International,* 17, pp. 218–226.

Olajide, F.A., Akpo, E.O. and Adeyinka, O.A., 2012, Palynology of Bog-1 Well, Southeastern Niger Delta Basin, Nigeria. *International Journal of Science and Technology*, 2, pp. 214–222.

Olayiwola, M.A. and Bamford, M.K., 2016, Petroleum of the Deep: Palynological proxies for palaeoenvironment of deep offshore upper Miocene-Pliocene sediments from Niger Delta, Nigeria. *Palaeontologia Africana,* 50, pp. 31–47.

Ojo, A.O. and Adebayo, O.F., 2012, Palynostratigraphy and paleoecology of chev-1 well, southwestern Niger delta basin, Nigeria. *Elixir Geoscience,* 43, pp. 6982–6986.

Ola, P. S & Adewale, B. K. (2014). Palynostratigraphy and Paleoclimate of the Sequences Penetrated by Meren 31 Side Tract-2 Well, Offshore Niger Delta, *InternationalJournal of Geosciences*, Vol. 5, 1206-1218. 92

Osokpor, J., Lucas, F.A., Osokpor, O.J., Overare, B., Elijah, I.O. and Avwenagha, O.E., 2015, Palynozonation and lithofacies cycles of paleogene to Neogene age sediments in PML-1 well, Northern Niger Delta Basin. *The Pacific Journal of Science and Technology*, 16, pp. 286–297.

Oyede, A.C., 1992, Palynofacies in deltaic stratigraphy. *Nigerian Association of Petroleum Explorationist Bulletin*, 7, pp. 10–16.

Reijers, K. J. A. (2011). Stratigraphy and sedimentology of the Niger Delta. Geologos, 17, 133-162. DOI: 102478/v 10118-011 -0008.3.

Reijers, T.J.A., Petters, S.W. and Nwajide, C.S., 1997, The Niger Delta Basin, sedimentary geology and sequence stratigraphy. In *African Basins*, edited by Selley, R.C., (Amsterdam: Elsevier), pp. 151–172.

Short, K.C. and Stauble, A.J., 1967, Outline of the geology of Niger Delta. *American Association of Petroleum Geologists, Bulletin*, 51, pp. 761–779.

Weber, K.J., 1971, Sedimentological aspects of oil fields in the Niger Delta, *Geologie en Mijnbouw*, 50, pp. 559–576.

Weber, K. J. and Dankoru. E.M., 1975, Petroleum geology of Niger Delta. In *Proceedings of the 9th annual conference on world petroleum congress*, (Tokyo: London Applied publishers' Ltd), 2, pp. 209–221.

Weber, K. J. (1971). Sedimentological aspects of oil field in the Niger Delta.Geologie en Mijnbouw, 50, 559 - 576.

Whiteman, A. (1982). Nigeria: Its Petroleum Geology Resources and Potential, (1 and 2), London, Graham and Tottman, 393p.

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