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Qualitative and Quantitative Signatures of Cenozoic Sediments in YZ-Well Niger Delta Basin Nigeria

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Abstract
The qualitative and quantitative signatures of Quaternary sediments were carried out. Ditch cuttings, intervals 3160-3250 m were analysed to establish palynozones, age determination, and depositional environments of sediments. The samples were subjected to standard laboratory processes of non-acid palynological preparation method. The Lithologic decription of the samples consists predominantly fine to medium grained sand with shale intercalations which conformed to the paralic Agbada Formation. The recovery yielded low to moderate palynomorphs within the sampled intervals. Microscopic examination yielded moderate to well-preserved palynomorph assemblages comprising pollen, spores, fungal remains, and dinoflagellate cysts. Maker species identified include: *Zonocostites ramonae*, *Elaeis guineensis*, *Magnastriatites howardi*, *Cyperaceaepollis* sp., and *Retibrevitricolporites protrudens*. Quantitative assessment revealed the highest palynomorph concentrations between 3180–3210m, indicating fluctuations in sedimentation rates and environmental conditions. Qualitatively, based on the Last Occurrence Datum (LOD) of *Cyperaceaepollis* sp and the consistent presence of marker species *Pachydermites diederixi* suggests an Aquitanian–Burdigalian Early Miocene age. Paleoenvironmental analysis revealed a marginal marine to deltaic setting characterized by alternating terrestrial and marine influences, supported by the dominance of swamp and mangrove indicators and minor dinocyst occurrences. The integration of both approaches offers a powerful tool in reconstructing sedimentary history and refining stratigraphic frameworks in deltaic systems. This study enhances biostratigraphic resolution, and underscores the importance of integrating qualitative and quantitative approaches for stratigraphic framework in the Niger Delta Basin.

Keywords: Cenozoic sediments, Niger Delta Basin, Zy-Well, Quaternary sediments, palynology, palynomorphs, palynozones

Introduction

Palynology is the branch of biostratigraphy that uses fossil content to establish relative ages and correlations of sedimentary strata. It plays a fundamental role in understanding the stratigraphy of the Niger Delta. Traditionally, biostratigraphic frameworks in the region were developed for petroleum exploration, focusing mainly on Tertiary (Paleogene–Neogene) sediments using palynomorphs (Okereke *et al*., 2022) [5]. However, Quaternary sediments have been less intensively studied because of their limited thickness, lateral heterogeneity, and restricted economic relevance in oil exploration. Despite this, Quaternary biostratigraphy is important for reconstructing paleoenvironmental changes, shoreline evolution, and basin dynamics (Okosun & Liebau, 2016) [6].

Qualitative and quantitative biostratigraphic approaches offer complementary insights, Qualitative method involves the identification and description of species, their first and last occurrences, and zonal schemes while Quantitative analyses through statistical treatment of abundance data, diversity indices, and ecological groupings enhance reproducibility and allow more precise correlations (Sowunmi, 1995; Adeonipekun & Olowokudejo, 2005). Applying both approaches to the Quaternary sediments of the Niger Delta provides the opportunity to develop high-resolution chronostratigraphic frameworks, constrain depositional environments, and establish baseline data for coastal management, hydrostratigraphy, and paleoecological studies.

The Quaternary period (last ~2.6 million years) is marked by significant climatic fluctuations, glacio-eustatic sea-level changes, and associated variations in sedimentary processes. In deltaic environments such as the Niger Delta, these changes strongly influenced sediment supply, facies distribution, shoreline migration, and ecological dynamics. The Niger Delta, one of the largest deltas in the world, provides an exceptional archive of Quaternary

depositional history due to its high sedimentation rates, complex fluvial-deltaic systems, and interactions with marine processes (Doust & Omatsola, 1990).

The Niger Delta's Quaternary sediments hold relevance for understanding sea-level rise, sedimentation rates, and environmental change in West Africa. As global climate change continues to impact coastal systems, insights from past Quaternary dynamics can inform predictions of future shoreline behavior, sediment budgets, and ecological resilience (Reijers, 2011).

Additionally, palynological evidence facilitates the establishment of biostratigraphic zones and the reconstruction of paleoenvironmental regimes operative during the accumulation of reservoir strata (Akata and Harry, 2019).

This study seeks to undertake an exhaustive Qualitative and Quantitative appraisal of the stratigraphic interval infiltereted YZ well situated Offshore the Niger Delta province. The overarching objective is to delineate palynozones while concurrently elucidating the age determination prehistoric climate condition that governed sedimentation insights that are indispensable for informed and efficient hydrocarbon exploration.

Geological Settings

The studied well ZY is located in the Offshore Depobelt of the Niger Delta Basin,

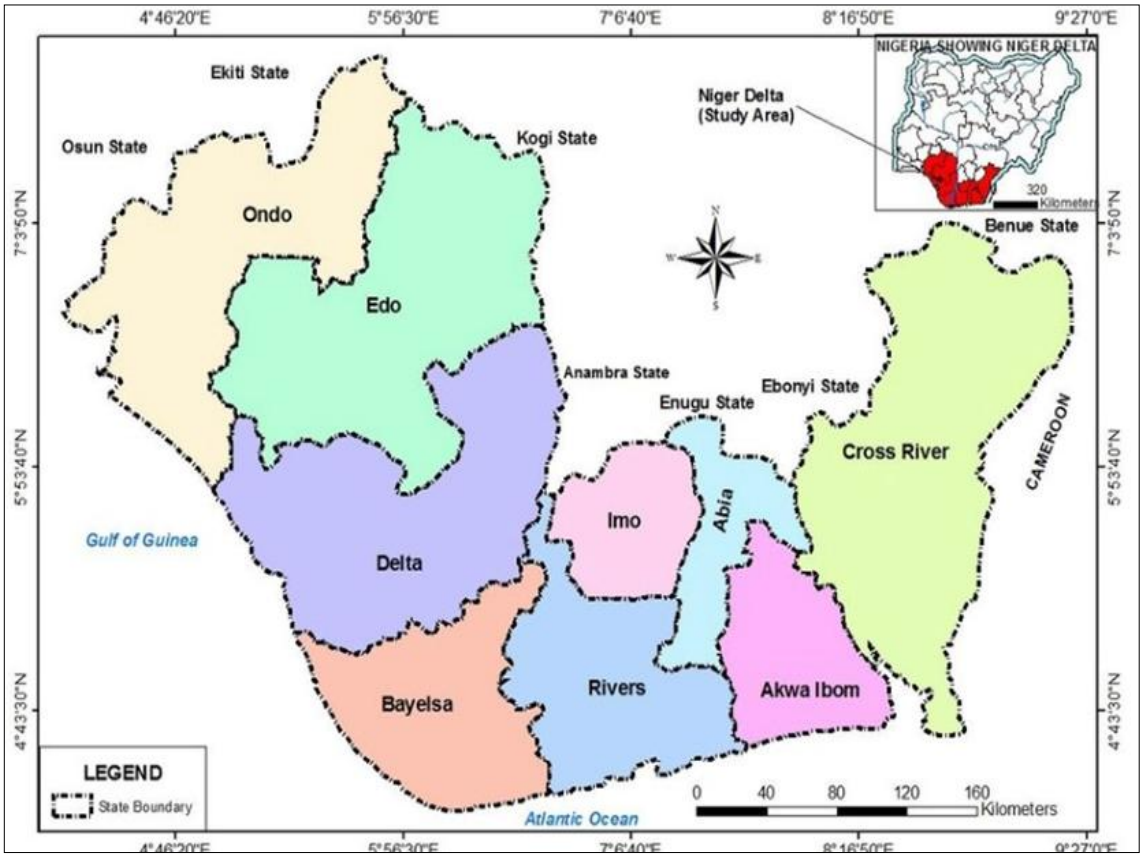


Fig 1: Map of the study area (modified after Doust and Omotsola 1990)

The Niger Delta Basin is one of the most studied sedimentary basins in Africa due to its vast hydrocarbon potential and complex geological evolution. It lies on the passive continental margin of West Africa and extends from about longitude 3°E to 9°E and latitude 4°N to 6°N (Doust and Omatsola, 1990). The delta is underlain by thick sedimentary successions deposited since the Late Cretaceous, following the rifting and opening of the South Atlantic.

The stratigraphic succession of the Niger Delta consists of three major formations (figure 2) that define its depositional history: the Akata, Agbada, and Benin Formations (Short and Stauble, 1967) [9]. The Akata Formation, at the base, is made up predominantly of marine shales with minor sand lenses, representing deep-marine to pro-delta environments. Overlying it is the Agbada Formation, composed of alternating sand and shale units deposited in delta-front to delta-top settings and forming the main hydrocarbon reservoir units. The Benin Formation caps the sequence with continental sands and gravels of fluvial origin. Together, these formations record the progradation of the delta through successive transgressive and regressive phases (Avbovbo, 1978; Kulke, 1995) [2, 4].

Structurally, the Niger Delta is characterized by growth faults, rollover anticlines, and collapsed crests resulting from shale mobility and differential loading (Evamy *et al*., 1978) [3]. These structural features have provided

traps for hydrocarbon accumulation, while shale diapirism and faulting have influenced the distribution of depositional facies and sediment thickness across the delta (Doust and Omatsola, 1990).

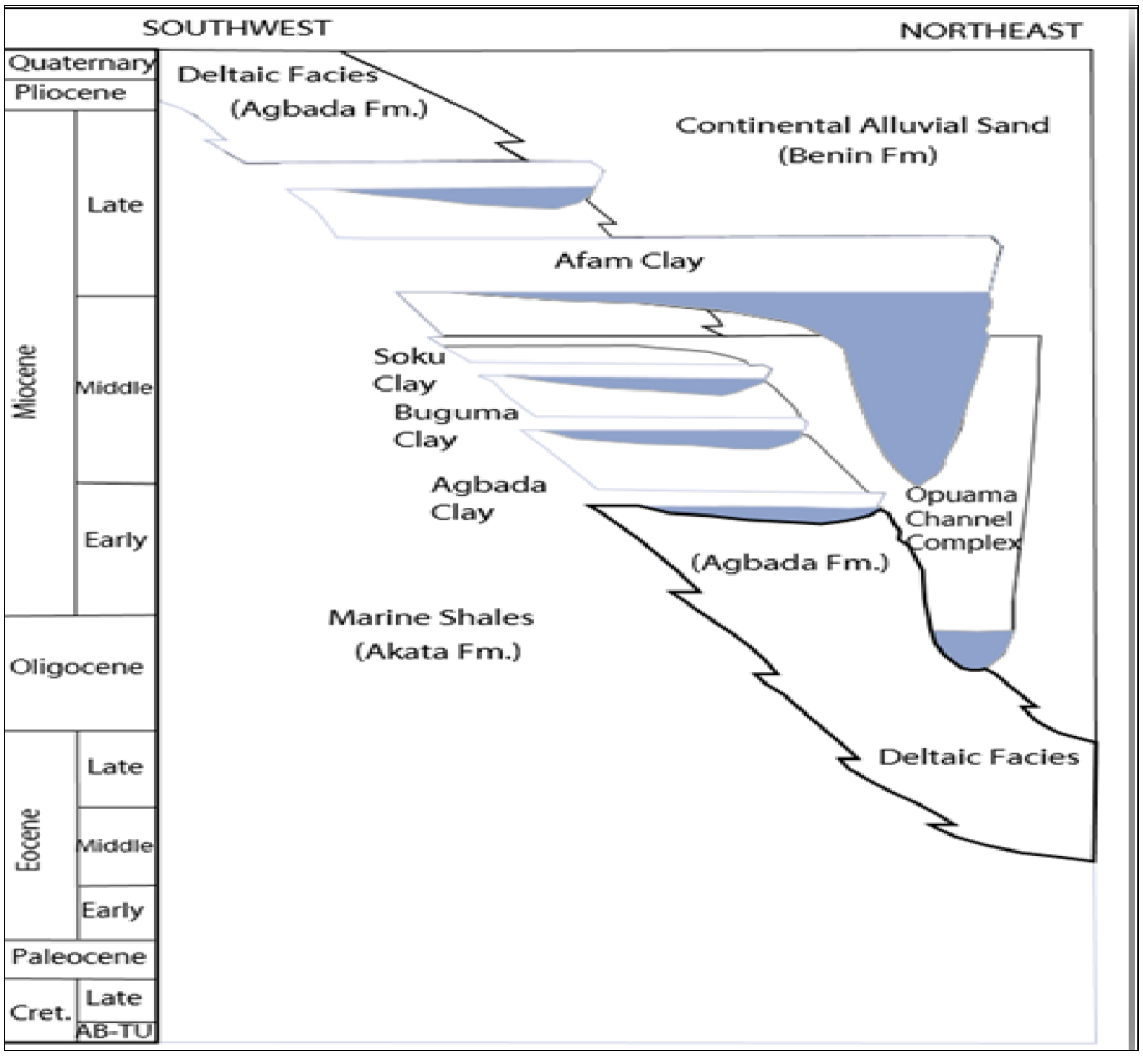


Fig 2: Stratigraphic column showing the three Formations of the Niger Delta (Adapted from Doust and Omatsola, 1990)

Materials and Methods

The palynological procedure in this study was based on non-acid method using Sodium-Hexametaphosphate (Riding and Hughes (2004)) [8]. 25grams of each sample ditch cuttings were weighed and disaggregated to increase the surface area. The disaggregated sample was placed in a labeled beaker and detergent was added to remove drilling mud. 4-10ml of water was then added and stirred, using a spatula. Water was added to the brim of the beaker and allowed to settle for one hour before decanting. This process was repeated 3 times to wash off the Sodium-Hexametaphosphate, detergent, and drill mud. The samples were decanted into small centrifuge tubes. This is to separate the dense mineral fraction from the light organic residue and allow the organic residue to flow to the top of the glass residue. Upon decanting the organic residue on the slide, it was covered with a cover slip and three drops of Norland optical adhesive were added. This was placed on a hot plate, and then heated gradually. The cover slip was dried, then removed with spatula and place on the slides.

Results and Discussion

Lithological description of the studied well.

The results of the analysis are below. (Table 3.1)

Table 3.1: Lithological description of the studied well

S/N	Depth (m)	Description
1	3160-3170	Shale, Brown, Calcereous
2	3170-3180	Shale, Dark brown, Calcereous
3	3180-3190	Shale, Brown, Calcereous
4	3190-3200	Shale, Black, Calcereous
5	3200-3210	Shale, Brown, Calcereous
6	3210-3220	Sandy Shale, Grey, Calcereous
7	3220-3230	Shale, Grey, Calcereous

8	3230-3240	Shale, Brown, Calcereous
9	3240-3250	Shale, Brown, Calcereous
10	3250-3260	Shale, Grey, Calcereous

Palynostratigraphic Zonation

Palynostratigraphic zonation allows for the subdivision of strata into biozones, which are small-scale stratigraphic units defined by the stratigraphic ranges of palynomorph species, independent of the lithology of the fossil-bearing beds. In this study, the results of the analysis carried out from 3160 - 3250m yielded good recovery. A total of 10 samples were prepared and analysed.

The top of a zone is defined by the First Occurrence Datum (FOD) of *a* specie. The top of this zone was not seen while the base is marked by the Last Occurrence Datum (LOD) of *Cyperaceaepollis* sp at 3160m.

Characteristics: The assemblages of palynomorphs taxa that characterize the zones are: *Racemonocolpites hians, Polypodiaceoisporites* sp., *Elaeis guineensis,*
Sapotaceoidespollenites sp., *Acrostichum aureum, Zonocostites ramonae, Laevigatosporites* sp., *Verrucatosprites* sp., *Retibrevitricolporites protrudens.*
Praedapollis flexibillis. Other taxa occurrences are *Leiosphaeridia* sp., *Sapotaceae, Psilatricoloporites crasssus, Peregrinipollis nigericus, Multiareolites formosus, Pteris* sp., and *Psilatricoloporites* sp.

Age: The zone is Early Miocene (Aquitanian – Burdigalian stage) because of the presence of *Cyperaceaepollis* sp. at the upper boundary of the zone.

Palynomorph assemblage and counts at Depth 3160(m)

S/N	Depth 3160(m)	Palynomorphs	Counts
1.	*Echitiletes sp*		1
2.	*Sclenopenphix sp*		1
3.	*Smorthtilete spore*		1
4.	*Fusiformisporites sp*		1
5.	*Dinocyst indet*		2
6.	*Cyperaceaepollis sp*		1
7.	*Magnestraitriporites howardi*		10
8.	*Monoporites annulatus*		1
9.	*Polypodia ceiosporites retirugatus*		1
	Tuberculodinium vancampoae		1

Palynomorph assemblage and counts at Depth 3170(m)

S/N	Depth 3170(m)	Palynomorphs	Counts
1.	*Polypodiaceiosporites retirugatus*		2
2.	*Tuberculodinium vancampoae*		1
3.	*Verrucatosporites farvus*		1
4.	*Smooth monolete spore*		2
5.	*Peregrinipollis nyericns*		2
6.	*Preadapollis spp*		1
7.	*Magnastraitriletes howardi*		28
8.	*Psilastephanocolporites spp*		1
9.	*Adeantherites simplex*		11
10.	*Monoporites annulatus*		1
11.	*Lycopodium sporites sp*		1

Palynomorph assemblage and counts at Depth 3190(m)

S/N	Depth 3190(m)	Palynomorphs	Counts
1.	*Vemcatosporites farvus*		1
2.	*Multicellites sp*		1
3.	*Magnastraiporites*		52
4.	*Polypodiaceisporites retirugatus*		1
5.	*Dinocyst*		1
6.	*Lycopodium sporites sp*		1
7.	*Polyadopollenite spp*		1
8.	*Retitricocporites sp*		1

9.	*Echipertporites estelae*	1
10.	*Adenantherites simplex*	1

Palynomorph assemblage and counts at Depth 3200(m)

S/N	Depth 3200(m)	Palynomorphs	Counts
1.	*Lvcopodium sporites*		3
2.	*Fusfiforisporites*		1
3.	*Dinocyst indet*		1
4.	*P. echinatus*		1
5.	*Magnastratiletes howardi*		17
6.	*Straitricolporites rotundiporus*		2
7.	*Polypodiacesporites retirugatus*		2
8.	*Pachydermites diederixi*		1
9.	*Smooth monoletespore*		2
10.	*monoporites annulates*		4

Palynomorph assemblage and counts at Depth 3210(m)

S/N	Depth 3210(m)	Palynomorphs	Counts
1.	*Magnastratriletes howardi*		16
2.	*Leoispearides sp*		1
3.	*Fusiformisporites sp*		1
4.	*Brevetricolporites guinett*		1
5.	*Pterospermella sp*		3
6.	*Pachydermites diederixi*		1
7.	*Verrucatosporites farvus*		1
8.	*Fungal spore*		2
9.	*Smooth monolete spore*		2
10.	*Peregrinipollis nigericus*		1
11.	*Echiperiporites sp*		1
12.	*Polypodiceiosporites retrigatus*		2
13.	*Lycopodium sporites sp*		1
14.	*Psilatricolporites sp*		1

Palynomorph assemblage and counts at Depth 3220(m)

S/N	Depth 3220(m)	Palynomorphs	Counts
1.	*Achritarch*		1
2.	*Echiperiporites echinatus*		1
3.	*Psilatriparites sp*		1
4.	*Dinocyst*		1
5.	*Smooth triletspore*		1
6.	*Psilaperiporites minimus*		1
7.	*Monoporites annulatus*		1

Palynomorph assemblage and counts at Depth 3230(m)

S/N	Depth 3230(m)	Palymorphs	Counts
1.	*Polypodiaceiosporites retirugatus*		2
2.	*Psilaporites sp*		1
3.	*Monoporites annuletus*		1
4.	*howardi*		15
5.	*Brevetricolporites gunetti*		1
6.	*Smooth triletespore*		1
7.	*Spirosyncolpites bruni*		1
8.	*Adenantherites simplex*		1

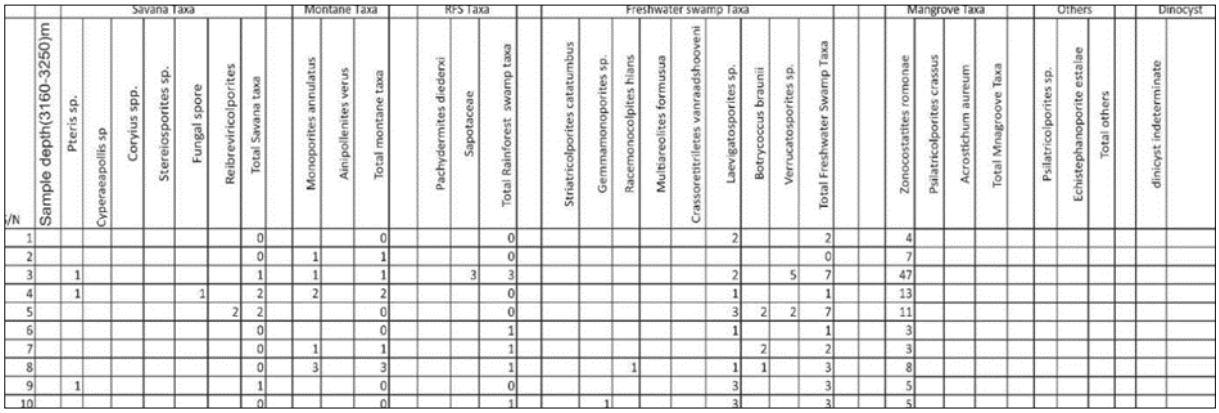
Palynomorph assemblage and counts at Depth 3240(m)

S/N	Depth 3240(m)	Polynomorphs	Counts
1.	*Polydiaceusporites retingatus*		2
2.	*Vaadranshooveni howardi*		5
3.	*Smoothtriletespore*		2
4.	*Leiosphearidia sp*		1

5.	*Psilastephanocolporites leavigatus*	1
6.	*Marattiaceae sp*	1
7.	*Lvcopodum sporites sp*	1
8.	*Smooth monolete spore*	1

Palynomorph assemblage and counts at Depth 3250(m)

S/N	Depth 3250(m)	Polynomorphs	Counts
1.	*Selenopenphex sp*		1
2.	*Aeritarch*		1
3.	*Triporoletes neogericus*		1
4.	*Psilatricolporites sp*		1
5.	*Lycopodium sporites sp*		3
6.	*Echiperiporites estelae*		1



		Savana Taxa							Montane Taxa			RFS Taxa			Freshwater swamp Taxa									Mangrove Taxa				Others			Dinocyst	
S/N	Sample depth(3160-3250)m	Pteris sp.	Cyperaeapollis sp	Corvius spp.	Stereiosporites sp.	Fungal spore	Reibrevricolporites	Total Savana taxa	Monoporites annulatus	Ainipollenites verus	Total montane taxa	Pachydermites diederxi	Sapotaceae	Total Rainforest swamp taxa	Striaticolporites catatumbus	Gemmamonoporites sp.	Racemonocolpites hians	Multiareolites formusua	Crassoretitriletes vanraadshooveni	Laevigatosporites sp.	Botrycoccus braunii	Verrucatosporites sp.	Total Freshwater Swamp Taxa	Zonocostatites romonae	Psilatricolporites crassus	Acrostichum aureum	Total Mnagroove Taxa	Psilatricolporites sp.	Echistephanoporite estalae	Total others	dinicyst indeterminate	
1								0			0			0						2			2	4								
2								0	1		1			0									0	7								
3		1						1	1		1		3	3						2		5	7	47								
4		1				1		2	2		2			0						1			1	13								
5							2	2			0			0						3	2	2	7	11								
6								0			0			1						1			1	3								
7								0	1		1			1							2		2	3								
8								0	3		3			1			1			1	1		3	8								
9		1						1			0			0						3			3	5								
10								0			0			1		1				3			3	5								

Fig 3: Palynological Distribution Count

The results of the qualitative and quantitative analyses of palynomorphs recovered from the studied interval (3160–3250 m) within the Quaternary sediments of the Niger Delta. The section includes the identification of recovered taxa, their distribution with depth, and the interpretation of the palynostratigraphic zonation, age, and depositional environment. The findings are discussed in the context of established Niger Delta biostratigraphic frameworks.

Palynomorph Recovery and Preservation

The palynological analysis of ten (10) samples yielded good to moderate recovery of both terrestrial and marine palynomorphs. The recovered assemblages consist of pollen grains, spores, fungal spores, and dinoflagellate cysts. Preservation was generally moderate to good, allowing for clear identification of most taxa. The occurrence of well-preserved forms such as *Zonocostites ramonae*, *Elaeis guineensis*, *Magnastriatites howardi*, and *Retibrevitricolporites protrudens* indicates minimal oxidation and a relatively stable depositional environment.

Quantitatively, the highest palynomorph concentration occurred between 3180 m and 3210 m, with abundant Magnastriatites howardi and Monoporites annulatus. Recovery decreased towards the upper and lower parts of the section, suggesting minor variations in sedimentation rate and depositional conditions.

Palynostratigraphic Zonation

Palynostratigraphic zonation was based on the stratigraphic distribution of key marker taxa. The top of the zone was not encountered within the studied interval, while the base is defined by the Last Occurrence Datum (LOD) of Cyperaceaepollis sp at 3160 m. This taxon, together with *Racemonocolpites hians*, *Elaeis guineensis*, and *Zonocostites ramonae*, forms the basis for identifying an Early Miocene (Aquitanian–Burdigalian) age.

Zonal Characteristics

The zone is characterized by a diverse assemblage of pollen and spores, including:

1. **Common taxa:** *Racemonocolpites hians, Elaeis guineensis, Zonocostites ramonae, Laevigatosporites* sp, *Polypodiaceiosporites* sp., *Retibrevitricolporites protrudens, and Acrostichum aureum.*

2. **Accessory taxa:** *Sapotaceoidespollenites* sp, *Verrucatosporites* sp, *Psilatricolporites crassus, Leiosphaeridia* sp, *and Multiareolites formosus*.

The dominance of Elaeis guineensis and Zonocostites ramonae both associated with mangrove and freshwater swamp vegetation supports a nearshore, deltaic depositional environment.

Quantitative Distribution of Palynomorphs

Quantitative results indicate that the most frequently occurring species across the studied depths are *Magnastriatites howardi, Monoporites annulatus, and Polypodiaceiosporites retirugatus*. The following observations were made:

3160–3190 m: High abundance of Magnastriatites howardi and Cyperaceaepollis sp., indicating high terrestrial influx and humid conditions.

3200–3210 m: Increased diversity with both freshwater and brackish taxa (*Pachydermites diederixi, Verrucatosporites farvus*), suggesting fluctuating salinity.

3230–3250 m: Low counts of dinoflagellate cysts and spores but consistent presence of *Lycopodiumsporites* sp. and *Echiperiporites estelae*, marking transition towards more continental influence.

This variation in abundance and diversity reflects alternating terrestrial and marginal marine conditions typical of the deltaic settings of the Niger Delta.

Age Determination

This study emphasizes Cenozoic sediments, palynological evidence from the identified marker taxa (*Cyperaceaepollis* sp, *Magnastriatites howardi*, and *Elaeis guineensis*) indicates an Early Miocene age (Aquitanian–Burdigalian). This suggests possible reworking of younger Quaternary deposits. However, the recovered assemblage aligns well with Early Miocene palynofloral zones established by Evamy *et al*. (1978) [3] and Germeraad *et al*. (1968).

Paleoenvironmental Interpretation

The co-occurrence of mangrove, freshwater, and terrestrial pollen with minor marine dinoflagellate cysts suggests deposition in a marginal marine to deltaic environment. The abundance of Zonocostites ramonae (mangrove pollen) and Elaeis guineensis (freshwater swamp pollen) supports a nearshore deltaic setting influenced by alternating marine transgression and fluvial discharge.

1. **High terrestrial influx:** Indicated by Magnastriatites howardi and Polypodiaceiosporites species.
2. **Marine influence:** Suggested by the presence of Tuberculodinium vancampoae and other dinocysts.
3. **Environmental implication:** The alternation between marine and terrestrial species implies deposition under fluctuating sea-level conditions, consistent with the progradational cycles of the Niger Delta during the Miocene.

Discussion

The palynological assemblage is consistent with known Miocene palynofloral zones of the Niger Delta. The dominance of *Zonocostites ramonae, Elaeis guineensis*, and *Magnastriatites howardi* reflects humid tropical conditions and supports the reconstruction of a lowland deltaic system dominated by mangrove and freshwater swamp vegetation.

The moderate abundance of marine palynomorphs (dinocysts) and brackish species indicates periods of marine transgression. These alternating signals reflect sedimentation during a time of sea-level fluctuations, likely controlled by climatic and tectonic processes active in the Niger Delta basin during the Early Miocene.

The results provide a robust framework for both biostratigraphic correlation and paleoenvironmental reconstruction, aligning with regional studies that describe the Niger Delta as a dynamic, deltaic complex with cyclic transgressive–regressive sedimentation patterns.

Conclusion

This study focused on the qualitative and quantitative analysis of ditch cuttings obtained from depths of 3160–3250 m within a selected Offshore well in the Niger Delta Basin. This study detailed a lithologic description, which revealed alternating fine-grained sand and shale units typical of deltaic environments. A non-acid (salt) preparation method following Riding and Hughes (2004) [8] was employed for palynological processing. This technique, involve Sodium-hexametaphosphate as a dispersant, ensured efficient recovery and preservation of delicate palynomorphs while avoiding the destructive effects of strong acids. Ten samples were analyzed using a binocular palynological microscope, and representative species were photographed for documentation.

The palynological investigation yielded a rich and diverse assemblage of microfossils, including pollen grains, spores, fungal spores, and dinoflagellate cysts. The most abundant and environmentally significant taxa include *Zonocostites ramonae, Elaeis guineensis, Magnastriatites howardi, Retibrevitricolporites protrudens, Cyperaceaepollis sp*, and *Racemonocolpites hians*. Preservation was generally moderate to good, indicating minimal oxidation and favorable depositional conditions. Quantitative counts revealed variation in palynomorph abundance with depth interval between 3180 m and 3210 m recorded the highest concentration of taxa, while upper and lower sections exhibited slightly lower recovery, reflecting subtle changes in sediment input, energy, and depositional setting.

Paleoenvironmental interpretation based on species composition suggests deposition in a marginal marine to nearshore deltaic environment influenced by alternating marine transgressive and fluvial regressive phases. The

abundance of mangrove and freshwater swamp indicators such as *Zonocostites ramonae* and *Elaeis guineensis* reflects humid tropical conditions and proximity to the shoreline. Occasional marine dinoflagellate cysts signify periodic marine incursions, consistent with sea-level fluctuations and sedimentary cycles characteristic of the Niger Delta Basin. These findings align with the region's known depositional history of alternating regression and transgression controlled by climatic and tectonic factors.

The integration of qualitative species identification with quantitative abundance analysis enhanced the resolution of biozonation and improved the accuracy of environmental interpretation.

Conclusion

The study successfully demonstrated the effectiveness of integrated qualitative and quantitative biostratigraphic methods in reconstructing the depositional and paleoenvironmental history of the Niger Delta. The palynological investigation of 3160-3250 m revealed a moderately diverse and well-preserved assemblage dominated by mangrove and freshwater swamp pollen, supported by minor marine elements, indicating deposition in a marginal marine to deltaic environment under warm, humid tropical conditions.

Biostratigraphic analysis identified key marker taxa (Cyperaceaepollis sp., Elaeis guineensis, Magnastriatites howardi, and Zonocostites ramonae), which correlate with the Early Miocene palynofloral zones rather than the Quaternary, suggesting that the studied sediments are older than initially assumed or may include reworked components. This highlights the need for careful field-level correlation and potential integration of radiometric dating techniques in future studies.

The research underscores the importance of combining lithologic data with fossil abundance statistics to achieve more precise interpretations of depositional environments. The observed alternation of terrestrial and marine palynomorphs signifies dynamic deltaic processes controlled by sea-level fluctuations, sediment supply, and climatic variation. These insights provide a useful reference framework for refining regional stratigraphic correlations and for ongoing paleoenvironmental and hydrogeological assessments within the Niger Delta.

This study therefore contributes meaningfully to the understanding of the biostratigraphy and paleoenvironmental evolution of the Niger Delta Basin. It bridges existing gaps in the Quaternary and Neogene stratigraphic record and demonstrates that the application of modern quantitative palynological techniques can significantly improve the accuracy and reproducibility of biostratigraphic interpretations in tropical deltaic settings.

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