

Palynological Biostratigraphy and Depositional Environment of AFOB-02 and AFOB-03 Wells, Greater Ughelli Depobelt, Niger Delta, Nigeria

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Abstract: This study involved the palynological study of AFOB-02 and AFOB-03 wells in the Greater Ughelli Depobelt of the Niger Delta basin of Nigeria. A total of 39 samples were analyzed from the depth of 3920–5690 feet for AFOB-02 and 4200–10920 feet for AFOB-03. Ditch cuttings from both wells were subjected to standard procedure for palynological studies. The lithology of both wells is composed of alternation of muddy sands and sandy mudstones, characteristic of the Agbada Formation in the Niger delta. The flora assemblage of AFOB-02 correlates with the broad Pan - tropical *Crassoretitriletes Vanraadshooveni* – *Echitricolporites spinosus* Zone/P600 Zone. The P600 Zone was subdivided into P670 subzone with sub zonal top of this zone marked by the quantitative base occurrence of *Pachydermites diderixi* and co-occurrence of *Brevicolporites guineti*, *Zonocostites ramonae*, *Monoporites annulatus*, *Laevigatosporites* sp., *Verrucatosporites* sp. and *Tillia Americana*, dated Early Miocene; and P680 subzone with the sub zonal top marked by the abundant occurrence of *Racemonocolpites hians* and co-occurrence of *Laevigatosporites* sp., *Arecipites exilimuratus*, *Inaperturopollenites* sp. and the brackish water swamp algae *Botryococcus braunni* and dated Middle Miocene; while the AFOB-03 correlates with the *Magnastriatites howardi* – *Echitricolporites spinosus* Zone/P600 Zone which was subdivided into the P630 subzone with the top marked by the acme/increase occurrence of *Praedapollis flexibilis*, co-occurrence of *Acrostichum aureum*, *Brevicolporites guinetti*, *Polypodiaceoisporites* sp. and *Monoporites annulatus*; and dated Early-Middle Miocene; P650-670 subzone marked at the top by the quantitative base occurrence of *Pachydermites diderixi* and other palynoflora such as *Polypodiaceoisporites* sp., *Sapotaceoidaepollenites* sp., *Laevigatosporites* sp., *Verrucatosporites* sp., *Podocarpidites* sp., *Peregrinipollis nigericus*, dated Middle Miocene and P680 subzone with the top marked by the abundant occurrence of *Racemonocolpites hians* and the base by the quantitative base of *Pachydermites diderixi*, dated Middle Miocene. From the recovered palynomorph, the sediments of the wells were deposited environments ranging from brackish to marine and nearshore environment.

Key words: Palynomorph • Miocene • Depositional Environment • Agbada Formation • Niger Delta

INTRODUCTION

The studied AFOB-02 and AFOB-03 wells lie within latitude 6°00'N and longitude 5°30'E (Figure 1) and is located within the Greater Ughelli Depobelt of the Niger Delta. The Cenozoic Niger Delta is situated at the intersection of the Benue Trough and the South Atlantic Ocean where a triple junction developed during the separation of South America and Africa in the Late Jurassic [1]. It consists of regressive wedge of clastic sediments reaching maximum thickness of about 12 km and represents the most substantial hydrocarbon province in the West African continental margin and also

ranks as one of the world's major hydrocarbon provinces [2-4]. Palynomorphs have been extremely useful in the study of stratigraphic sequences of rocks and the potential for oil and gas exploration as demonstrated creditably by the oil industry. Because palynomorphs are resistant to decomposition and are produced in great abundance, their recovery from rocks and sediments provides scientists with information needed to describe plant life of past ages. Sowunmi stated that the flora of an area generally provides a good reflection of the major climatic regime of that area, it is hence possible to reconstruct past climates and environments through the study of fossil plants [5]. The source of pollen and spores

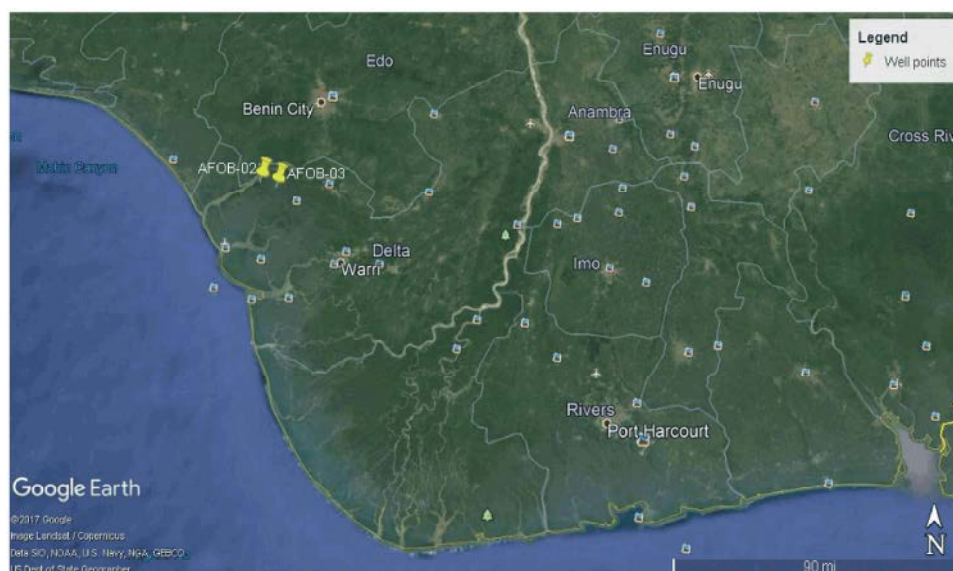


Fig. 1: Map of the study area showing well locations

in the Niger Delta, can be confidently related to the regions transverse by rivers Niger and Benue, which include Sahelian and Sudanian vegetation zones as well as Guinea-Congolian rainforests and the mangrove swamps. Hence, majority of the pollen in the Niger Delta come from the regions north and northeast of the Gulf of Guinea [6].

MATERIALS AND METHODS

Ditch cuttings from AFOB-02 and AFOB-03 wells from which a total of 39 samples were sampled and analyzed from the depth of 3920–5690ft for AFOB-02 and 4200–10920ft for AFOB-03. Palynological analysis followed the standard procedure of the samples being dished/placed equally into well labeled plastic cups at 20grams each and placed in a functioning fume cupboard which served to extract the released dangerous fumes produced during hydrofluoric digestion of samples. Few drops of concentrated Hydrofluoric acid (HF) were applied to each sample in the plastic cups and properly stirred with glass rod. This allowed for the breakage and/or digestion of the silicate components and the digestion allowed to stay overnight. Next day distilled water is added to the samples in the cups, stirred and allowed to stand for about 30-40mins. The upper layer is thereafter carefully decanted leaving the residue in the cup. Carbonates are removed with the aid of hot 10% hydrochloric acid (HCl). The beakers are well labeled and the digested samples are poured gently into the beakers, while 10% HCl applied on the samples each. The beakers

containing the samples are arranged on hot plate and heated for about 25 to 30 minutes. The samples are decanted at interval of 1 hour each 3 times. A 5 micron sieve is then used to filter away the remaining silicates, mud and clay, this is used in collaboration with the Branson sonifier. The sieve also does the work of *heavy liquid separation* (Use of either Zinc Bromide or Zinc Chloride). However, in some cases few drops of warm concentrated HNO_3 is added to remove cellulose materials and to make the slide clearer for analysis. The recovered organic matters are uniformly spotted on arranged cover slips of 22/32mm, then allowed to dry for mounting. The slides were analyzed to obtain the palynomorphs (pollen, spores and dinoflagellates) and the abundance and diversity was plotted using the Strata Bug graphical software. All stratigraphically important taxa are counted throughout.

RESULTS AND DISCUSSION

Sedimentology: From the detailed lithostratigraphic descriptions (Table 1 and 2), the lithologies show the alternation of muddy sands and sandy mudstones, the sandy mudstones are brown to dark grey in colour (Occasionally black to brown), non-fissile, hard and calcareous. The muddy sands are light grey, fine-grained (Occasionally coarse-grained), sub-angular to sub-rounded, well sorted and occasionally ferruginized. According to Short and Stauble, the Agbada Formation is characterized by the alternation of sandstone and sand bodies with shale layers [7]. The sandstone is fine to

Table 1: Sedimentologic description table for AFOB-02

Depth (feet)	Description
3920 - 3980	Muddy Sands: Light grey, medium grained, angular/subangular and very well sorted. Mica flakes are present
4100 - 4130	Sandy Mudstones: Dark grey, hard, calcereous and non-fissile
4220 - 4340	Muddy Sands: Light grey, coarse/very coarse grained, pebbly, subangular/subrounded and moderately well sorted
4400 - 4640	Mudstones: Brown, soft/moderately hard and non-fissile. The accessory minerals present are ferruginous materials and carbonaceous matter
4700 - 5240	Sandy Mudstones: Dark grey, hard, calcereous and non-fissile Ferruginous materials are the accessory minerals present.
5300 - 5330	Muddy Sands: Light grey, medium/coarse grained, subangular/subrounded and moderately sorted. Ferruginous materials are the accessory minerals present.
5390 - 5420	Sands: Light grey, very fine grained, angular and very well sorted
5510 - 5660	Muddy Sands: Light grey, very fine grained, angular and very well sorted. Ferruginous materials are the accessory minerals present.
5660 - 5690	Sandy Mudstones: Brown, moderately hard, calcereous and non-fissile. Carbonaceous matter is the accessory minerals present.

Table 2: Sedimentologic description table for AFOB-03

Depth (feet)	Description
4200 - 4530	Sandy Mudstones: Light/dark grey, hard, calcereous and non-fissile
4860 - 6960	Muddy Sands: Light grey, very fine/fine grained occasionally medium, subangular and moderately well sorted. Carbonaceous matter is the accessory mineral present.
7320 - 8400	Sandy Mudstones: Brown/dark grey, moderately hard and subfissile/non-fissile
8760 - 9480	Muddy Sands: Light grey, fine/medium grained, subangular and moderately well sorted. Carbonaceous matter is the accessory mineral present.
9810 - 10920	Sandy Mudstones: Brown/dark grey, moderately hard and fissile/non-fissile.

coarse grained, predominantly unconsolidated. The alternations of sandstone and shale are the result of differential subsidence, variation in the sediment supply and shifts of the delta depositional axes which cause local transgressions and regressions [7]. The alternations of the sandstone and shale in the studied well intervals (AFOB-02: 3920–5690 feet and AFOB-03: 4200–10920 feet) reveals that it penetrated the Agbada Formation of the Niger Delta. In general, the upper part of the formation has a higher sandstone percentage than the lower part, this demonstrates the progressive, seaward advancement of the Niger Delta through geological time despite the numerous, transgressive sequences found in the Agbada Formation, the Agbada Formation generally is marine [7].

Palynostratigraphy

AFOB-02 Well: Twenty (20) ditch cutting samples were analyzed for palynomorphs. The palynoflora assemblages were moderately abundant, diverse and preserved at most horizons. Thirty-seven (37) palynomorphs species were identified. The assemblage is quantitatively dominated by terrestrially derived forms including: *Zonocostites ramonae*, *Monoporites annulatus*, *Retibrevitricolporites obodoensis/protrudens*, *Retitricolporites irregularis*, *Racemonocolpites hians*, brackish water swamp species, *Psilatricolporites crassus* and *Pachydermites diderixi*. Dinoflagellate cysts were absent.

The flora correlates with the broad Pan - tropical *Crassoretitriletes Vanraadshooveni – Echitricolporites Spinosus* Zone [8]. The sequence also correlates with the P600 Zone [9]. The P600 Zone was subdivided into two Subzones namely P670 and P680 Subzones. The well thus ranges in age from Early Miocene at the base to Middle Miocene at the upper section. Details of the palynological Zones and Subzones recognized are discussed below and are graphically shown in Figure 2 and 3.

Palynostratigraphy, Age and Paleoenvironment: *Crassoretitriletes Vanraadshooveni – Echitricolporites Spinosus* / P600

(i) Sub-zone: P670

Stratigraphic Interval: 4, 910 – 5, 300 feet (TD)

Assigned age: Early Miocene

Diagnosis: The sub zonal top of this zone is marked by the quantitative base occurrence of *Pachydermites diderixi* at 4950ft while the base is tentatively placed at 5, 300 feet, the depth of the last sample analyzed. Other microflora assemblage in this zone includes *Brevicolporites guineti*, *Zonocostites ramonae*, *Monoporites annulatus* and *Pachydermites diderixi*, abundance of *Laevigatosporites* sp. and *Verrucatosporites* sp., lone occurrences of *Tillia Americana* and *Peregrinipollis nigericus*. This assemblage is indicative of a marine and nearshore environment [2].

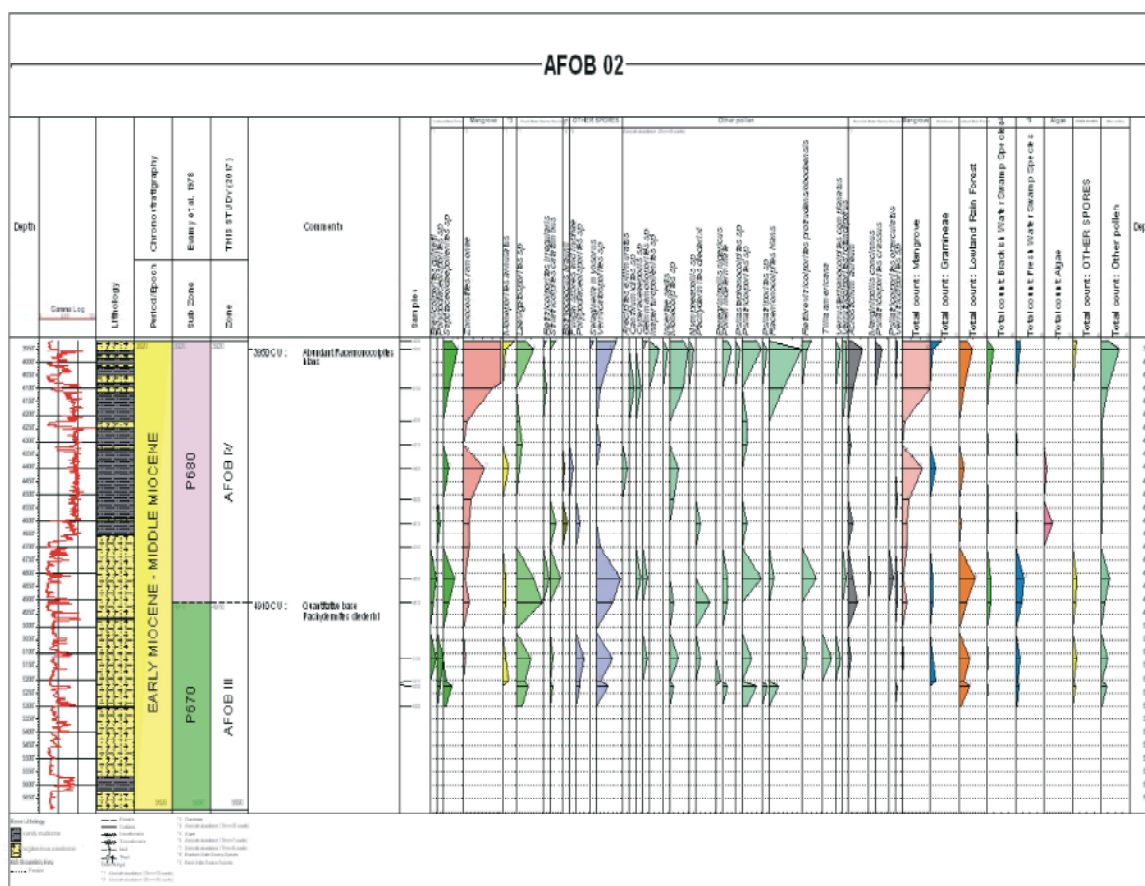


Fig. 2: Palynomorphs distribution chart of AFOB-02 well

(ii) Sub-zone: P680

Stratigraphic Interval: 3,920 - 4,910 feet

Assigned age: Middle Miocene

The sub zonal top is marked by the abundant occurrence of *Racemonocolpites hians* at 3950 feet and the quantitative base occurrence of *Pachydermites diderixi* at 4950 feet defines the base. Other palynoflora recorded within this interval include the abundance of *Monopores annulatus* and *Monocolpites* sp., occurrence of *Laevigatosporites* sp., *Arecipites exilimuratus*, *Botryococcus braunni*. This assemblage is indicative of a marine and nearshore environment [2].

AFOB-03 Well: Nineteen (19) ditch cutting samples were analyzed for palynomorphs. The palynoflora assemblages were moderately abundant, diverse and preserved at most horizons. Forty-seven (47) palynomorphs species were identified. The assemblage is quantitatively dominated by terrestrially derived forms including: *Zonocostites*

ramonae, *Monopores annulatus*, *Acrostichum aureum*, *Retibrevitricolporites obodoensis/protrudens*, *Retitricolporites irregularis*, *Racemonocolpites hians*, brackish water swamp species, *Psilatricolporites* sp. and *Pachydermites diderixi*. *Leiosphaeridia* sp., a dinoflagellate cyst was recovered also.

The flora correlates with the broad Pan - tropical *Magnastriatites howardi* – *Echitricolporites spinosus* Zone [8]. The sequence also correlates with the P600 Zone [9]. The P600 Zone was subdivided into three Subzones namely P630, P650-670 and P680 Subzones. The well thus ranges in age from Early Miocene at the base to Middle Miocene at the upper section. Details of the palynological Zones and Subzones recognized are discussed below and are graphically shown in Figure 4 and 5.

Palynostratigraphy, Age and Paleoenvironment: *Magnastriatites howardi* – *Echitricolporites Spinosus* / P600.

DEPTH (FEET)	EPOCH / SERIES	SUB-EPOCH / SUB-SERIES	AGE / STAGE	GERMERAAD (<u>et al.</u> 1968)	Evamy <u>et. al.</u> (1978)		This study 2017	BIODATUM REMARKS
					ZONE	SUBZONE		
3920 3950	MIOCENE	EARLY-MIDDLE MIOCENE	BURDIGALIAN-LANGHIAN	CRASSORETITRILETES VANRAADSHOOVENI – ECHITRICOLPORITES SPINOSUS	P600	P680	AFOB-IV	→ Abundant <i>Racemonocolpites hians</i>
4910						P670	AFOB-III	→ Quantitative base <i>Pachydermites diderixi</i>
5300TD								

Fig. 3: Palynological zones identified in the AFOB-02 Well

(1). Sub-zone: P630

Interval: 8, 400 – 10, 920 feet (TD)

Assigned age: Early – Middle Miocene

The sub zonal top of this zone is marked by the acme/

increase occurrence *Praedapollis flexibilis* at 8, 400 feet while the base is tentatively placed at 10, 920 feet, the depth of the last sample analyzed. Other microflora assemblage in this zone includes *Laevigatosporites* sp.,

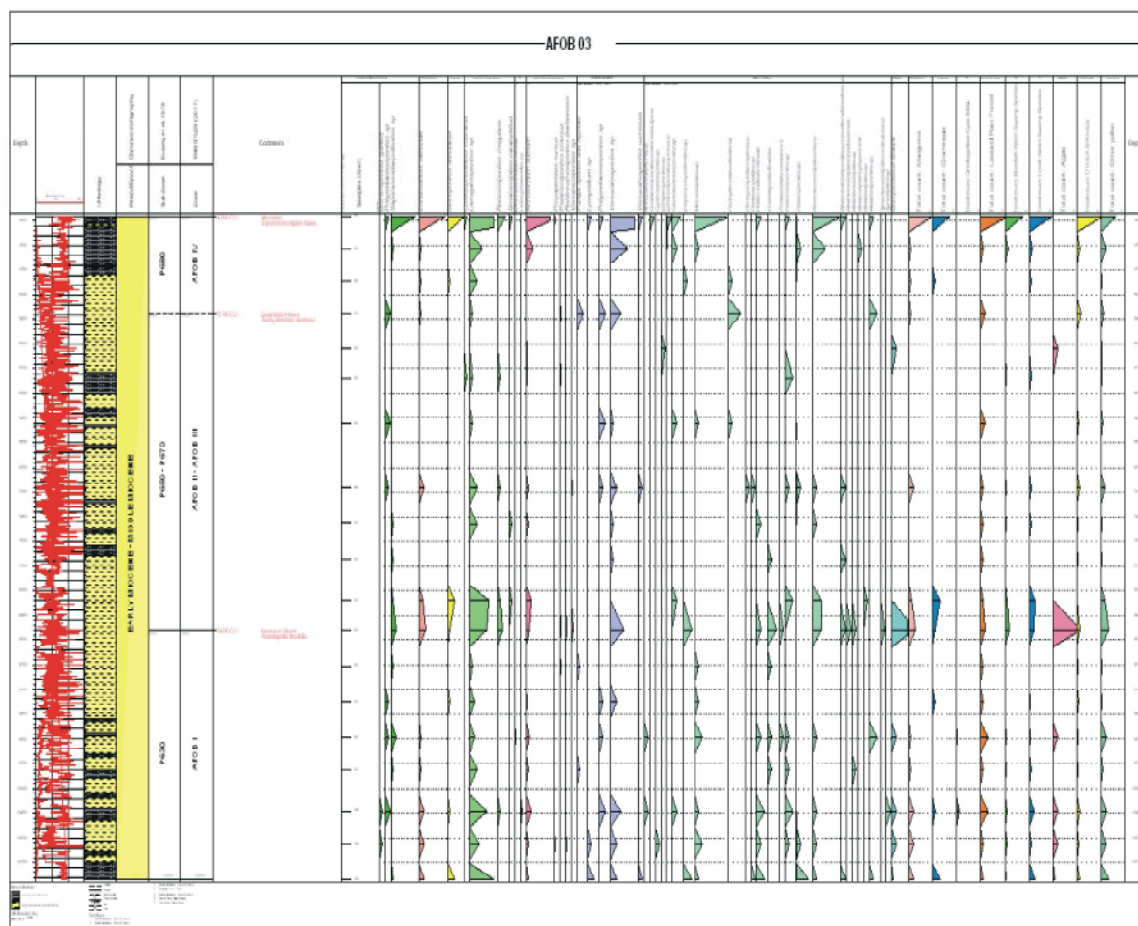


Fig. 4: Palynomorphs distribution chart of AFOB-03 well

Zonocostites ramonae, *Verrucosporites* sp., *Acrostichum aureum*, *Brevicolporites guinetti*, *Polypodiaceoisporites* sp. and *Monoporites annulatus*. This assemblage is indicative of an estuarine or brackish water environment [2].

(2). Interval: 5, 190 – 8, 400 feet

Assigned age: Middle Miocene

Sub-zone: P650 – P670

The sub zonal top is marked by the quantitative base occurrence of *Pachydermites diderixi* at 5, 190 feet and acme/increase occurrence of *Praedapollis flexibilis* at 8, 400 feet. Other palynoflora recorded within this interval include *Polypodiaceoisporites* sp., *Sapotaceoidapollenites* sp., *Laevigatosporites* sp., *Verrucosporites* sp., *Podocarpidites* sp., *Peregrinipollis nigericus*, *Praedapollis flexibilis* and the algae *Botryococcus braunii*. This assemblage is indicative of a deposition in environments fluctuating between marine and nearshore environment [2].

(3). Interval: 4, 200 – 5, 190 feet

Assigned age: Middle Miocene

Sub-zone: P680

The sub zonal top is marked by the abundant occurrence of *Racemonocolpites hians* at 4, 200 feet and the base by the quantitative base of *Pachydermites diderixi* at 5, 190 feet. Other palynoflora recorded within this interval include *Sapotaceoidapollenites* sp., *Zonocostites ramonae*, *Monoporites annulatus*, *Laevigatosporites* sp., *Acrostichum aureum*, *Monocolpites* sp., *Verrucosporites* sp., *Verrucosporites usmensis*, *Psilatricolporites* sp., *Psilatricolporites* sp., *Retibrevitricolporites protrudens/odosoensis*, *Retitricolpites gageoneti* and *Retitricolporites* sp. This assemblage is indicative of a deposition in environments fluctuating between marine and nearshore environment [2].

DEPTH (FEET)	EPOCH / SERIES	SUB-EPOCH / SUB-SERIES	AGE / STAGE	GERMERAAD (1968)	Evamy et al. (1978)		This study 2017	BIODATUM REMARKS
					ZONE	SUBZONE		
4200	MIOCENE	EARLY - MIDDLE MIOCENE	AQUITANIAN - LANGHIAN	MAGNASTRIATITES HOWARDI - ECHITRICOLPORITES SPINOSUS	P600	P680	AFOB-IV	→ Abundant <i>Racemonocolpites hians</i>
5190						P650 - P670	AFOB-II - AFOB-III	→ Quantitative base <i>Pachydermites diderixi</i>
8400						P630	AFOB-I	→ Acme/increase occurrence <i>Praedapollis flexibilis</i>
10920TD								

Fig. 5: Palynological zones identified in the AFOB-03 Well

**PLATE 1
AFOB-02**

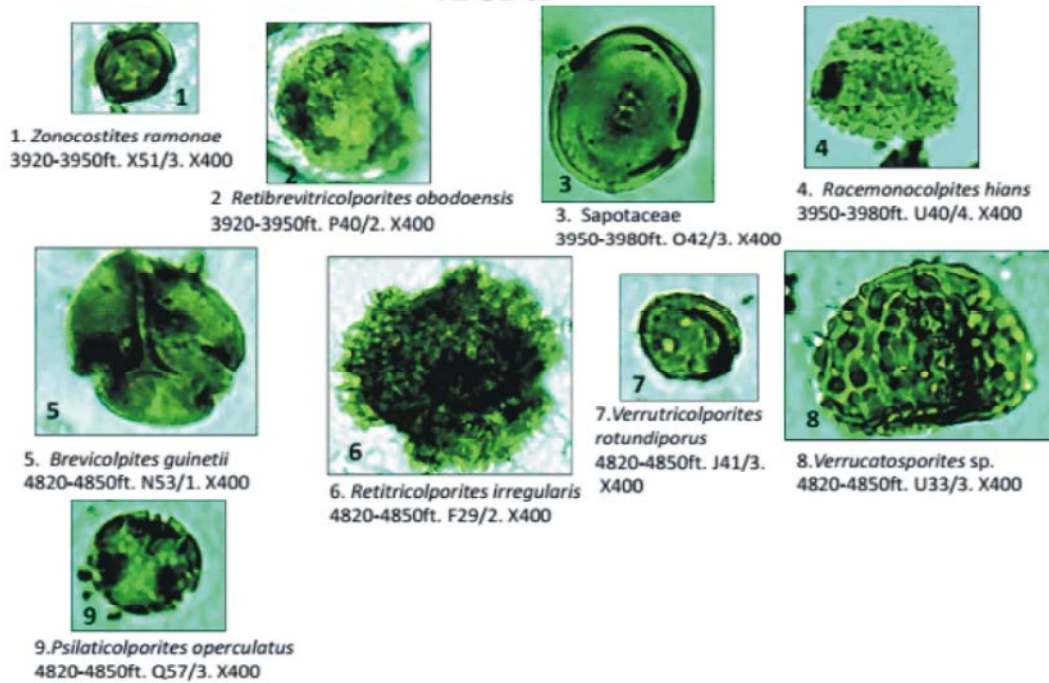


Plate 1: Some of the palynomorphs recovered from AFOB-02 Well

**PLATE 2
AFOB-03**

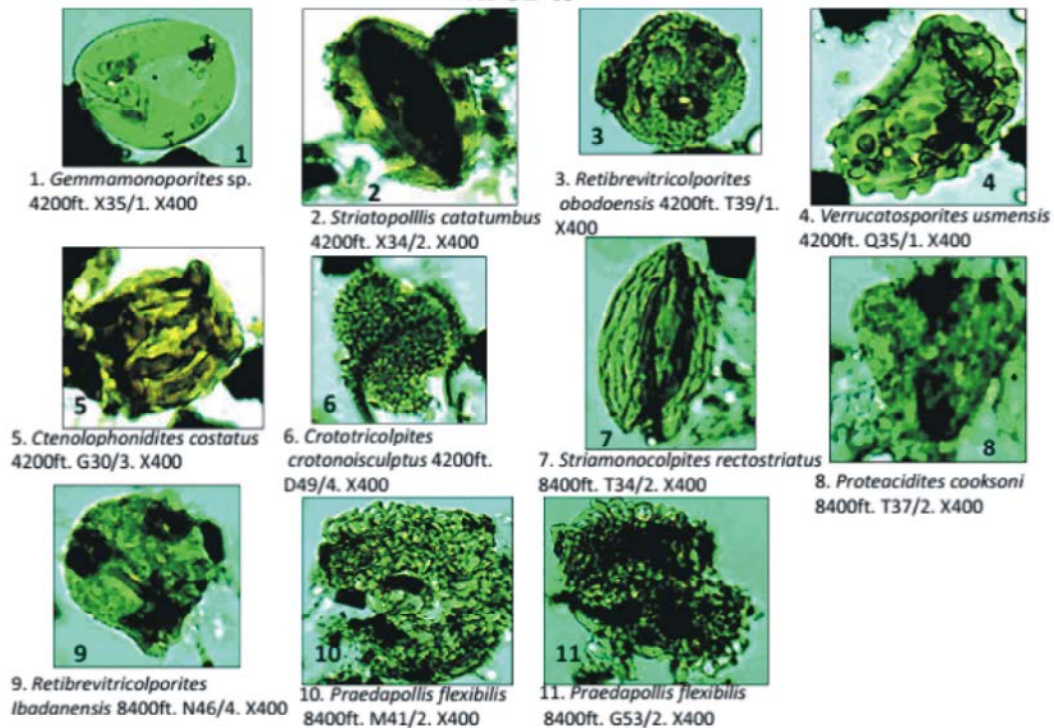


Plate 1: Some of the palynomorphs recovered from AFOB-03 Well

CONCLUSION

This study was carried out on ditch cutting samples from AFOB-02 and AFOB-03 wells drilled in the Greater Ughelli Depobelt of the Niger Delta basin of Nigeria. The studied depth interval ranges from 3920 feet to 5690 feet for AFOB-02 and 4200 feet to 10920 feet for AFOB-03.

The lithology of both wells is composed of alternation of muddy sands and sandy mudstones, revealing nine lithostratigraphic units for AFOB-02 and five lithostratigraphic units for AFOB-03, characteristic of the Agbada Formation in the Niger delta.

The flora assemblage of AFOB-02 correlates with the broad Pan - tropical *Crassoretitriletes Vanraadshooveni* – *Echitricolporites Spinosus* Zone. The sequence also correlates with the P600 Zone. The P600 Zone was subdivided into two Subzones namely P670 and P680 Subzones, while the AFOB-03 correlates with the *Magnastriatites howardi* – *Echitricolporites spinosus* Zone. The sequence also correlates with the P600 Zone. The P600 Zone was subdivided into three Subzones namely P630, P650-670 and P680 Subzones.

The observed palynofloral assemblages indicate that the sediments of the wells were deposited in a range of environment viz: brackish to marine and nearshore environment, also dated as Miocene. The alternation of sandstone and shales/mudstones within the sequence provides the combination of source, reservoir and cap rocks essential for hydrocarbon generation, accumulation and trapping.

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