Palynomorphs and Age Characterization of Rock Succession in Well X-1, OML 108, Offshore Niger Delta Nigeria

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Authors’ contributions

This work was carried out in collaboration between both authors. Author ANA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author SEO managed the analyses of the study. Both authors read and approved the final manuscript.

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ABSTRACT

Palynological studies in Nigeria are mainly confined to the Tertiary Niger Delta, where several studies have been carried out for the discovery of natural oil and gas in this particular basin during late 1950s. The accuracy and profitability of the exploration process can be enhanced by the micropaleontological monitoring through the palynological analysis of ditch cuttings for age determination. Fifty ditch cutting samples from intervals 8040 ft and 11010 ft of Well X-1, OML 108, Ukpeokiti field, offshore Niger Delta Nigeria were analyzed for their palynofloral content, in a view to establish the biozonation framework for the purpose of age characterization of the rock succession. Palynological sample processing and analysis followed standard methods of treatments with different concentrations of Hydrochloric acid, Hydrofluoric acid and organic acid for digestion of carbonates, removal of silicates and washing or centrifuging for concentration of the palynomorphs respectively in order to liberate the palynomorphs from the extraneous organic matter in the rock matrix. The palynofloral analysis yielded a total number of forty-three (43) pollen, seven (7) spores and one dinoflagellate cyst, from which four subzones based on palynofloral assemblage of marker species, their stratigraphic tops and base including their abundance and diversity were recognized.

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The zones are from youngest to oldest: Stereisporites sp, Racemonocolpites hians, Verrutricolporites rotundiporus and Retibrevitricolporites obodoensis/protundens zones corresponding with pollen sub zones: P850-830, P820, P780 and P770 respectively, indicating Late Miocene to Middle Miocene age.

In conclusion, the palyno-zones of this study compare well with the pollen zones of [3], therefore shows that the rock succession was deposited during the Middle to Late Miocene epoch.

Keywords: Palynoflora; zonation; age; Miocene; Niger Delta; ditch cuttings; offshore.

1. INTRODUCTION

This study seeks to establish the biozonation framework and age of the rock succession from fifty (50) ditch cutting rock samples between intervals 8040 ft and 11010 ft of Well X-1, OML 108, Ukpokiti field, offshore Niger Delta Nigeria (Fig. 1). In order to breakdown the matrices of rock samples, digest and separate all inorganic components of rock samples to maximize the yield of insoluble organic matter components, the samples were treated with different concentrations of acids using standard methods of palynological sample procedure.

1.1 Previous Palynological Studies

Although much palynological works have been carried out in the Niger Delta basin, there is little published information available due to confidentiality maintained by oil companies operating in Nigeria however, the palynology of the of the Tertiary Niger Delta has attracted the attention of several workers as: [1,2,3,4,5,6], among others. Evamy et al. [3], erected the pollen zones of the Niger delta published in the Niger delta chronostratigraphic chart which has been used to correlate rocks from Niger delta and adjacent basins. Olajide et al. [7], recovered Miospores from sediments from Bog-1 well in the Niger Delta basin. They assigned Late Oligocene-Mid Miocene age based on the co-occurrence of pantropical stratigraphic markers such as Zonocostites ramonaee, Retimomoclist spluribaculatus, Retibrevitricolpites protundens, Psilatricolporites Crassus, Circatricosisporites dorogensis, Retitricolporites irregularis, Race-monocolpiteshians, Pachydermites diederixi, Brevicolporites guinetii, and Proxapertrites cursus.

Ige [8], studied the Vegetation and Climatic History of the Late Tertiary Niger delta, based on Pollen. [9], studied the Late Miocene to Early Pliocene palynostratigraphy and Paleo environment of ANE-1 Well, Eastern Niger delta and placed the Miocene/Pliocene boundary with the First Appearance Datum (FAD) of Nymphaeapollis clarus and increase in Monoporites annulatus. They also concluded that the environment of deposition of the studied interval varies from coastal to marginal marine and used foram test linings to subdivide the macro environments into coastal deltaic, coastal deltaic to inner neritic, and inner neritic environments. [10], used the ditch cuttings and outcrops of Anambra and Niger-Delta Basin penetrated by Bende-1 well to describe the lithostratigraphy, paleoecology, paleobathymetry,

Fig. 1. Location of the study area block (OML, 108) Offshore Niger Delta
depositional environment and the relative age. [11], worked on palynostratigraphic analysis of the Agbada formation (NEP-1 Well) Offshore Eastern Niger Delta basin. They analyzed thirty-six composite ditch cutting samples and proposed three palynological zones: *Echiperiporites estelae*, *Psilatricolpites Okeizei* and *Foevoetricolpites* sp and assigned a Late Miocene to Early Pliocene age for the sediments. [12], used sporomorph assemblage from the lignite and carbonaceous shale at oyivo quarry around umuahia to assign Oligocene to Early Miocene Age to the sediments. They noted that the deposits belong to the Ogwashi-Asaba Formation and were deposited in Upper to Lower deltaic environment. [13], worked on the Palynological Investigation of Oligocene - Lower Miocene Sediments in Well z, offshore Niger Delta, Nigeria. They erected nine palynological zones and correlated with [3], to delineate Oligocene to lower Miocene age for the sediments.

1.2 Basin Stratigraphy

The propitious Niger Delta geology has been fairly studied since the discovery of oil in this basin in 1958. Among the workers are [14,15,16, 17,18,19,6], among others.

The Niger Delta is located on the continental margin of the Gulf of Guinea in Equatorial West Africa. It is located at the southern margin of Nigeria between latitudes 03° and 06°N and longitudes 005°E and 008°E. The Niger Delta province is delineated by Benin and Calabar hinge lines at the northwestern and eastern boundaries of the delta respectively, while the Gulf of Guinea borders the Niger Delta basin in the south and the base of the Benue Trough, Anambra Basin and Abakaliki High mark the northern boundary [20].

Three main lithostratigraphic units recognized and delineated in the Niger Delta are the Akata, Agbada and Benin Formations. These reflect a complex mixture of marine, fluvio-marine, littoral and deltaic plain environment in a coarsening upward sequence.

The Akata Formation is the basal sequence about 600 m thick, characterized by uniform shale development and the shale is generally dark grey, with alternation of sand and silt at the upper part with plant remains and mica flakes. The age of this formation spans from Palaeocene-Recent and it is the major source of hydrocarbon in the Delta. Overlying the basal marine unit is the paralic Agbada Formation, which is made up of alternating sandstone, siltstone and shale. The Formation is about 4500 m thick. The percentage of sand increases upward while that of shale increases downward. This indicates a cyclic sequence of fluvial and marine deposits. This Formation extends throughout the Niger Delta subsurface and is the most explored unit. The age of Agbada Formation decreases from north to south, from Eocene to possibly Recent and is the hydrocarbon prospective sequences in the Niger Delta.

Benin Formation is the topmost and most shallow part of the deltaic clastic wedge. According to, the Formation can be easily recognized based on its high sand percentage (70% -100%). This continental deposit has a few shale intercalations and thickness of about 200m with age of Oligocene in the north and becomes progressively younger southward (Fig. 2). The Niger delta province is a prolific and a well-known petroleum system, where hydrocarbon is produced from rocks (sandstone and unconsolidated sands) of Eocene to Pliocene age in the onshore areas and from Pliocene to Pleistocene sedimentary units in the offshore sections, with expected production from the flanks of Cretaceous rocks.

2. MATERIALS AND METHODS

Materials: materials used are sieves, distilled water, water jet, kerosene, aluminum bowls, liquid soap, hotplate, phials etc.

Palynological Sample Preparation Procedure:

In order to completely digest and separate all inorganic components of rock samples to maximize the yield of insoluble organic matter components, the samples were treated with organic acids to breakdown the matrices of rock samples, to separate heavy liquids and oxidize the samples to maximize the potential for recovery. All treatments followed standard (published and unpublished) methods and techniques.

A total number of fifty (50) ditch cutting samples between interval 8040 ft and 11010 ft of well X-1 were subjected to these treatments. Two commonly used acids for this procedure were
hydrochloric acid and hydrofluoric acids. The following stages were followed for the treatments:

1. Samples were laid out sequentially in batches and composited. 20 gms of sample were weighed into a 250 ml plastic beaker (10 gm or 7 gm for each component of a composite sample).
2. 10% HCL was added drop wise until beaker was quarter filled, stirred with a glass rod and left to stand for about 2 hours. There was an effervescence, the process was discontinued for about 5 minutes until reaction completely subsided by adding water.
3. Water was added allowed to settle and decanted and washed. (washing was generally done with water for normal samples and alcohol for oil based samples to remove excess hydrocarbon from residue, thus, washing medium was added to the sample either in the beaker or test tube stirred properly and either leave to settle or centrifuge to concentrate the palynomorphs, drained out medium and repeated for two times).
4. Concentrated HF (60%) was added drop wise until beaker was quarter filled and stirred continuously for 5 minutes with a PVC rod and left to stand in the fume cupboard overnight.
5. Beakers were filled up with distilled water, stirred, and left to stand till the sample settled and water was decanted.
6. Residue were put into a labeled 25 ml glass beaker, 50 ml 36% HCL was added and placed on a hot plate and left to boil.
7. It was Removed from heat and left to cool, the beaker was filled up with distilled water, stirred, left to settle and decanted and washed.
8. Residue was decanted into a labeled test tube and centrifuged at 2,000 RPM for 5 minutes.
9. The test-tube was filled to three quarter with Zinc chloride, covered, inverted and shaken thoroughly, then centrifuged at 1,600 RPM for 10 minutes.
10. Floating material were decanted into another labeled glass test tube.
11. Step 10 was repeated and floating materials were decanted into the same test tube.
12. Test tube was filled with 0.5% HCL and shaken properly, centrifuged at 1,600 RPM for 10 minutes. Decanted and repeated twice with 0.5% HCL, third time with distilled water and lastly with alcohol.

13. Residue was decanted into Pyrex glass funnel of the pressure unit and filtered with a 10mm Nylon Sieve.

14. Residue was transferred to beaker from sieve, then centrifuged in a phial.

15. Three drops of soffranin stain was added to the residue and stirred for uniform mixing. The residue was pipetted into cover slips numbered and spread on top of hot plate and evaporated to dryness. The uniform spotting type was used to ensure even distribution of Palynomorphs.

16. Few drops of Norlant (mounting medium) were put on dully labeled glass slides and mounted on cover slips.

17. The slides were dried in the sun for 5 minutes after which they were ready for microscopic examination.

18. Palynomorph analysis was carried out by determining Palynomorph specimens to the specific level and/or generic level, using a Trinocular Biological Microscope.

3. RESULTS AND DISCUSSION

3.1 Results

The palynofloral analysis yielded a moderate recovery of palynomorphs dominated by land-derived species like the brackish water, *Acrostichum aureum*, *Psilastephanocolporites sapataeae*, *Gemmanomonopites sp.*, *Psilatricolporitescrassus*, *Retitricolporites irregularis*, *Psilatricolporites sp.*, *Crassoretitritlesvanraadshooveni*, *Verrutricolporites rotundiporus*, *Nymphaea pollis clarus*, *Cyperaceaepollis sp.* and *Racemonocolpiteshians*. Other palynomorphs recorded in high proportion include, *Monoporites annulatus*, *Zonocostitesramonae*, *Retibrevitricolporitesbodoensis/protundens* pteridophyte spores like *Laevigatosporites* sp. And *Verrucatosporites* sp. A significant number of *Botryococcus brauni* and Fungal spores were also recorded. A total number of forty-three (43) pollen, seven (7) spores and one dinoflagel late cyst were recovered. The Palynomorph distribution, abundance and diversity chart of the recovered forms together with the Palynomorph zones recognized are presented in Fig. 3, and some of the photomicrographs of the recovered forms are presented in Plate 1.

3.1.1 Plate 1

*Canthium* sp (coordinate: n55/4, depth: 8610) 2. *Crassoretitritlesvanraadshooveni* (coordinate: t56/3, depth: 9930) 3. *Cyperaceaepollis sp* (coordinate: s49, depth: 10,650) 4. Fungal spore (coordinate: q37/1, depth: 9930) 5. *Gemmanomonopites sp* (coordinate: j45/3, depth: 8,310) 6. *Multiareolitesformosus* (coordinate: v40/4, depth: 8310) 7. *Monoporitesannulatus* (coordinate: k38/1, depth: 8,190) 8. *Laevigatosporites* sp (coordinate: v36/4, depth: 8190) 9. *Polyadopollenitesvancampoi* (coordinate: f32/3, depth:) 10. *Peregrinipollisnigericus* (coordinate: q46/2, depth: 8430) 11. *Nymphaeapollicoscluarus* (coordinate: k44/2, depth: 9090) 12. *Racemonocolpiteshians* (coordinate: i56/3, depth: 9090) 13. *Pachydermittesdiederiki* (coordinate: p51/2, depth:) 14. *Polypodiceoisporites* sp (coordinate: n42/2, depth: 9990) 15. *Proteaciditescooskoni* (coordinate: o28/2, depth: 9930) 16. *Retitricolporate* sp (coordinate: k38/2, depth: 8,310) 17. *Psilastephanocolporitesspatataeae* (coordinate: k46/2, depth: 9930) 18. *Retibrevitricolporitesbodoensis* (coordinate: w54/1, depth: 8,310) 19. *Acrostichumaureum* (coordinate: p27/4, depth: 8820) 20. *Striaticolporitescatatumbus* (coordinate: v41/1, depth: 8,310) 21. *Steresiporites sp* (coordinate: u37/3, depth: 8190) 22. *Verrucolporitesrotundiporus* (coordinate: r30/1, depth: 10,530) 23. *Strianocolpitesrectostriatus* (coordinate: m44/4, depth: 10,110) 24. *Verrucatosporites* sp (coordinate: g50, depth: 8250).

3.2 Discussion

3.2.1 Palynomorph zonation

Palynological zonation of the Well is largely based on palynofloral assemblage of significant species as well as their stratigraphic distribution with reference to the zonation scheme of [3]. The section of the Well analyzed has been broadly assigned to the P800 and P700 palynological zones of [3]. The zones were further subdivided into the P850 -830, P820, P780 and P770 subzones recognized based on the following criteria: Top Occurrence of chronostratigraphically significant Palynomorph species First Downhole Occurrence (FDO), Base Occurrence of Palynomorph marker species (Last Downhole Occurrence (LDO) and Palynomorph abundance and diversity peaks.
dated with Palynomorph markers species whose stratigraphic ranges are well established in the Niger Delta and worldwide. The definition and the characteristics of the recognized zones are given as follows:

### 3.2.2 Biozone P800

**Subzone: P850 – P830: Stereisporites sp Zone 4:**

- **Interval:** 8,040 – 8,190ft
- **Age:** Late Miocene

**Definition:** This subzone is characterized by Quantitative Base Occurrence of Stereisporites sp at 8,190ft, with low recovery of Psilastephanocolporites sapotaceae and Psilitricolporites crassus. Echiperiporites estalae, Psilatricolporites sp., Retitricolporites sp., Laevigatosporites sp., Verrucatosporites sp., and Retibrevitricolporites obodoensis/protundens has a fairly moderate occurrence in this subzone. High abundant of Monoporites annulatus, Zonocostites ramonae, Fungal spore and Botryococcus braunii also characterized this zone. The paucity of Peregrini pollis nigericus and Cyperaceae pollis sp which are the boundary markers between the P850 and P840, P840 and P830, subzones precluded the delineation of a boundary between the three subzones which indicates Late Miocene age.

**Subzone: P820: Racemonocolpiteshians Zone 3:**

- **Interval:** 8,190 – 8,610ft
- **Age:** Late Miocene

The subzonal top of this interval is defined by Quantitative Base Occurrence of Stereisporites sp. at 8,190ft., while the base is marked by Top Regular Occurrence of Racemonocolpiteshiansat 8,610ft. This subzone is characterized by high percentage of Psilastephanocolporites sapotaceae, Laevigatosporites sp., Polyodiumcosporites sp., verrucatosporites sp., Zonocostites ramonae, Monoporites annulatus and Botryococcus braunii are moderately present.
Table 1. Palynomorph biostratigraphic summary of Well-X1, showing the biozonation and age of the sediments

| Depth (ft) | Epoch/Period          | Age (Ma) | Paly Zones | Significant palynomorph datums                                                                 |
|------------|-----------------------|----------|------------|---------------------------------------------------------------------------------------------|
| 8,040      | First sample analyzed |          |            |                                                                                             |
| 8,040 - 8,190 | Late Miocene         | 6.0 – 9.5 | P850 – P830 | Interval characterized by the Quantitative Base Occurrence of Stereisporites sp at 8190ft. This suggests a Late Miocene age |
| 8,190 - 8,610 | Late Miocene         | 9.5 – 10.51 | P820       | Interval characterized by Quantitative Base Occurrence of Stereisporite ssp. at 8,190ft. and Top Regular Occurrence of R. hians at 8,610ft, indicating a Late Miocene age |
| 8,610 - 9,930 | Late Miocene - Middle Miocene | >10.51 | P770       | Interval characterized by Top Occurrence of Verrutricolporitesrotundiporus at 9,930ft and regular occurrences of Retibrevitricolporitesobodoensis/protundens, Pachydermitesdiederixi, among others. |
| 11,010     | Last sample analysed  |          |            |                                                                                             |
3.2.3 Biozone: P700

Subzone: P780: \textit{Verrucolporitesrotundiporus}

Zone 2:

Interval: 8,610 – 9,930ft.

Age: Late Miocene

The top of this subzone is defined by Top Regular Occurrence of \textit{Racemonocolpiteshians} at 8,610ft. while the base is marked by Top Occurrence of \textit{Verrucolporitesrotundiporus} at 9,930ft. This subzone is characterized by abundance of \textit{Verrucosporite} ssp, \textit{Retibrevitricolporitesbodoensis/ protundens}, \textit{Psilastephanocolporites sapotacea}e and \textit{Psilatricolporitescrassus}. \textit{Acrostichumaureum}, \textit{Psilatricolporites} sp., \textit{Laevigatosporite} ssp., \textit{Zonocostitesramonae}, fungal spore and \textit{Pachydermitesdiederixi} are also present in moderate quantities with a decrease in percentage of \textit{Monoporitesannulatus} species.
Subzone P770: Retibrevitricolporitesobodoensis/protundens zone1

Interval: 9,930 – 11,190ft

Age: Middle Miocene

The subzonal top of this interval is defined by Top occurrence of Verrutricolporitesrotundiporus at 9,930ft., while the base is tentatively placed at 11,010ft., which is the Terminal Depth (TD) of the Well.

This subzone is characterized by regular occurrence of Verrutricolporitesrotundiporus, Retibrevitricolporitesobodoensis/protundens, Pachydermitesdiederixi, Acrostichumaureum, Laevigatosporites sp. And Verrucatosporites sp. Fungal spore are also moderately present.

This zone recorded a decrease in percentage of Monoporites annulatus and Zonocostitesramonae (Table 1) indicating a Middle Miocene age.

4. CONCLUSION

The results of the analysis shows that the studied interval (8,040 – 11,010ft) of well X-1, revealed four palyno-zones from base to top: Retibrevitricolporitesobodoensis/protundens, Verrutricolporitesrotundiporus, Racemonocolpiteshians and Stereisporites zones corresponding with P770, P780, P820 and P830-P650subzonesof [3] respectively, which indicates Middle Miocene to Late Miocene epoch.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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