Miospore Biostratigraphy of Oligocene – Lower Miocene Sediments in Well X, Deep Offshore Niger Delta

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Abstract: ***The miospore biostratigraphy has been carried out on ditch cutting rock samples from Oligocene and Lower Miocene sediments in well X, deep offshore Niger Delta following the standard method of palynological sample processing and analysis. The rock succession is characterised by the alternation of thick black shales and grey shales with thick Medium to coarse grained, fairly well sorted sandstone at the base believed to be turbidite sand of the Upper Akata formation. while the top of the studied interval is more paralic and made of black shales intercalating with medium to coarse grained sandstones and siltstones at intervals characteristically of the paralic Agbada Formation (figure 3). The palynologigal analysis of samples yielded a well preserved and diverse biostratigraphic relevant Miospores among which fifty- nine Miospores were identified. On the basis of the first and last downhole occurrences of these Palynological events, twelve miospore biozones were erected. The zones are from the base to top: Zonocostites ramonae, Inaperturopollenites sp, Striatriculpites pimulus, Pachydermites diederixi, Dualidites laevigatus, Retitricolporites irregularis, Retibrevitricolpites obodoensis, Anacolosidites luteoide, Racemonocolpites hians, Monoporites annulatus, Verrutriculporites rotundiporis, and Magnastiatites howardi. These zones were correlated with the standard palynological biozonation schemes in the area and used it to delineate the Oligocene/Lower Miocene boundary.***

Keywords: Biostratigraphy, Miospores, Age, Zones, Oligocene, Miocene, Niger Delta

1. Introduction

High resolution biostratigraphic framework is fundamental in the design of an effective exploration strategy to reduce the complexities and enhance the degree of reliability and precision in the stratigraphic mapping of the siliciclastic sequences of the Niger delta basin. The area under study is located in the South eastern part of the deep offshore Niger delta within ExxonMobil block in the Niger delta oil mining lease. The aim of the research was to use high resolution biostratigraphy as a tool for the age characterization of the rock succession in one EXXONMOBIL hydrocarbon exploratory well (X), deep offshore Niger delta, Nigeria (figure 1). The main objectives of the research were to study the lithologic characteristics of the rocks in order to determine the lithostratigraphic units penetrated by the well and to erect the biozonation model of the well using pollen and spores as tools and use it to characterize the age of the sediments.

1.1 Niger Delta Stratigraphy

Although the stratigraphy of the Niger Delta clastic wedge has been documented during oil exploration and production, most stratigraphic schemes remain proprietary to the major oil companies operating concessions in the Niger Delta Basin. Stratigraphic evolution of the Tertiary Niger Delta and underlying Cretaceous strata is described by [1]. [2], developed a hydrocarbon habitat model for the Niger Delta based on sequence stratigraphic methods. [3] and [4] described depositional environments, sedimentation and physiography of the modern Niger Delta. The three major highly diachronous lithostratigraphic units defined in the subsurface of the Niger Delta (Akata, Agbada and Benin Formations, Figure 2) decrease in age basinward, reflecting the overall regression of depositional environments within the Niger Delta clastic wedge. The formations reflect a gross coarsening-upward progradational clastic wedge [1], deposited in marine, deltaic, and fluvial environments [5] and [6]. The Akata Formation is the basal unit of the Tertiary delta complex. This lithofacies is composed of shales, clays, and silts at the base of the known delta sequence. They contain a few streaks of sand, possibly of turbiditic origin [7], and were deposited in holomarine (delta-front to deeper marine) environments [5]. This formation is characteristically over pressured and range in age from the Paleocene to Recent. The Agbada Formation overlies the Akata Formation and forms the second of the three strongly diachronous Niger Delta Complex formations. This is the hydrocarbon-prospective sequence in the Niger Delta. As the principal reservoir of Niger Delta oil, the formation has been well studied. The Agbada Formation is represented by an alternation of sands (fluviatile, coastal, and fluviomarine), silts, clays, and marine shales (shale percentage increasing with depth) in various proportion and thicknesses, representing cyclic sequences of offlap units. These paralicclastics are the truly deltaic portion of the sequence and were deposited in a number of delta-front, delta-topset, and fluvio-deltaic environments. (OML) map (Figure, 1).

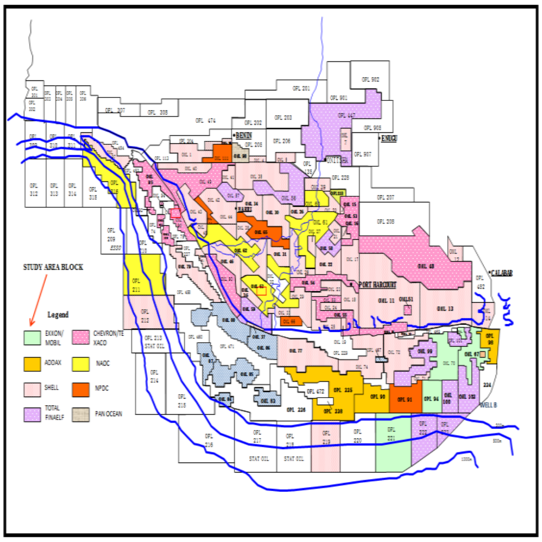

Figure 1: Niger delta oil mining lease (OML) map showing locations of major oil company blocks

The upper part of the Agbada Formation often has sand percentages ranging from 50 – 75%, becoming increasingly sandy towards the overlying Benin Formation. The lower part has less than 40% sand and the shaliness increases downwards and laterally into the Akata Formation. Agbada Formation is overlain by the third formation, the Benin Formation, a continental latest Eocene to Recent deposit of alluvial and upper coastal plain sands that are up to 2000 m thick. This is the freshwater bearing formation in the Niger Delta (figure 2).

1.2 Previous Palynological Studies

Niger delta stratigraphy has been well studied using pollen and spore from Cretaceous to recent sediments in Niger delta and other adjoining sedimentary basins in Nigeria. Among the earlier authors who utilized pollen and spore for age characterization are [8], who discussed the palynology of the Tertiary sediments from tropical areas including South America, West Africa (Nigeria) and Asia. They described and illustrated forty-nine biostratigraphic relevant miospores from which seven pan - tropical zones were erected and used to delineate all geologic boundaries from Maastrichtian to Pleistocene. The zones are from base to top: *Proteacidites dehaani* zone delineating the Maastrichtian sediments; *Proxapertites operculatus* delineating the lower Paleocene to lower Eocene; *Monoporities annulatus* covering the mid Eocene; *Verrucatosporites usmensis* delineating the upper Eocene; *Magnasriatites howardi* of Oligocene to lower Miocene; *Crassoretitriletes vanraadshooveni* delineates the top of lower Miocene and the *Echitriporites spinosus* zone delineating the middle Miocene to Pleistocene intervals. They further subdivided these zones regionally and recognized *Retidiporites magdalenensis* and *Reitibrevitricolpites triangulates* subzones in *Proxapertites operculatus* zone and also recognized *Cicatricosisporites dorogensis* and *Verrucatosporites rotundiporis* subzones in *Magnasriatites howardi* zone. They also compared these zones in Nigeria, Borneo, Caribbean and other areas. The studied interval of the well fall within the *Magnastriatites howardi* zone of [8]. [9] studied some new Eocene pollen of Ogwashi- Asaba Formation in southeastern Nigeria. They systematically described and illustrated forty new Eocene pollen grains attributed to twenty- three genera among which three were originally described. [10], summarized the dinocyst and miospore biozonation models for Maastrichtian-Pleistocene succession of Nigerian sedimentary basins. She erected nineteen informal dinocyst zones and seventeen miospore assemblage zones and compared the dinocyst zones with zonation schemes covering the type Maastrichtian -Pleistocene sections and compared the miospore zones with that of [8].

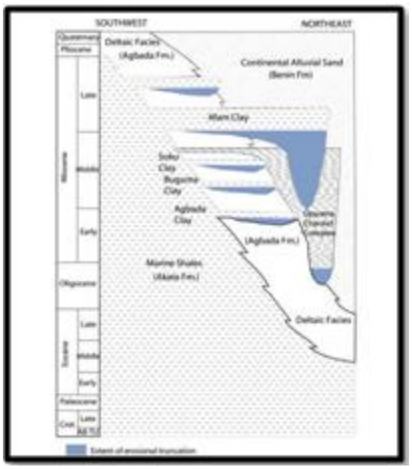

Figure 2: Stratigraphic column showing formations of the Niger Delta Modified from [13] and [14].

[11], erected the pollen zones published in Niger delta geological data table. [12], studied the Late Miocene to Early Pliocene palynostratigrphy and Paleoenvironment of ANE-1 Well, Eastern Niger delta and placed the Miocene/Pliocene with the First Appearance Datum (FAD) of *Nymphaeapollis clarus* and increase in *Monoporites annulatus*.

2. Method of Study

The methods used were the sedimentological analysis and Palynostratigrphy of the ditch cutting rock samples. A total of one hundred and fifty-five (155) ditch cutting rock samples were analyzed texturally and lithologically for his study. The Lithological analysis was done with the aid of the gamma ray log. Variations in the gamma ray log signatures were used in differentiating the lithologic units with high gamma ray log values depicting shale while low gamma ray values corresponds with sandy units. The textural analysis was made by viewing these samples under the microscope with a grain size comparator in order to identify the different rock types penetrated by the well and its variability within succession. The sedimentary structures and associated accessory mineral content of the sediments were also considered within the limit of the available data. In order to recover the palynomorphs from the rock matrix, the ditch cutting rock samples were composited at 30-60 Feet intervals and subjected to standard Palynological sample preparation method involving various acid treatments for the removal of carbonates, silicates, oxidation, washing, concentration of palynomorphs, staining and mounting into microscope slides with subsequent analysis for pollen and spores. A total of one hundred and two (102) slides were made from the well and analyzed for pollen and spores. The analysis involved the identification of the palynomorphs from genus to species level using albums and catalogues of Niger delta palynomorphs and other available useful journals of both local and global importance; recognition and proper counting and study of general distribution of the palynomorphs in the sediments in order to characterize the age of the sediments.

3. Results and Discussions

3.1 Lithostratigraphy

The Litholog of the well is presented in Figure (3). The rock succession is characterised by the alternation of thick black shale and grey shales with thick Medium to coarse grained, fairly well sorted sandstone at the base believed to be turbidite sand of the Upper Akata formation. The top of the studied interval is more paralic and made of black shales intercalating with medium to coarse grained sandstone and siltstone at intervals characteristically of the paralic Agbada Formation (figure 3).

3.2 Biozonation and Age

Palynological analysis yielded well preserved and diverse miospores useful for biostratigraphy among which eighty-eight Miospores (seventy- four pollen and fourteen spores) were identified. On the basis of first and last downhole occurrences of these palynological events, twelve miospore biozones were erected and used to characterize the age of the sediments from Oligocene to Lower Miocene (Figure, 4).

3.2.1 Miospore Biozonation of Well X: The miospore range chart and biozonation of well X, is presented in (figures, 4). The zones are defined from base to top as follows:

Zone (i): *Zonocostites ramonae* zone–Oligocene. The palynological events that define the base of this zone are the last downhole occurrences of *Avicenia* sp, *Zonocostites ramonae, Verrutricolporites rotundiporis, Triorites africaensis* and *Retibrevitricolpites triangulatus.* This corresponds with the base of the studied interval, 12920 ft (Figure, 4). The top of this zone is at 12620 ft and defined by the last downhole occurrences of *Verrucatosporites usmensis, Beskipolis elegans* and first downhole occurrences of *Alsophidites* sp, and *Buttinia adrevi.*

Zone (ii): *Inerperturopollenites* sp zone- Oligocene- The base is defined by the top of zone A, while the top is at 12400 ft and characterized by the first downhole occurrence of *Sonneratia alba, Lycopodium* sp, *Inerperturopollenites* sp, *Cyperacaepollis* sp, *Canthimidites* sp and *Rhizophora mangle;* last downhole occurrences of *Monoporites annulatus, Striatriculpites catatumbus, Triculpites retibaculatus and Ainipollenites versus.*

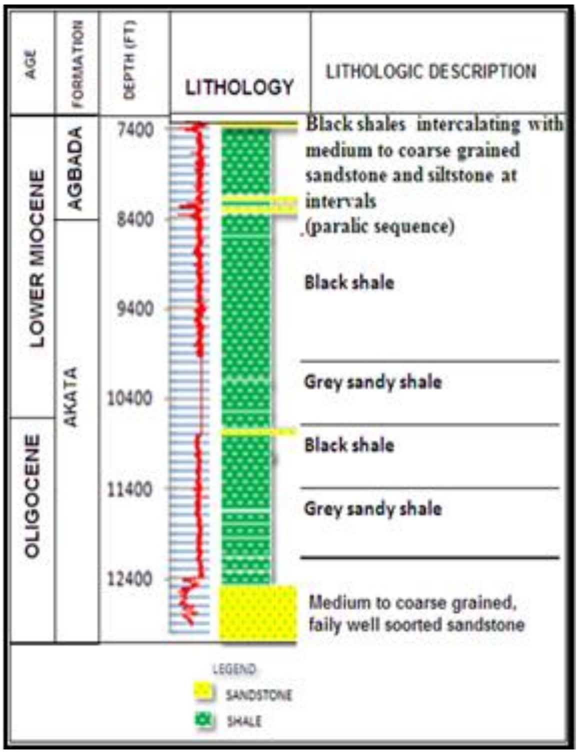

Figure 3: Litholog of well X

Zone (ii): *Inerperturopollenites* sp zone- Oligocene- The base is defined by the top of zone A, while the top is at 12400 ft and characterized by the first downhole occurrence of *Sonneratia alba, Lycopodium* sp, *Inerperturopollenites* sp, *Cyperacaepollis* sp, *Canthimidites* sp and *Rhizophora mangle;* last downhole occurrences of *Monoporites annulatus, Striatriculpites catatumbus, Triculpites retibaculatus and Ainipollenites versus.*

Zone (iii): *Striatriculpites pimulus* zone- Oligocene- The base is the same as the top of zone (ii) while the top is at12240 ft and marked by the first downhole occurrences of *Triorites africaensis* and last downhole occurrences of *Peregrinipollis nigericus, Striatriculpites pimulus* (394), *Echitiporites trianguliformis, Retistephanocolpites gracilis, Psilatriculporites crassus, adenantherine simplex,* and *Avicenia marina.*

Zone (iv): *Pachydermites diederixi* zone- Oligocene- The base is defined by the top of zone (iii), while the top is at 10770ft and characterized by the first downhole occurrences of *Avicenia marina, Mauritidites crassibacculatus,Psilamonocolpites marginatus, Dualidites laevigatus, Gardenia imperalis, Catostema astonii, Proxapertites annisosculpture, Rhizophora apiculata, Tubifloridites antipodica* and the last downhole occurrence of *Pachydermites diederixi, Myrtaceidites* sp, *Cicatricocisporites dorogensis* and *Carryopollenites veripites.*

Zone (v): *Dualidites laevigatus* zone- Oligocene. The base is the same as the top of zone (ii) while the top is at10350 ft. The events that define the top of this zone are: the first downhole occurrences of *Ctenopholon parviforlius, Proxapertiptes cursus, Scaveola plumeri, Compositopollenites rudis, Avicenia marina* and the last downhole occurrence of *Sapotaceoidopollenites* sp,

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Perfoticolprites digitatus (376), *Retitricolporites irregularis, Deltoidospora* sp, *Nympha furiticans*, *Brevicolpites guinetti, Luminitzera littorea, Ilex* sp, and *Retidiporites* sp.

Zone (vi): *Retitricolporites irregularis* zone- lower Miocene. The base is the same as the top of zone (v) while the top is at 10050 ft. The top is characterized by the first downhole occurrences of *Psilatriculporites Crassus, Rostriapollenites robustus, and Adenantherine simplex, Luminitzera littorea, Retibrevitricolpites obodoensis* and the last downhole occurrence of *Retitricolporites* sp, and. *Verrucatosprites* sp.

Zone (vii): *Retibrevitricolpites obodoensis* zone - Lower Miocene. The base is the same as the top of zone (vi) while the top is at 9720 ft. The top of this zone is defined by the first downhole occurrences of *Peregrinipollis nigericus, Verrucatosprites* sp, *Retistephanocolpites williamsi, Retibrevitricolpites obodoensis, Anacolosidites luteoides, Psilatriculporites* sp, and *Cupanidites recticularis.*

Zone (viii): *Anacolosidites luteoide* zone- Lower Miocene. The base is the same as the top of zone (vii) while the top is at 9210 ft and defined by the last downhole occurrences of *Elaesis guineansis* and *Racemonocolpites hians.*

Zone (ix): *Racemonocolpites hians* zone- Lower Miocene The base is the same as the top of zone (viii) while the top is at 8970 ft. The top is defined by first downhole occurrence of *Ainipollenites versus, Striatriculpites pimulus* (394), *Echitiporites trianguliformis, Retistephanocolpites gracilis, Aletesporites* sp, *Echiperiporites* sp, *Retitricolporites guineansis, Polypodiaceisporites spedia, Gemmamonocolpites gemmatus, Racemonocolpites hians* and *Danea* sp and the last downhole occurrences of *Crassoretitriletes vanraadshoeveni and Forveotriculporites crassiexinus.*

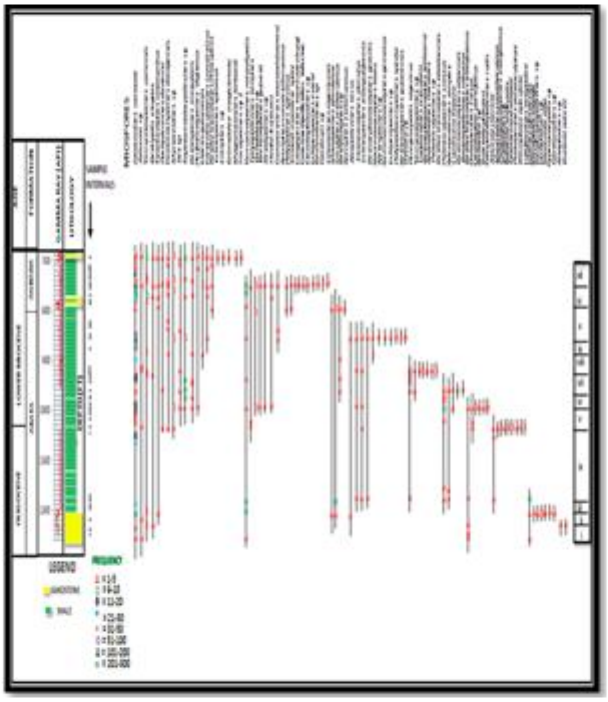


Figure 4: Miospore range chart and biozonation of well X

Zone (x): *Monoporites annulatus* szone -Lower Miocene- The base is the same as the top of zone (ix) while the top is at 8250 ft and defined by the first downhole occurrences of *Arecipites crassiexilimuratus, Monoporites annulatus, Triculpites rectibaculatus, Retitriculporites* sp, and the last downhole occurrences of *Retibrevitriculpites protrudens, Polypodiites specious,* and *Arecipites exilimuratus.*

Zone (xi) *Verrutricolporites rotundiporis* zone- Lower Miocene- The base is the same as the top of zone (x) while the top is at 7860ft.The top is defined by the first downhole occurrences of *Verrutricolporites rotundiporis*, *Retidiporites* sp, *Deltoidospora* sp, *Nympha fruiticans, Brevicolpites guinetti, Arecipites crassiexilimuratus, Polypodiites specious, Longapertites vaneendenburgi, Ctenopholonphonidites* sp, *Echiperiporites estella, Constructipollenites infectus, Canthium* sp, *Gemmatriletes* sp, *Filtrotriletes nigeriensis, Crassoretitriletes vanraadshoeveni,* smooth monolith spore, and *Carryopollenites veripites.*

Zone (xii): *Magnastiatites howardi* zone- Lower Miocene- The base is the same as the top of zone (xi) while the top is at 7350 ft and characterised by the first downhole occurrences of *Forveotriculporites crassiexinus, Zonocostites ramonae, Avicenia* sp, *Verrucatosporites usmensis, Beskipolis elegans, Pachydermites diederixi, Striatriculpites catatumbus, Sapotaceoidopollenites* sp, *Cicatricocisporites dorogensis, Elaesis guineansis, Echitriporites spinosus, Ericipites sp, Grimsdalea magiclavata, Magnastiatites howardi, Triculpites* sp 2, *Ilex* sp, *Retitricolporites irregularis, Perfotriculporites digitatus, Myrtaceidites* sp, and *Retibrevitriculpites protrudens.* Some of the recovered Miospore microphotographs are presented in plates 1 to 3.

3.2.2 Age Characterization

The erected miospore zones were compared with pantropical zones of [8] and [11], and used it to delineate the Oligocene/Lower Miocene boundary (Figure, 5).

The Oligocene interval: This interval is characterised by Miospore zones, (i to iv). Some age diagnostic palynomorphs used to delineate this interval include: *Zonocostites ramonae, Beskipollis elegans, Verrucatosporites usmensis, Crassoretitriletes vanraadshoeveni, Triculpites retibaculatus, Canthimidites, Proxapertites annisosculpure, Verrutriculporites rotundiporis, Retitriculporites irregularis, Retibrevitricoporites protrudens, Retibrevitricoporites obodoensis, Pachydermites diederixi, Striatriculpites catatumbus, Perfotriculporites digitatus, Racemonocolpites hians, Polypodiaceisporites* sp, *Striatriculpites pimulus, Dualidites laevigatus etc.* The occurrence of *Zonocostites ramonae* at the base of the well indicate an age not older than Oligocene. The Rhizophora pollen *Zonocostites ramonae* evolved in the western coast of Africa in Oligocene and has continued in coastal and marine sediments of the tropics to Recent [8]. There has not been any record of *Z. ramonae* in Nigeria in pre Oligocene time. First regular increase in *Zonocostites ramonae* has been consistently found in the Miocene and has been used to recognize Miocene sediments. The pre Miocene recorded low frequency occurrence of this pollen as in the case of this interval in the studied wells therefore an Oligocene age is indicated for the sediments. Also the co occurrence of known Eocene to Miocene palynomorphs such as *Verrucatosporites usmensis, verrutricolporites rotundiporis, Beskipollis elegans* etc is an indication of an age not younger than Miocene. The top of this interval is constrained by the first downhole occurrence (FDO) of *Dualidites laevigatus* recorded in the *Dualidites laevigatus* zone. This pollen has not been recorded in sediments older than Oligocene. This judgement is also supported by the incoming of the Oligocene /Miocene transition miospores as *Catostema astooni*, *Perfotrocolorites digitatus*, *Carryopollenites veripites*, *Sapotaceidopollenites* sp etc. The top of this interval is recognised at 10550 ft and correlate well with *Verrucatosporites usmensis* of [8] and P620 of [11], pollen zones published in the Niger delta chronological data table (Figure, 5).

The lower Miocene interval: This interval is recognised by miospore zones (v-xii). The diagnostic miospore events used to characterise this interval include: the last downhole occurrences (LDO) of *Retibrevitricolpites protrudens, Retitriculporites guianensis, Retibrevitricolpites obodoensis* and the first downhole occurrences (FDO) of *Perfotriculporites digitatus, Magnastrites howardi, Grisdalea Magiclavata etc.* The FDO of *Magnastrites howardi* has not been recorded above the lower Miocene age therefore delineates the lower Miocene interval. Although *Grimdalea magiclavata* and *Magnastrites howardi* are scarce may be due to environmental condition, *perfotricolporites digitatus* is appreciably recorded. This interval fall within the *Magnastrites howardi* zone of [8] and P630 - P780 of [11], pollen zones (Figure, 5). Other significant events at this interval are the first downhole occurrences of *Retibrevitricolpites obodoensis, Anacolosidites luteoides,Racemonocolpites hians, Verrutriculporites rotundiporis, and Caryadopollenites veripites.*

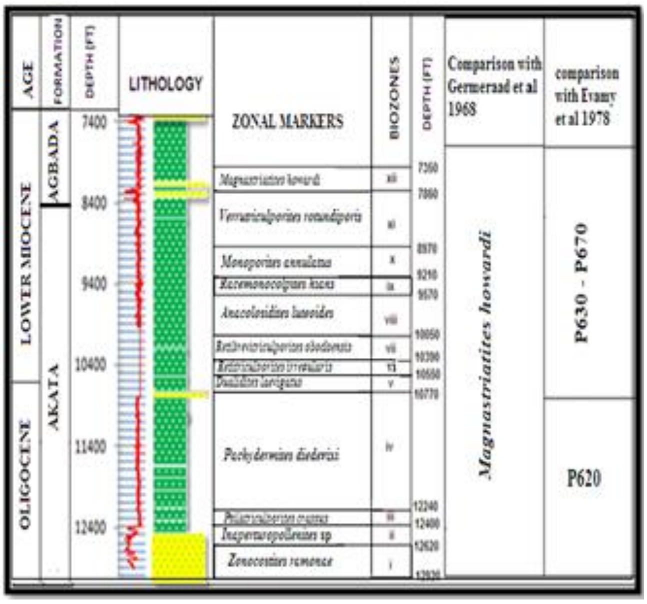


Figure 5: Miospore biozones of well X, in comparison with [8], and [11] zonation models

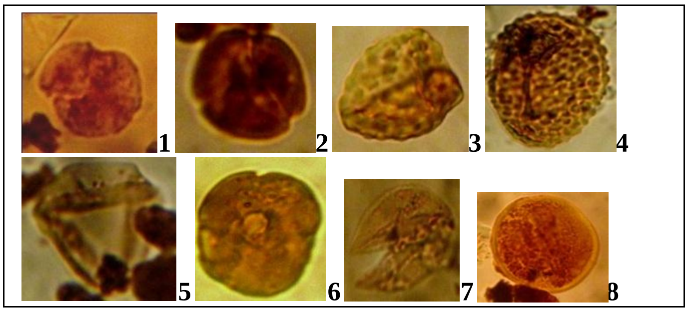
4. Summary / Conclusion

The sedimentological analysis and petrophysical information from Gamma Ray log show that the rock succession is characterised by the alternation of thick black shale and grey shales with thick Medium to coarse grained, fairly well sorted sandstone at the base believed to be turbidite sand of the Upper Akata formation. The top of the studied interval is more paralic and made of black shales intercalating with medium to coarse grained sandstone and siltstone at intervals characteristically of the paralic Agbada Formation. Palynological analysis of the studied wells yielded a well preserved and diverse biostratigraphic relevant Miospores among which fifty nine Miospores were identified. On the basis of the first and last downhole occurrences of these Palynological events, twelve miospore biozones were erected. The zones are from the base to top: *Zonocostites ramonae*, *Inaperturopollenites* sp, *Striatriculpites pimulus*, *Pachydermites diederixi*, *Dualidites laevigatus*, *Retitricolporites irregularis*, *Retibrevitricolpites obodoensis*, *Anacolosidites luteoide*, *Racemonocolpites hians*, *Monoporites annulatus*, *Verrutriculporites rotundiporis*, and *Magnastiatites howardi.* and compared with the *Verrucatosporites usmensis* and *Magnastriatites howardi* zone of [8] and P620 to P780 of [11], and used it to delineate the Oligocene/Lower Miocene boundary. In conclusion, the studied interval, dates between upper Oligocene (Chatian) and lower Miocene and penetrated the Akata and Agbada Formation.

Plate 1

1	*Avicenia* sp
2	*Avicenia* sp
3	*Verrucatosporites usmensis*
4	*Verrucatosporites usmensis*
5	*Alsophidites* sp
6	*Sonneratia alba*
7	*Inaperturopollenites* sp
8	*Psilatriculporites crassus*
9	*Psilatriculporites crassus*
10	*Adenantherine simplex*
11	*Aletesporites* sp
12	*Striatricolpites pimulus*
13	*Arecipites exilimuratus*
14	*Dualaidites laevigatus*
15	*Perfotricolporites digitatus*

Plate 1



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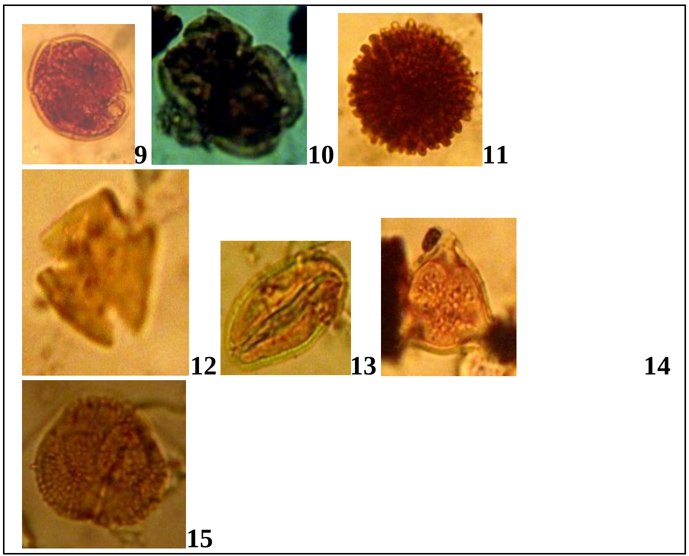


Plate 2

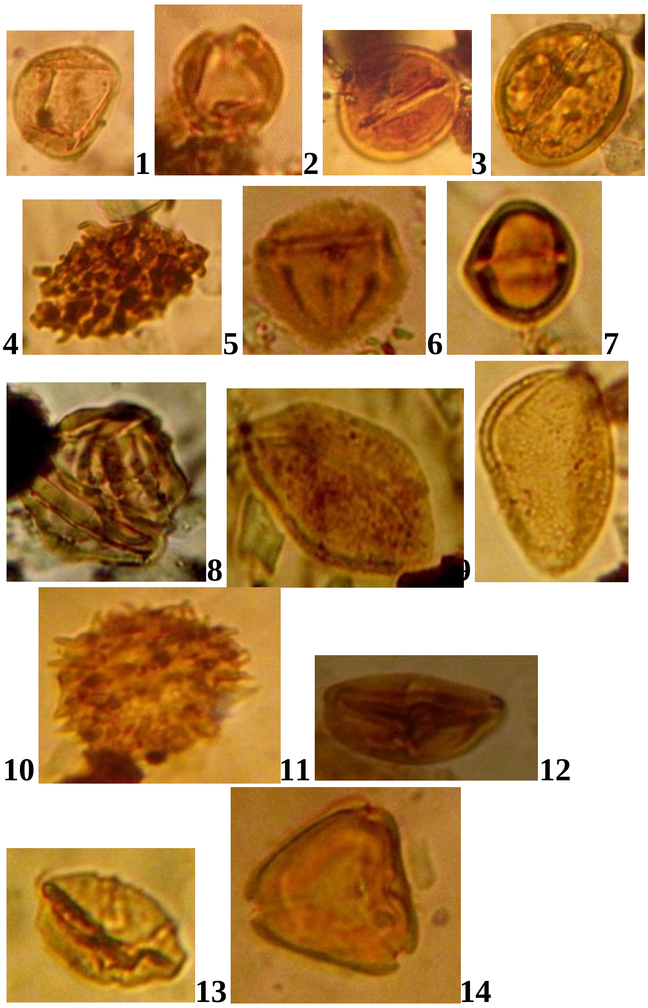
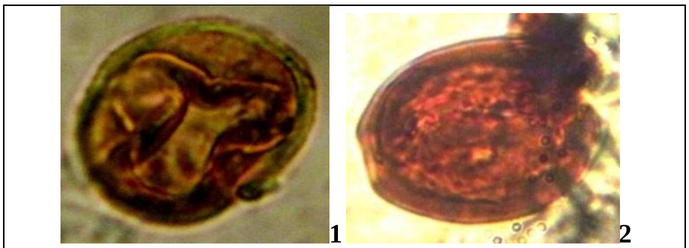


Plate 3



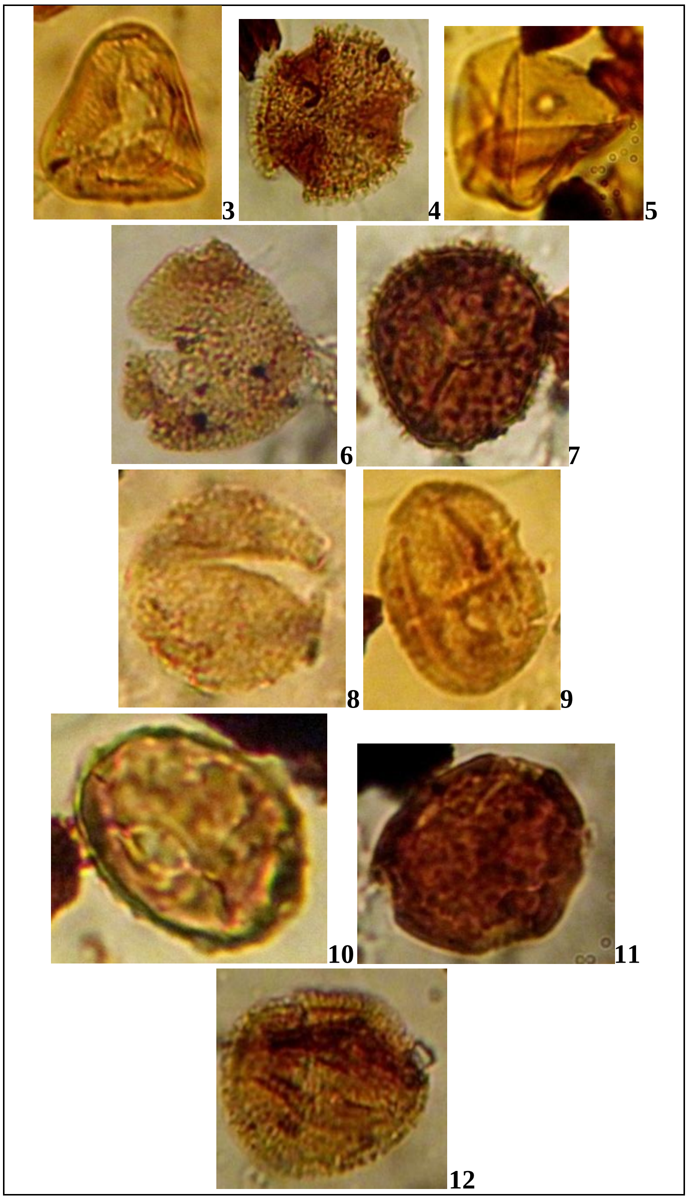


Plate 2

1	*Caryapollenites veripites*
2	*Caryapollenites veripites*
3	*Psilamonocolporites marginatus*
4	*Mauritidites crassibaculatus*
5	*Tubifloridites antipodica*
6	*Lumlitzera littorea*
7	*Zonocostites ramonae*
8	*Magnatriatites howardi*
9	*Retimonocolpites obaensis*
10	*Retimonocolpites obaensis*
11	*Spinizonocostites baculatus*
12	*Verrutricolporites rotundiporis*
13	*Verrutricolporites rotundiporis*
14	*Cupaneidites reticularis*

Plate 3

1	*Anacolosidites luteoides*
2	Retidiporites sp
3	*Retitricolporites irregularis*
4	*Deltoidospora* sp
5	*Monoporotes annulatus*
6	*Polypodiaceisporites spedia*
7	*Danaea* sp

8	*Racemonocolpites hians*
9	*Polypodiites specious*
10	*Sapotaceoidaepollenites sp*
11	*Pachydermites diederixi*
12	*Forveotricolporites crassiexinus*

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