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Palynostratigraphy of Well Z, OPL 310, Offshore Dahomey Basin, South-Western Nigeria

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Abstract:
Background*: Palynological studies in Nigeria are largely confined to the propitious Cenozoic Niger Delta following the discovery of hydrocarbon in the basin since the late 1950s but the quest for more discovery of hydrocarbon has led to the extension of exploration to adjacent Cretaceous basins in Nigeria. The success of a drilling project depends largely on the accuracy of the exploration process where palynology finds its practical uses. Palynological monitoring through the analysis of ditch cuttings rock samples for age determination and paleoenvironmental interpretations are important tools in stratigraphic correlation aspects of the exploration business.*
Materials and Methods*: The data available for this study was a gamma ray log, and a total number of fifty (50) ditch cuttings samplespenetrating from interval 1,620 to 3500ft of well Z, OPL 310, Dahomey basin, South western Nigeria. These samples were analyzed for their palynofloral and lithofacies contents. The palynological data was used for erecting the biozonation framework for the purpose of reconstruction of the age of the rock succession penetrated by the well. Palynological sample processing and analysis followed standard methods of maceration with Hydrochloric acid to rid the sample of Calcium carbonate and Hydrofluoric acid to remove siliceous matter; separation of inorganic matter with heavy liquid and oxidation to rid the sample of pyrites and to liberate palynomorphs from extraneous organic matter for better recovery.*
Results*: Lithologically, the rock succession in well Z, consist of two lithofacies units: a basal sandstone unitcharacteristically milky white, coarse to pebbly, sub-angular and poorly sorted with shale intercalations with glauconite pellets and mica flakes; overlain by a dark grey, non-fissile shale alternating with sandstone. The basal sandstone/shale unit is characteristic of the Oshosun Formation while the upper shaly unit is typical of Afowo Formation.A moderate rich recovery of miospores were recorded from which seven subzones premised on palynofloral assemblage of significant species, their stratigraphic distribution including their first and last downhole occurrences were recognized. The zones are from oldest to youngest: Racemonocolpiteshians, Arecipitesexilimuratus, Retibrevitricolporitesobodoensis, Retibrevitricolporitesprotrudens, Beskipollis elegans, Verrutriculporitesrotundiporus and EchiperiporitesEstelae corresponding with P480, P520, P540, P560, P740, P770 and P780 respectively of palynological zones of,[1]indicating late Eocene to Late Miocene age for the studied interval. An unconformity recognized by the total disappearance of P600 zone was encountered between Palynological zone P560 and P740 subzones.*
Conclusion:*the rock succession studied penetrated Oshosun and Afowo formations and is dated late Eocene to Late Miocene in age.*
Key Word*:Palynology, Dahomey, Oshoshun, Afowo, Eocene, Miocene, Lithofacies, Zones.*

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I. Introduction

Ditch cutting rock samples from well Z, located in OPL 310 offshore Dahomey basin, south western Nigeria (figure 1), were subjected to palynological analysis. The aim of this study was to establish the miospore biozonation framework of the well for the purpose of age characterization. Palynological zonation of the well was based on the palynofloral assemblage of significant species as well as their stratigraphic distribution with reference to the zonation schemes of [1]. A total number of fifty (50) samples and gamma ray log penetrating interval 1620 to 3500ft of well Z, were used for this research. Standard palynological sample processing procedure of maceration with Hydrochloric acid to rid the sample of Calcium carbonate and with Hydrofluoric acid to remove siliceous matter; separation of inorganic matter with heavy liquid and oxidation process to liberate palynomorphs from extraneous organic matter were followed. Notable early palynostratigraphic research works in Dahomey basin include [1,2,3,4, 5,6,7,8], among others.

Basin stratigraphic setting: The Dahomey basin is a marginal pull-apart basin initiated during the Early Cretaceous separation of South American and Africa plates thereby constituting part of a system of West Africa pre-cratonic basins developed during the commencement of rifting, associated with the opening of the Gulf of

Guinea in the Late Jurassic to Early Cretaceous [4,9]. It extends from Southeastern Ghana through Togo and Benin Republic on the west side to the Okitipupa ridge on the east side in the southern part of Nigeria. The basin consists of Cretaceous-Tertiary sequence, which outcrops in an arcuate belt roughly parallel to the ancient coastline. The Tertiary sediments thin out to the east and are partially cut off from the sediments of Niger Delta basin against the Okitipupa basement ridge (figure 2).

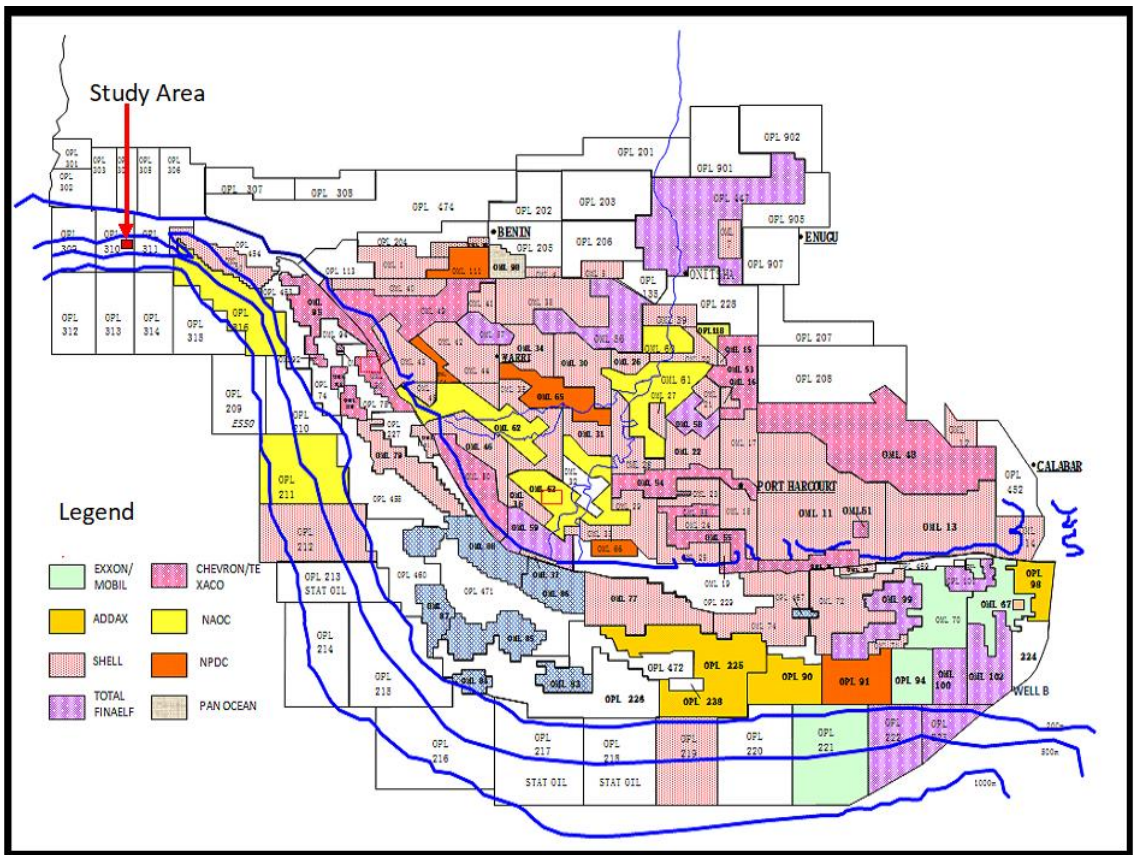

Figure 1: Niger delta and the adjoining basin oil mining lease (OML) map showing location of the study area.

BASIN STRATIGRAPHY:

The stratigraphy and stratigraphic architecture (Figure 3)) have been well established by various workers [10,11,12,13]. However, [12] placed together the stratigraphy of eastern Dahomey basin from surface as well as subsurface data, deciphering that in most part of the basin, the stratigraphy is dominated by monotony of sand and shale alternations with minor proportion of limestone and clay. The summary of the stratigraphy of the Cretaceous to Cenozoic sedimentary pile which unconformably overlies the basement complex is given in figure 3. Abeokuta group is the oldest group of sediment in the basin, lying non-conformably on the basement[10]. [11]worked on the lithostratigraphy of Dahomey basin and recognized (3) formations belonging to the Abeokuta group based on lithologic homogeneity and similarity of origin. This group is the thickest sedimentary unit within the basin. The formations from oldest to youngest are Ise, Afowo and Araromi formation. Ise formation unconformably overlies the basement complex of Southwestern Nigeria, consisting of conglomerate and grits at the base which is in turn overlain by coarse to medium grained sand with interbeded kaolinite. The conglomerate is imbricated and at some locations, ironstone occur [13]. An age range of Neocomian-Albian is assigned to this formation based on paleontological assemblages. Afowo formation overlies the Ise formation, and composed of coarse to medium grained sandstone with variable but thick interbedded shale, siltstone and claystone. The sandy facies are tarbearing[14], while shale is organic-rich. Using palynological assemblage, a Turonian age is assigned to the lower part of this formation, while the upper part ranges into Maastrichtian [16]. The youngest Cretaceous formation in the group is Araromi formation, which conformably overlies the Afowo formation. It is composed of fine-medium grained sandstone at the base, overlain by shale, siltstone with interbedded limestone, marl and lignite. [11] assigned a Maastrichtian to Paleocene age to this formation based on faunal content. The Imo Group overlies the Abeokuta group and chronologically consists of two lithostratigraphic units which from oldest to youngest are Ewekoro and Akinbo formation. Ewekoro formation overlies the Araromi formation in the basin and is described to be a shaly limestone unit. This formation is an

extensive limestone body, which is traceable over a distance of about 320km from Ghana in the west, towards the eastern margin of the basin in Nigeria [10]. It is highly fossiliferous and Paleocene in age. Akinbo formation which is made up of shale and clay sequence overlies the Ewekoro formation[16]. The claystone is concretionary and predominantly kaolinite). The base of the formation is defined by the presence of glauconitic bands with lenses of limestone [16,17]. Also based on faunal contents the formation is Paleocene-Eocene in age. Oshosun formation overlies the Akinbo formation and consists of greenish-grey or beige clay and shale with interbeds of sandstone. The shale is thickly laminated and glauconitic. This formation is phosphate-bearing [10,13]. An Eocene age is assigned to this formation based on fossil content. Conformably overlying the Oshosun formation is the Ilaro formation and consists of massive, yellowish, poorly consolidated cross-bedded sandstone. The formation shows rapid lateral facies changes. The youngest stratigraphic sequence in the eastern Dahomey basin is the Benin formation. It is also known as the coastal plain sand [10] and consists of poorly sorted sand with lenses of clay. The sands are in parts cross bedded and show transitional to continental characteristics. The age is Oligocene to Recent.

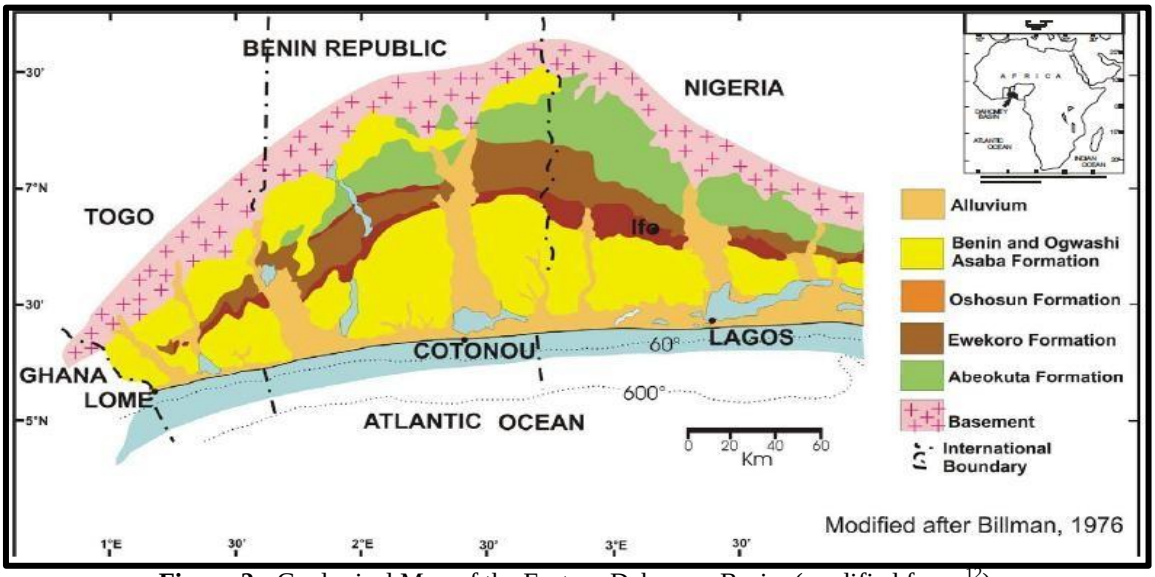

Figure 2: Geological Map of the Eastern Dahomey Basin, (modified from [12])

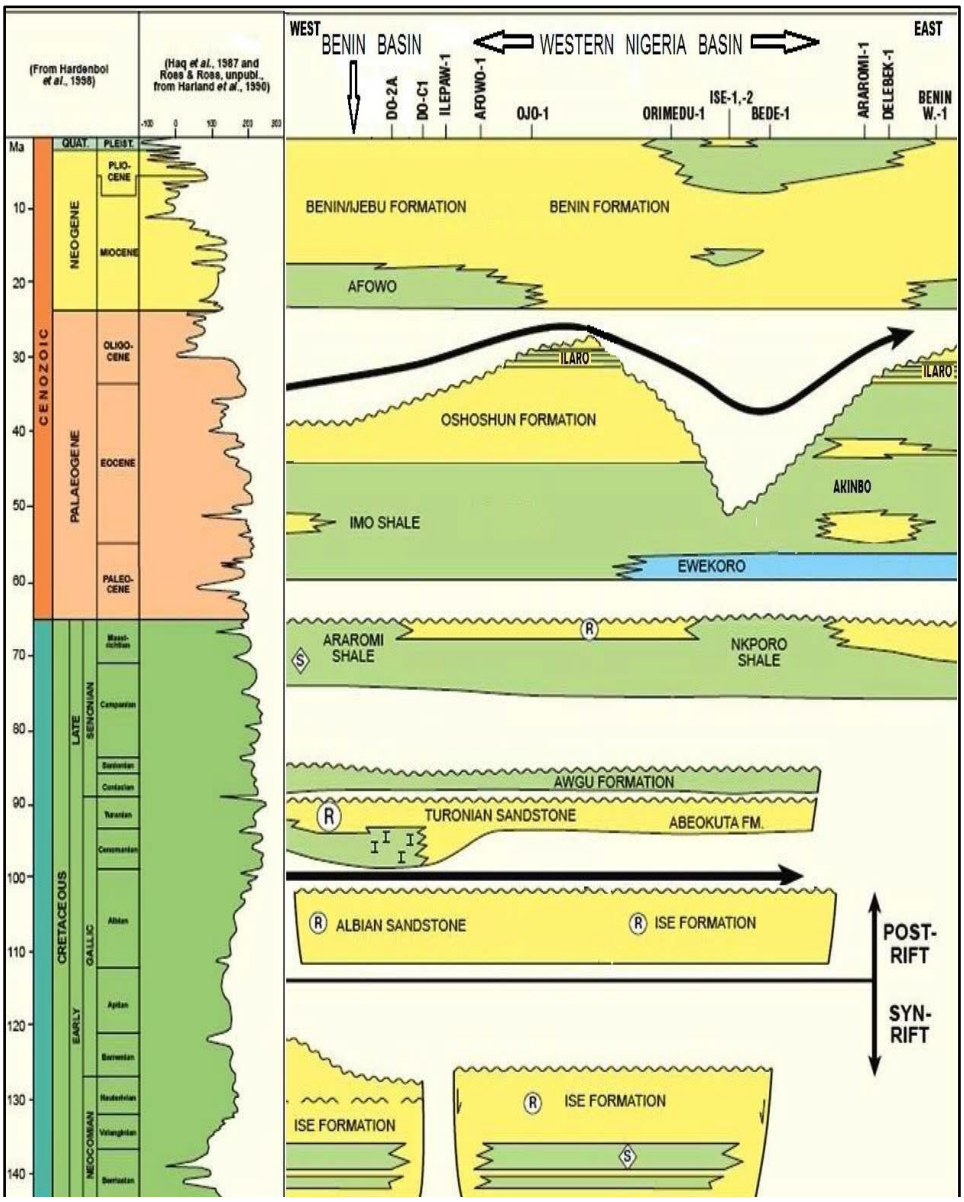

Figure 3: Schematic cross section showing lithostratigraphic units of Dahomey and Western Nigeria offshore basins.

II. Material and Methods

Lithofacies analysis was aided by the gamma ray log.

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. A total number of fifty (50) ditch cutting samples between interval 1,620 and 3500ft of well Z 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. 20gms of sample were weighed into a 250ml plastic beaker (10gm or 7gm 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. (precaution: If at this point, there was effervescence, the process was discontinued for about 5 minutes until reaction completely subsided)
3. Water was added allowed to settle and decanted and washed
4. The reaction was discontinued by adding water, it was allowed to settle and decanted.

5. Concentrated HF (60%) was added drop wise until beaker is quarter filled and stirred continuously for 5 minutes with a PVC rod and left to stand in the fume cupboard overnight
6. Beakers were filled up with distilled water, stirred, and left to stand till the sample settled and water was decanted.
7. Residue were put into a labeled 25ml glass beaker, 50ml 36% HCL was added and placed on a hot plate and left to boil.
8. 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
9. Residue was decanted into a labeled test tube and centrifuged at 2,000 RPM for 5 minutes.
10. 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.
11. Floating material were decanted into another labeled glass test tube.
12. Step 10 was repeated and floating materials were decanted into the same test tube
13. 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.
14. Residue was decanted into Pyrex glass funnel of the pressure unit and filtered with a 10mm Nylon Sieve.
15. Residue was transferred to beaker from sieve, then centrifuged in a phial.
16. 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.
17. Few drops of NorIant (mounting medium) were put on dully labeledglass slides and mounted on cover slips.
18. The slides were dried in the sun for 5minutes after which they were ready for microscopic examination.

III. Result

The lithostratigraphy of the well Z is presented in figure,4.

Palynostratigraphy:

Thepalynological analysis yielded well distributed important pollen and spore markers useful for age characterization (Plates, 1 - 2). Palynological zonation of the well is based on the palynofloral assemblage of significant species as well as their stratigraphic distribution with reference to the zonation schemes of [1] (figure 5).

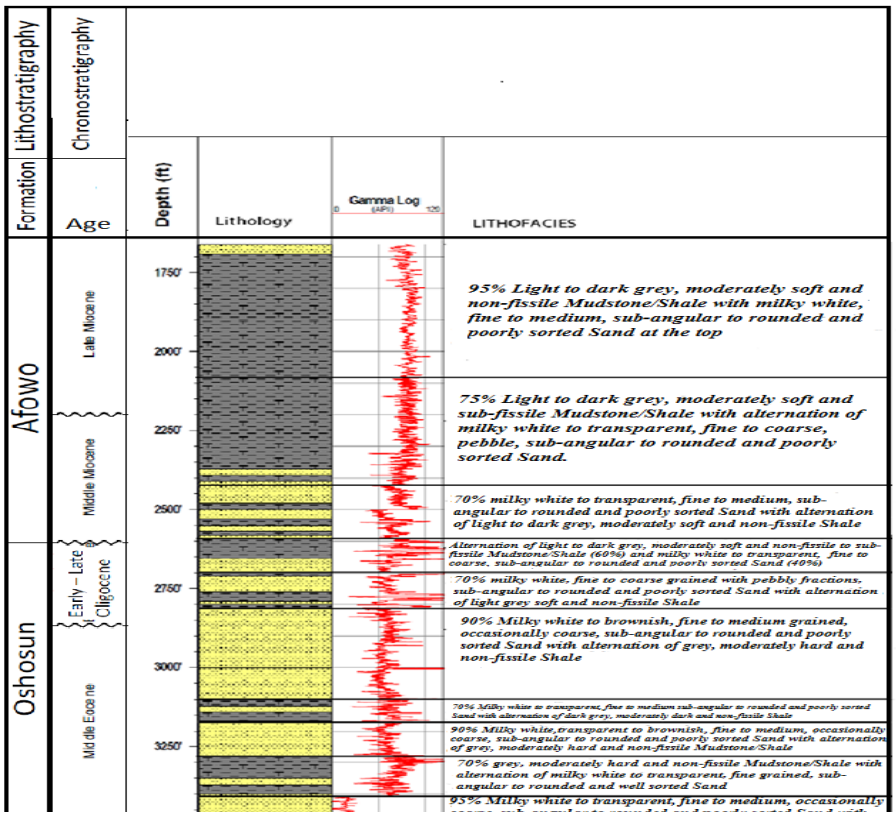

Figure 4: Lithostratigraphy of well Z

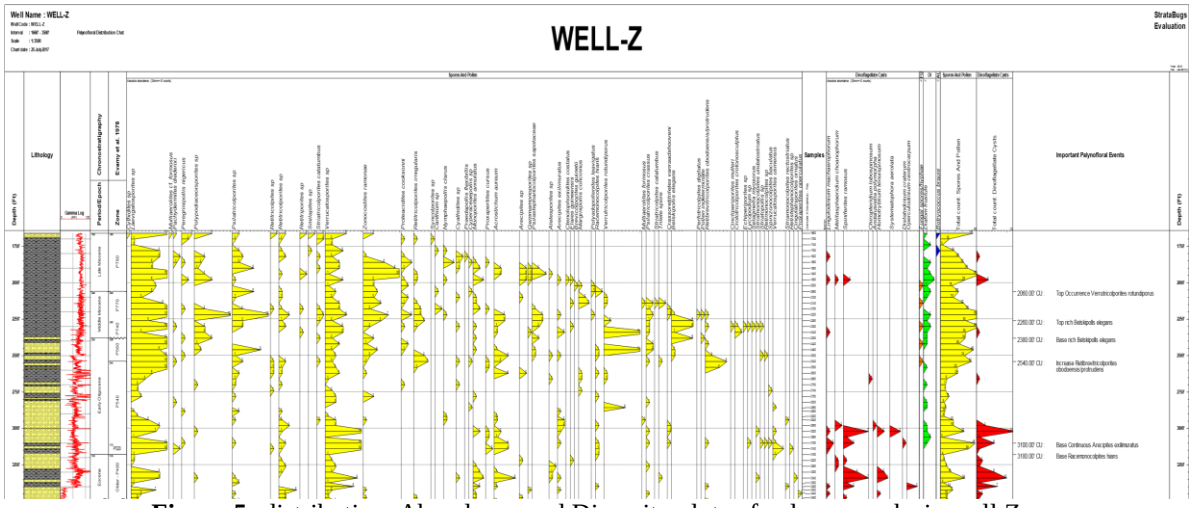

Figure 5: distribution, Abundance and Diversity plots of palynomorphs in well Z.

PLATE 1

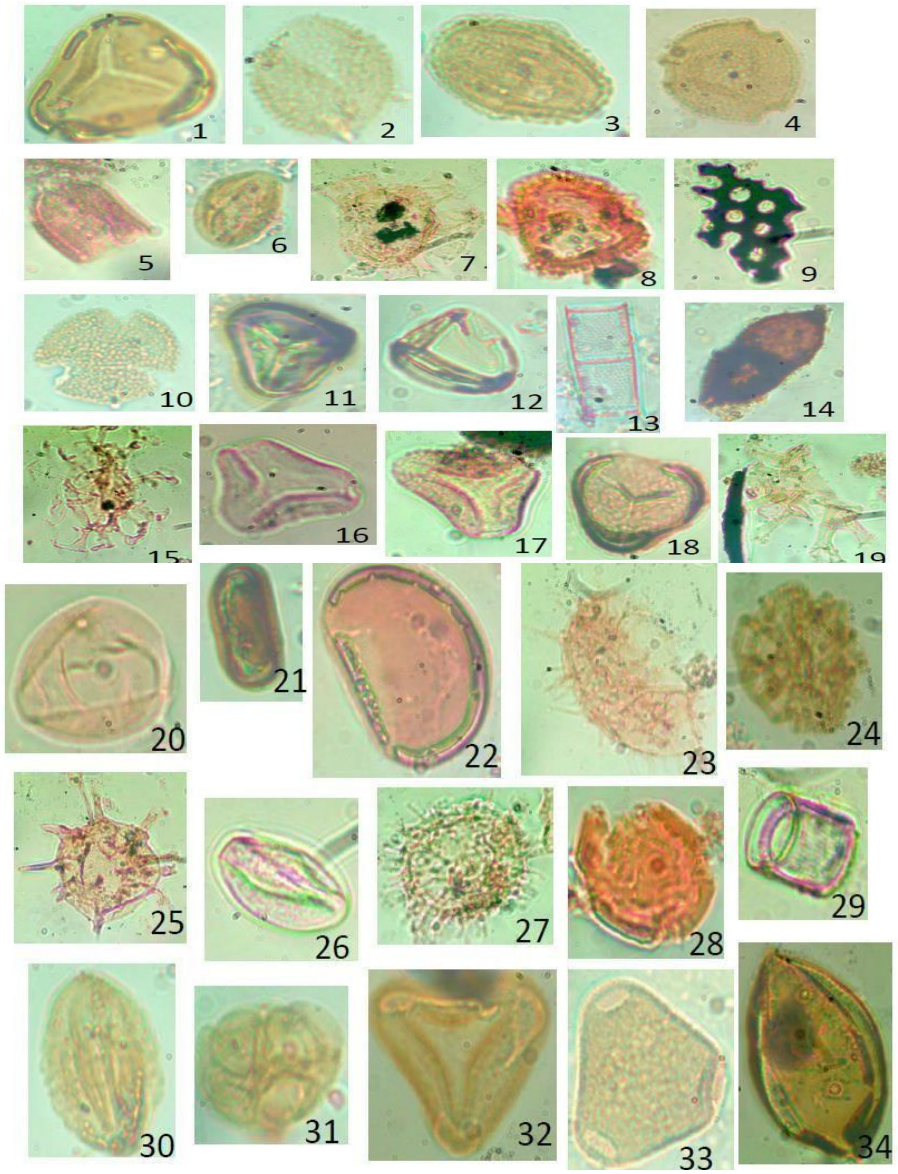

PLATE 1

1. *Acrostichumaureum*(2180-2220)
2. *Arecipitesexilimuratus*(2180-2220)
3. *Belskipollis elegans* (2180-2220)
4. *Canthium*sp (1620-1680)
5. *cfMultiareolitesformosus*(2300-2340)
6. *cfVerrutricolporitesrotundiporus*(2060-2100)
7. *Chiropteridiumlobospinosum*(2620-2660)
8. *Cingulatisporitesornatus*(3300-3340)
9. *Crassoretitriletesvanraadshooveni*(2980-3020)
10. *Crototricolpitescrotonoisculptus*(2260-2300)
11. *Cyathidites*sp (1620-1680)
12. *Cyperus*sp (2020-2060)
13. *Diatom frusule*(2060-2100)
14. Fungal spore (1980-2020)
15. *Distatodinium criterium* (3060-3100)
16. *Elaeisguineensis*(2260-2300)
17. *Elaeisguineensis*(3180-3220)
18. *Lycopodium* sp (2260-2300)
19. *Homotrybliumtenuispinosus*(3260-3300)
20. *Monoporitesannulatus*(2340-2380)
21. *Multiareolitesformosus*(2100-2140)
22. *Laevigatosporites*sp (2260-2300)
23. *Lingulodiniummachaerophorum*(2300-2340)
24. *Peregrinipollisnigericus*(2140-2180)
25. *Melitasphaeridiumchoanophorum*(2940-2980)
26. *Marginipollisconcinnus*(2700-2740)
27. *Operculodiniumcentrocarpum*(3380-3400)
28. *Pachydermitesdiederixi*(3100-3140)
29. *Diatom frusule*(2540-2580)
30. *Perfotricolpitesdigitatus*(2180-2220)
31. *Polyadopolleniteslaevigatus*(2180-2220)
32. *Polypodiaceoisporites*sp. (2140-2180)
33. *Proteaciditescooksonni*(2260-2300)
34. *Proxapertites cursus* (2140-2180)

PLATE 2

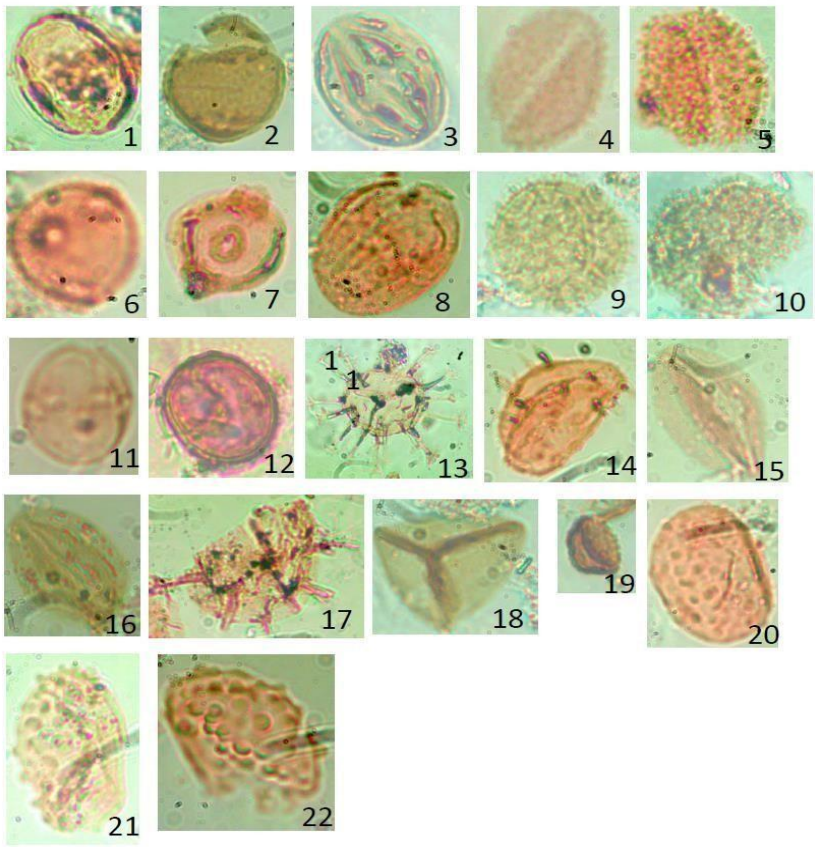

PLATE 2

1. *Proxapertitesoperculatus* (3420-3440)
2. *Psilatricolporitescrassus*(2100-2140)
3. *Psilatricolporites*sp (2020-2060)
4. *Racemonocolpiteshians* (2260-2300)
5. *Racemonocolpiteshians* (3380-3400)
6. *Retibrevitricolporitesprotundens* (2460-2500)
7. *Retibrevitricolporitesprotundens* (2540-2580)
8. *Retistephanocolporites*sp (3100-3140)
9. *Retitricolporitesirregularis* (2220-2260)
10. *Retitricolporitesirregularis* (2220-2260)
11. *Sapotacea*sp (2260-2300)
12. *Selaginellamyosorus* (2260-2300)
13. *Spiniferitesramosus* (3260-3300)
14. *Spinizonocolpitesbaculatus* (2700-2740)
15. *Striamonocolpitesundertostriatus* (2260-2300)
16. *Striatricolporitescatatumbus* (2140-2180)
17. *Systematophoraareolata* (2980-3020)
18. Triletes spore (2100-2140)
19. *Verrutricolporitesrotundiporus*(2100-2140)
20. *Verrrucatosporites*sp (2980-3020)
21. *Verrucatosporitesusmensis* (2820-2860)
22. *Verrucatosporitesusmensis* (3140-3180)

IV. Discussion

Lithostratigraphy: The result of the lithological analysis revealed that the rock succession in well Z, consist of two lithofacies units: the basal sandstone unit with alternation of shale with the sandstone characteristically milky white to transparent and brownish, Fine to coarse, pebbly, sub-angular to rounded and poorly sorted to well sorted with glauconite pellets at some horizons; overlain by the light to dark grey, moderately hard and non-fissile shale or mudstone sequence with accessory mineral assemblage which includes mica flakes, glauconite pellet, carbonaceous detritus and ferruginous materials. The basal sandstone/shale unit is characteristic of the Oshosun Formation while the upper shaly unit is typical of Afowo Formation (figure 4).

Biozonation and age characterization: The well section under study is assigned late Eocene to late Miocene based on the evidence of the palynological study (Table 1). Descriptions of the palynological zones recognized are provided below:

Biozonation of well Z

ZONE P700:

Subzone: P780: *Echiperiporitesestelae*

Interval: 1620 - 2080ft

Age: Late Miocene

Definition of the *Echiperiporitesestelae*zone 7:

The top of the subzone could be probably shallower than the first sample analyzed at 1,620ft and the base is defined by the top occurrence of *Verrutricolporitesrotundiporus*at 2,080ft. The subzone is characterized by absent or very rare occurrence of *Echiperiporitesestalae*and*Verrutricolporitesrotundiporus*, but with presence of *M*ultiareolites*formosus, Pachydermitesdiederixi, Racemonocolpiteshians, Laevigatosporites*sp, *Nymphaeapollisclarus, Verrucatosporites*sp., *Peregrinipollisnigericus.* Correlation with the [1] palynological Zonation scheme,assignlate Miocene age to the subzone.

Subzone: P770: *Verrutriculporitesrotundiporus*

Interval: 2080 - 2260ft.

Definition of the *Verrutriculporitesrotundiporus* zone 6:

The top is marked by top occurrence of *Verrutricolporitesrotundiporus*at 2,080ft while its base is defined by the top rich occurrence of *Belskipollis elegans at* 2260ft.

The interval exhibited exceptional characteristics of distribution of *Verrutricolporitesrotundiporus* throughout the subzone and *Marginipollisconcinnus*enjoyed its maximum development too. Other pollens which abundantly present are*Laevigatosporites*sp., *Polypodiaceoisporites*sp., *Psilatricolporites*spwhile *Belskipollis elegans* occurs in sparsely distribution. According to the [1] Palynological Zonation scheme, the age of the subzone is assigned to middle Miocene.

Subzone P740:*Beskipollis elegans*

Interval:2260 - 2380ft

Definition of the *Beskipollis elegans* zone 5:

The top boundary is defined by the top rich occurrence of *Belskipollis elegans at* 2260ft while its lower boundary is marked by the base rich occurrence of *Belskipollis elegans at*2380ft.

The subzone is uniquely and mainly characterized by the distribution of *Belskipollis elegans* which shows its maximum development and high percentage occurrence. Apart from this interval, the regular occurrence of *Belskipollis elegans* reduces along the underline subsequent subzones. According to the Palynological Zonation scheme of [1], the age of the subzone is assigned to middle Miocene.

Remarks***:*** A noticeable and well pronounced unconformity was encountered between Palynological zone P700 and P500, which represents total disappearance of P600. Subzone P740 overlain P560 unconformably depicts that some geological events have been truncated either by hiatus or erosional truncation leading to the large interval of geological time scale of rock record disappearance and thus creating a huge time lag of Late Oligocene to Early Miocene.

Zone P500:

Subzone: P560: *Retibrevitricolporitesprotrudens*

Interval: 2,380 - 2,540ft

Definition of the *Retibrevitricolporitesprotrudens* zone 4:
The top boundary could not be specifically defined due to the unconformity occurred between subzone P560 and the overlain subzone P740 at 2,380ft, but the base could be actively marked by the increase in *Retibrevitricolporitesobodoensis/protrudens*at 2,540ft. The interval is characterized by the gradual development of *Retibrevitricolporitesobodoensis/protrudens*with some scattered appearance of*Peregripollisnigericus.* According to the [1]Palynological Zonation scheme, the age of the subzone is assigned to *Early Oligocene.*

Subzone: P540: *Retibrevitricolporitesobodoensis*
Interval: 2,540 - 3,100ft.
Definition of the *Retibrevitricolporitesobodoensis*zone 3:
The top is defined by the increase in *Retibrevitricolporitesobodoensis/protrudens a*t 2,540ft while its base is marked by the base continuous occurrence of *Arecipitesexilimuratus*at 3,100ft.
The subzone is characterized by the uniqueness of the *Peregrinipollisnigericus and Arecipitescrassimuratus*having their base occurrence at or near the base of subzone. According to the [1] Palynological Zonation scheme, the age of the subzone is assigned to *Early Oligocene.*

Table 1: Biozones in Comparism with [1].

Zones	Zonal Markers	Comparism with[1]	Age	Depth Interval (Ft)
7	*Echiperiporitesestelae*	P780	Late Miocene	2160
6	*Verrutriculporitesrotundiporus*	P770	Middle Miocene	2080
5	*Beskipollis elegans*	P740		2260
4	*Retibrevitricolporitesprotrudens*	P560		2380
3	*Retibrevitricolporitesobodoensis*	P540	Early Oligocene	2540
2	*Arecipitesexilimuratus*	P520		3100
1	*Racemonocolpiteshians*	P400	Eocene and older	3180
				3500

Subzone P520: *Arecipitesexilimuratus*
Interval: 3,100 - 3,180ft
Definition of the*Arecipitesexilimuratus*zone 2
The top boundary of the subzone is defined by the base continuous occurrence of *Arecipitesexilimuratus*at 3,100ft while its base is marked by base occurrence of *Racemonocolpiteshians*at 3,180ft.
The interval is characterized by the presence of *Verrucatosporitesusmensis*which shows a top very rich occurrence while *Retimonocolpites*spshows a quantitative base in this subzone. According to the Palynological Zonation scheme, of [1,] the age of the subzone is assigned to *Early Oligocene.*
ZONE P400*:*
Subzone P400:*Racemonocolpiteshians*
Interval: 3,180 - 3,500ft
Definition of the *Racemonocolpiteshians*zone 1
The top of the subzone is defined by the base occurrence of *Racemonocolpiteshians*at 3,180ft while its base is tentatively placed at 3,500ft. The paucity of key elements of palynomorphs within this interval limits the well to late Eocene and older (Table 2).

V. Conclusion

The lithostratigraphy shows that the rock units penetrated by the well Z, are the Oshosun and Afowo Formations while the Comparism of the biozones with [1] P400 to P780 indicates Late Eocene to late Miocene age for the interval studied.

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