PALYNOLOGICAL AND CALCAREOUS NANNOFOSSIL BIOSTRATIGRAPHY OF OM-4 AND OM-A WELLS, WESTERN NIGER DELTA, NIGERIA

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Abstract
Palynological and calcareous nannofossil analyses were carried out on 50 ditch cutting samples each from two wells OM-4 and OM-A, western Niger Delta, Nigeria with the aim of establishing their biozones. Studied intervals in both wells ranged from 8200 – 11350 ft. Acid method was used for palynomorph processing while smear slide method was used for calcareous nannofossil. The palynomorphs yielded 51 and 44 species in OM-4 and OM-A wells respectively while the calcareous nannofossils had a poor yield of 1 species in OM-4 well and 17 species in OM-A well. Based on the contained diagnostic marker palynomorphs and calcareous nannofossils present in the wells, three palynomorph zones, Retibrevitricolporites protudens/obodoensis – Verrutricolporites sp Zone (T1), Monocolpites sp – Magnastriatites howardi Zone (T2) and Crassoretitriletes vanraadshooveni Zone (T3) were identified in OM-4 well, while an indeterminate Zone (T4), Peregrinipollis nigericus – Cyperaceaepollis sp Zone (T5) and Psilatriporites sp –Retitricolporites sp Zone (T6) were identified for the OM-A well. The informal T1, T2 and T3 zones established in OM-4 well corresponded to the P650, P670-P680 and P720 subzones. Also, the three zones, T4, T5 and T6 established in OM-A well, corresponds to the P830, P840 and P850 subzones and the Echitricolporites spinosus pan tropical palynological zone. No calcareous nannofossil zone was established in OM-4 well due to very poor recovery, while Discoaster quinqueramus – Discoaster berrigrenni Zone (NN11) was identified in OM-A well. The wells were assigned Miocene Epoch based on the presence of Miocene markers.

Keywords: *Biozones, Diagnostic marker, Palynomorphs, Miocene.*

Introduction

The use of palynomorphs and calcareous nannofossils in present day studies based on their characteristics which include their rapid diversification, considerable resistance to obliterations by acids, ease to process and their abundance have made them relevant in biozonation and correlation, paleoenvironmental and paleoclimatic studies and biochronology of strata. This has encouraged the use of these fossils to carry out a detailed biostratigraphic study of OM-4 and OM-A wells. This study is aimed at carrying out a palynological and calcareous nannofossil biostratigraphy of OM-4 and OM-A wells by identifying the palynomorphs and calcareous nannofossils present in the strata penetrated by the two wells and establishing biozones based on palynomorphs and calcareous nannofossil assemblages for the strata penetrated.

Location and Geology of the Study Area

The Niger Delta lies between latitude 4° and 7°N and longitudes 3° and 9°E in the southern part of Nigeria. The studied OM-4 and OM-A wells are located on the onshore part of the Niger Delta, on latitude 4°38′ N and longitude 6°48′^{0} N and 4°37′E and 6°47′E respectively (Figure 1). The Niger delta basin contains sediments of Paleogene to Holocene which are deposited in high energy deltaic environment. These formations are basically laid in three

lithostratigraphical order which include Benin Formation, Agbada Formation and Akata. Both wells fall within the Agbada formation within the coastal swamp depobelt.

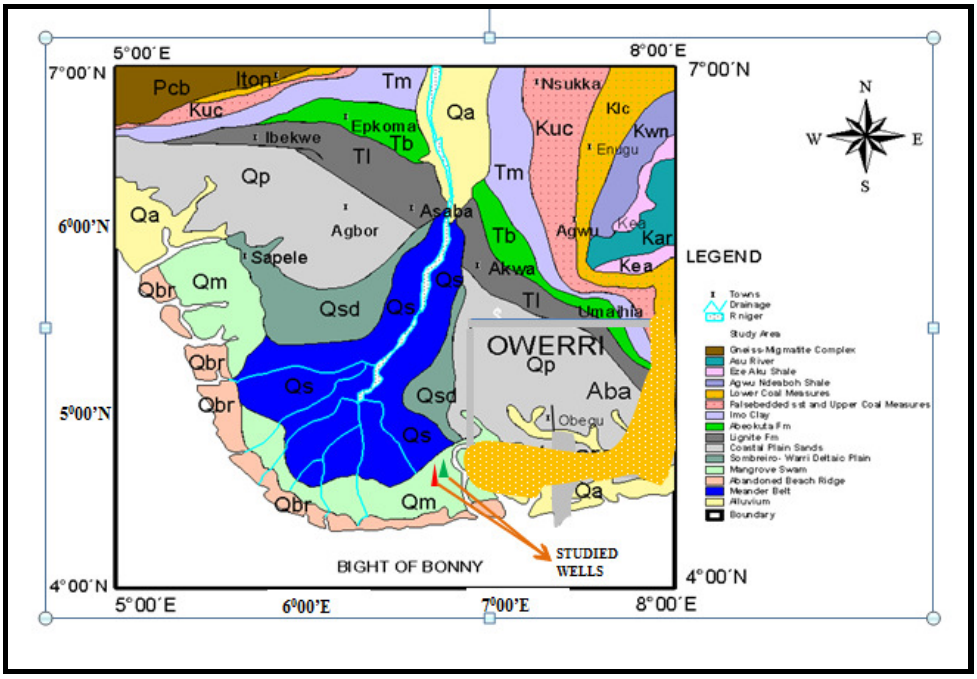

Figure 1: Geological map of Niger Delta showing the location of the studied wells (Modified after Knox & Omotasola, 1990)

Materials and Methods

Ditch cuttings and well logs (Gamma ray and sp logs) were given by Chevron Nigeria Plc. 50 ditch cutting samples collected at depth intervals of 30 ft from each well between intervals of 8200 ft to 11400 ft were studied in both wells respectively. Lithology logs were generated from the well logs showing varying lithologic units ranging from silty shale to shales to sandstone.

Preparation of the palynologic samples were done using standard procedures that involved labeling (The sample names were coded for proprietary reasons), cleaning and weighing of the samples, followed by complete digestion of the samples in hydrochloric and hydrofluoric acid for the removal of carbonates and silicates respectively. The palynomorphs were counted on each of the two slides prepared per sample. The slides were viewed under the binocular microscope (National) at a magnification of X400 in Mosunmolu Nigeria Limited laboratory, Lagos, Nigeria. Forms observed were identified and named using palynological albums as well as descriptions of previous workers (Germeeraad *et al.*, 1968; Evamy *et al.*, 1978; Adegoke *et al.*, 1986). The identified species were noted, counted and recorded on the analysis sheet using the tally system. The process was repeated for all the slides. The results were inputted into the stratabug software (2011) to prepare the palynomorphs distribution chart.

Calcareous nannofossils were recovered using the smear slide method. This was achieved by scraping about 5 g of the sample on a glass cover-slip and adding drops of distilled water to make a thick sediment suspension which was smeared thinly across the surface of the cover slip with a flat tooth pick, and placed on a hot plate to dry rapidly. A glass slide was affixed over the cover-slip using optical adhesive medium. The slides were viewed under the microscope for calcareous nannofossil identification using the binocular microscope (Meiji

Techno) at a magnification of X1000, also at Mosunmolu Nigeria Limited laboratory, Lagos. The species identification was done using calcareous nannofossils albums as well as descriptions of previous workers (Martini, 1971; Okada & Bukry, 1980; Ajayi & Okosun, 2012).

Result and Discussion

Recovery of palynomorphs was good from both wells in terms of abundance, diversity and preservation at all depth (Figures 2 and 3) but was extremely poor for calcareous nannofossils, showing a lone species occurrence in OM-4 well and low abundance and diversity at two depths in OM-A well (Figures 4 and 5).

Palynomorph Distribution

The distribution of palynomorphs, (pollen, spores, dinoflagellates and algae) in the studied section varied from one depth to another in diversity and abundance. Pollen and spore preservation was fair in both wells with total species count of fifty-one and forty-four in OM-4 and OM-A wells respectively. The lists of the forms of palynomorphs as recovered from the ditch cuttings from both wells as plotted on the charts are as follows:

(i) *Pollen and Spores:* Zonocostites ramonae, Laevigatosporites sp., Monoporites annulatus, Cypereapollis sp, Peregrinipollis nigericus, Gemmamonoporites sp, Pachydermites diederixi, Psilatricolporites crassus, Racemonocolpites hians, Retibrevitricolporites protudens/obodoensis, Retitricolporites irregularis, Sapotaceoidaepollenites sp, Striatricolpites catatumbus, Tricolporite sp, Verrustephanocolpites complanatus, Verrutricolporites rotundiporus, Podocarpus sp, Acrostichum aureum, Crassoretitriletes vanraadshooveni, Magnastriatites howardi, Polypodiceoisporites sp, Selaginella myosurus, Verrucatosporires sp, Lycopodiumneogenicus, Magnastriatites sp, Alnus vera, Canthiumidites sp, Chenopodiaceae sp, Alnipollenites verus, Stereisporites sp, Charred graminae cuticle, Fungal spores and hyphae, Inaperturopollenites sp, Monocolpites sp, Praedapollis flexibillis, Praedapollis sp, Proteacidites cooksonni, Bombacacidites sp, Ctenolophonidites costatus, Psilastephanocolporites minor, Retitricolporites bendeensis, Belskipollis sp, Corspnipollenites jussiaeensis, Echistephanoporites echinatus and Spirosyncolpites bruni

(ii) *Dinoflagellates:* Leiosphaeridia sp, Dinocyst indeterminate

(iii) *Algae:* Botryococcus braunii

Calcareous Nannofossil Distribution

The ditch cuttings analysed for calcareous nannofosssils from both wells yielded poor recovery in both abundance and diversity. OM-4 well contained a lone species, *Coronocyclus nitescens* at depth 6430 ftwhile a total of 17 species, *Discoaster quinqueramus, Discoaster bergrenii, Calcidiscus leptoporus, Calcidiscus tropics, Discoaster brouweri, Discoaster exillis, Discoaster loeblichi,, Discoaster pentaradiatus, Discaoster sp, Discoaster variabilis, Helicosphaera carteri, Pontosphaera multipora, Reticulofenestra pseudoumbilicus*(5-7" and 7"), *Sphenolithus abies and Sphenolithus moriformis* were recovered in OM-A well. Highest diversity of the species occurred at 8440 ft, lone occurrence at 9760 ft.

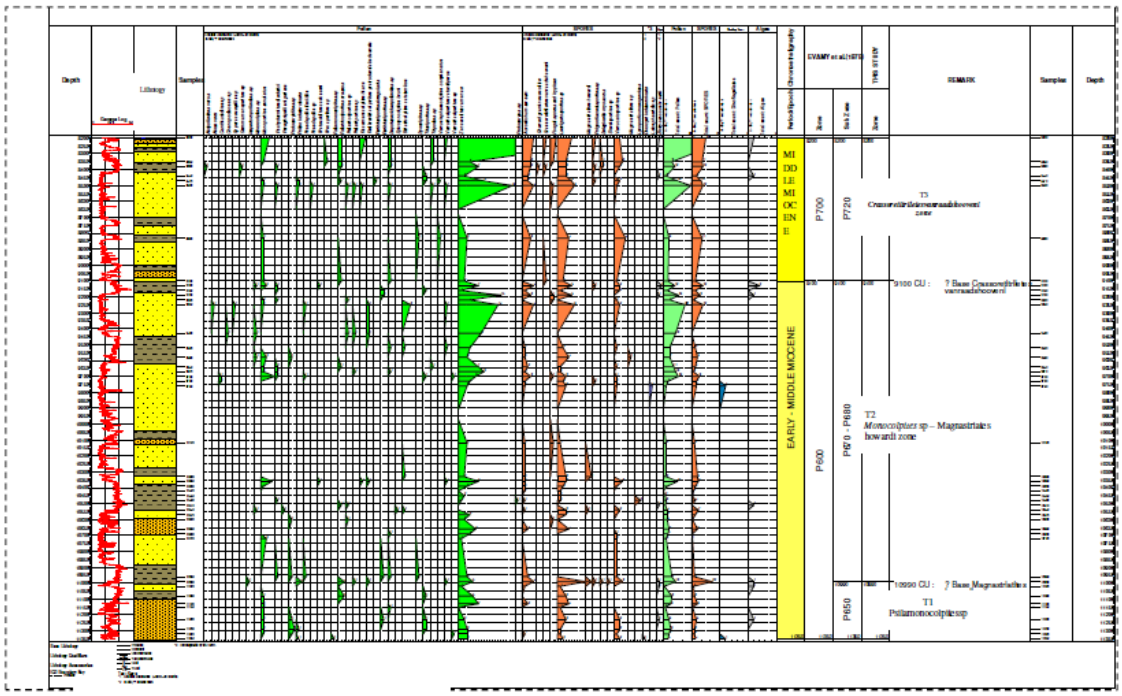

Figure 2: Palynomorph Distribution of OM-4 well

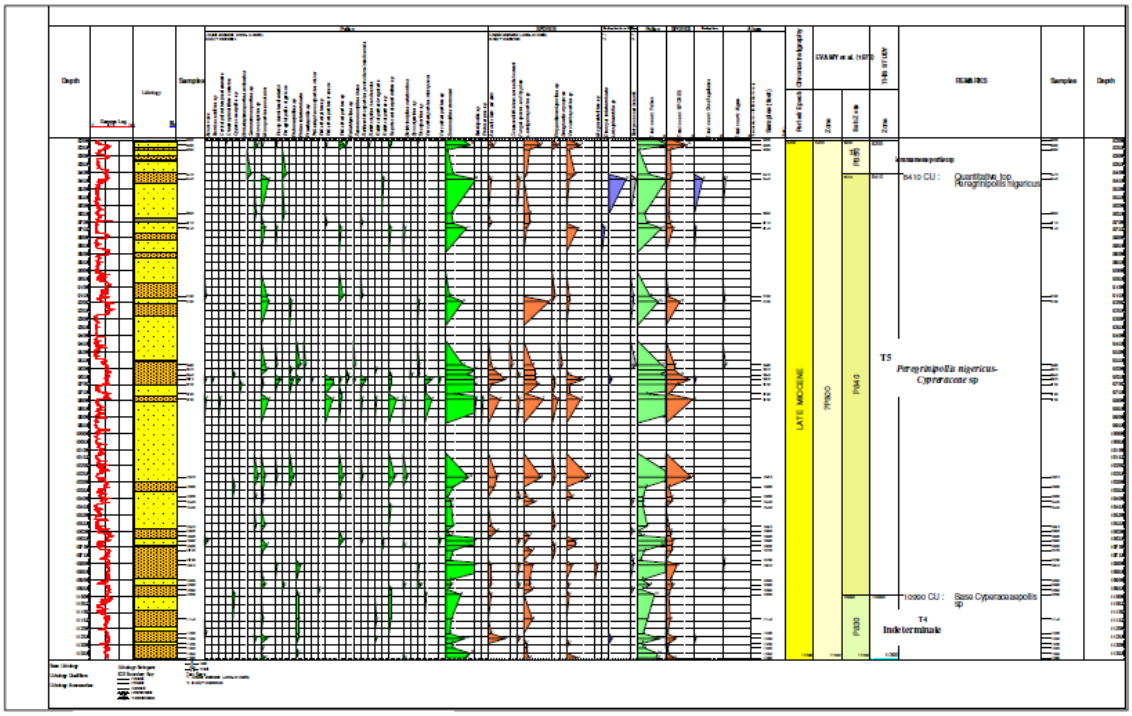

Figure 3: Palynomorph Distribution of OM-A well

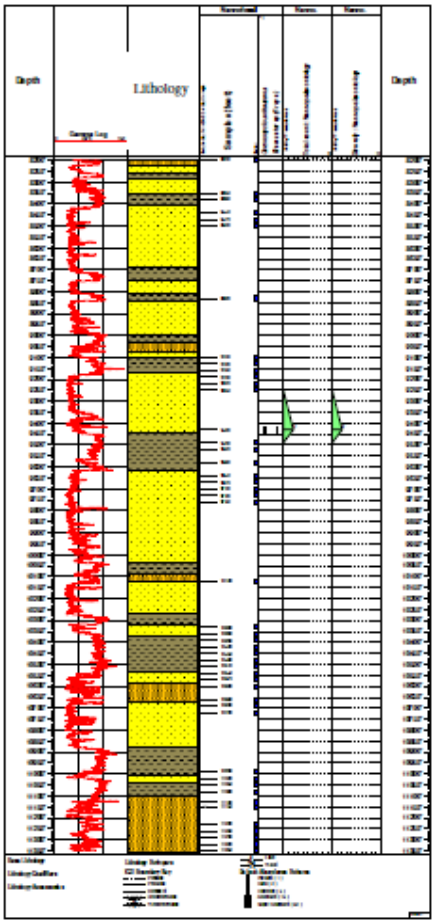

Figure 4: Calcareous Nannofossils Distribution of OM-4 well

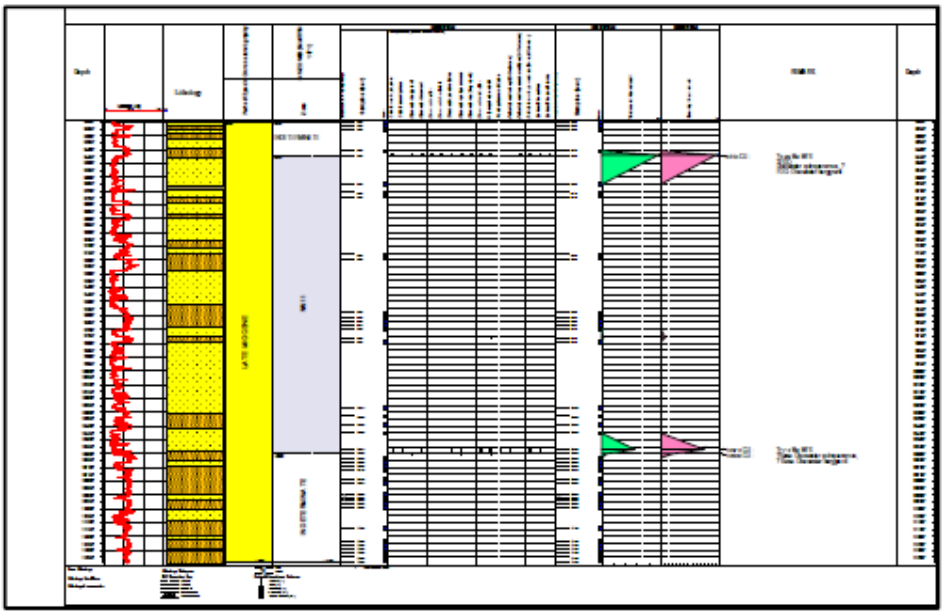

Figure 5: Calcareous Nannofossils Distribution of OM-A well

PalynomorphBiozonation

Palynomorph biozonations for both wells were defined by the first downhole occurrence (FDO) and last downhole occurrences (LDO) of one or more stratigraphically important species in accordance to the International Stratigraphic Guide (Murphy & Salvador, 1999). Three informal biozones introduced as T3, T2 and T1 biozones were proposed in OM-4 and T6, T5 and T4 were proposed inOM-A well. The three biozone types established are the taxon range zone, concurrent range zone and interval zone.

ZONE T1: *Retibrevitricolporites protudens/obodoensis* – *Verrutricolporites* sp Zone
Zone type: Interval zone
Depth: 11350 - 10990 ft
Age: Early Miocene
This is an interval zone which has its base marked by the LDO of *Verrutricolporites* sp at 11350 ft and the top by the LDO of *Retibrevitricolporites protudens/obodoensis* at 10990 ft, both species having their only occurences at these depths. The associated species within this zone are: *Monoporites annulatus, Zonocostites ramonae, Podocarpidites* sp, *Retitricolporites* sp, *Sapotaceoidaepollenites* sp, *Tricolporite* sp, *Psilamonocolpites* sp, *Stereisporites* sp, *Acrostichum aureum*, *Laevigatosporites* sp, *Verrucatosporites* sp, *Botryococcus braunii*, *Psilatriporites* sp. This zone corresponds with the P650 of (Evamy*et al*., 1978) which has the top of the zone marked with the LDO of *Magnastriatites howardi*.

ZONE T2: *Monocolpites* sp – *Magnastriatites howardi* Zone
Zone type: Concurrent range zone
Depth: 10990 - 9100 ft
Age: Early Miocene
This zone is marked at the base by the LDO of *Magnastriates howardi* at 10900 ft and at the top by the FDO of *Monocolpites* sp at 9100 ft. Other associated species within the zone are *Pachydermites diederixi*, *Spirosyncolpites* sp, *Striatricolpites catatumbus, Podocarpus* sp, Fungal spores and hyphae*, Magnastriatites* sp*. Retibrevitricolporites protudens/obodoensis, Psilatricolporites crassus, Verrutricolporites rotundiporis*, *Praedapollis flexibillis, Proteacidites cooksonni, Polypodiaceoisporites* sp, *Selaginella myosurus*, *Stereisporites* sp and *Leiosphaeridia* sp (dinoflagellate). This zone corresponds with (Evamy *et al*., 1978) P670 - P680 zone which is marked at the top by LDO of *Crassoretitriletes vanraadshooveni* at the base by LDO of *Magnastriates howardi*.

ZONE T3: *Crassoretitriletes vanraadshooveni* Zone
Zone type: Taxon range zone
Depth: 9100-8200 ft
Age: Middle Miocene
The zone is a taxon-range zone marked at the base and the top by the LDO andFDO of *Crassoretitriletes vanraadshooveni* at 9100 ft and 8200 ft. Other associated species within the zone include *Alnipollenites verus, Gemmamonoporites* sp, *Praedapollis* sp, *Proxapertites* sp, *Psilatricolporites* sp, *Psilatriporites* sp, *Racemonocolpites hians*, *Retitricolpories irregularis* and *Verrustephanocolpites complanatus.* This zone corresponds with the P720 of (Evamy *et al*., 1978), as it is bounded at the base by LDO of *Crassoretitriletes vanraadshooveni.*

ZONE T4: Indeterminate Zone
Depth: 11350 – 10990 ft
The zone was marked as "indeterminate" because there were no marker species occurring within the zone*.* This zone corresponds with that of (Evamy *et al*., 1978) P830 subzone as it is bounded at the top by the LDO of *Cyperaceaepollis* sp, which marks the base of P840 and the top of P830.

ZONE T5: *Peregrinipollis nigericus- Cyperaceaepollis* sp Zone
Zone type: Concurrent range zone
Depth: 10990 – 8410 ft
Age: Late Miocene
The base is marked by the LDO of *Cyperaceaepollis* sp at 10990 ft and the top of the zone by the quantitative FDO of *Peregrinipollis nigericus* at 8410 ft. Also marking the top of the zone is the LDO of *Gemmamonoporites* sp, while those marking the base of the zone are the LDO of *Verrutricoplites microporus*. Other species associated with the zone are *Monocolpoites* sp, *Monoporites annulatus, Psilatricolpites* sp, *Pachydermites diederixi*, *Retitricolpites* sp, *Podocarpidites* sp, Pollen indeterminate*, Praedapollis* sp, *Psilastephanocolpites minor, Laevigatosporites* sp, *Polypodiaceoisporites* sp, *Selaginella myosurus*, *Verrucatosporites* sp, *Leiosphaeridia* sp and *Botryococcus braunii* (algae).
This zone corresponds with the P840 subzone of (Evamy *et al.,* 1978), which has the top marked by *Peregrinipollis nigericus* and at the base by *Cyperaceaepollis* sp.

ZONE T6: *Psilatriporites* sp - *Retitricolporites* spZone
Zone type: Interval zone
Depth: 8410 – 8200 ft
Age: Late Miocene
The zone is an interval zone marked at the top by the FDO of *Psilatriporites* sp at 8200 ft and at the base by the FDO of *Retitricolporites* sp, at 8410 ft. Other long ranging species running through the zone include: *Monocolpites annulatus, Psilatricolpites* sp, *Retitricolporites bendeensis, Sapotaceoidaepollenites* sp, *Tricolpites* sp, *Zonocosites ramonae, Acrostichum aureum*, *Laevigatosporites* sp, *Polypodiaceoisporites* sp, *Verrucatosporites* sp. The zone corresponds to pollen zone P850 of (Evamy *et al*., 1978) which has its base marked by the FDO of *Peregrinipollis nigericus*.

Table 1: Summary of Palynomorph Biozonation in both wells

Depth	Age	Palynomorph Zone and name (Present Study)	Informal	Evamy *et al*., 1978 zones	Well	Biozone Type
9100-8200 ft		*Psilatriporites* sp- *Retitricolporites* sp	**T6**	**P850**		**Interval**
10990-9100 ft	**Late**	*Peregrinipollis nigericus* –	**T5**	**P840**		**Concurrent**
	Miocene	*Cyperaceaepollis* sp			**OM-A**	**Range**
11350-10990 ft		Indeterminate	**T4**	**P830**		**Indeterminate**
9100-8200 ft	**Middle**	*Crassoretitriletes*	**T3**			**Taxon**
	Miocene	*vanraadshooveni*		**P720**		
10990-9100 ft		*Monocolpites* sp –	**T2**	**P670-P680**		**Concurrent**
	Early	*Magnastriates howardi*				
11350-10990 ft	**Miocene**	*Retibrevitricolporites*	**T1**		**OM-4**	**Interval**
		protudens/obodoensis –		**P650**		
		Verrutricolporites sp				

Calcareous Nannofossils Biozonation
Diagnostic marker species within the wells formed the basis for biozonations for both wells. It is important to note that the poor yield of nannofossils made the division impossible in OM-4 well and broad in OM-A well.

The entire OM-4 well was completely barren of calcareous nannofossil except at 9430 feet where a lone occurrence of *Coronocyclus nitescens* (which is long ranging species), was recorded. This made biozonation of calcareous nannofossil impossible in this well.

Recovery of calcareous nannofossils from OM-A well gave the total species count of seventeen (17) as seen in figure 4. Based on the assemblages of diagnostic species and notable nannofossil events, the FDO and LDO of 2 diagnostic species, *Discoaster quinqueramus* and *Discoaster berggrenii* at 8440 ft and 10600 ft was used to mark the top and the base of the zone. This zone corresponds with NN11 zone of (Martini, 1971), CN 9a and 9b of (Okada & Bukry, 1980) and NN11a and b subzones of (Ajayi & Okosun, 2012).

Conclusion

Six palynomorph zones (T1-T3 in OM-4 well and T4-T6 in OM-A well) were proposed in both wells and they correspond to the already established pollen zones of Evamy *et al*., 1978. These are *Retibrevitricolporites protudens/obodoensis*– *Verrutricolporites* sp Zone (T1), *Monocolpites* sp – *Magnastriatites howardi* Zone (T2) and *Crassoretitriletes vanraadshooveni* Zone (T3) in OM-4 well, while an indeterminate Zone (T4), *Peregrinipollis nigericus* – *Cyperaceaepollis* sp Zone (T5) and *Psilatriporites* sp –*Retitricolporites* sp Zone (T6) were identified for the OM-A well. The informal T1, T2 and T3 zones established in OM-4 well corresponded to the P650, P670-P680 and P720 subzones of Evamy *et al.,* 1978. Also, the three zones, T4, T5 and T6 established in OM-A well, correspond to the P830, P840 and P850 subzones of (Evamy *et al*., 1978). Zones established by previous workers (Olajide *et al*., 2012; Adeigbe, 2013; Jennifer *et al*., 2014) which corresponds to the pollen zones within which these informal zones fall, have been used mainly in age determination and paleoenvironmental interpretations. No calcareous nannofossil zone was established in OM-4 well due to very poor recovery while *Discoaster quinqueramus – Discoaster berrgrenni Zone* (NN11) was identified in OM-A well which depth ranges did not have a clear correlation with any of the palynomorph zones.

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