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Palynostratigraphy and Paleoenvironmental Evaluation of V-Well In Y-Field Offshore, Niger Delta Basin Nigeria.

Victoria Okereke[1*], Richmond Ideozu[1], Monday Udofia[2], Jacinta Nkiru Chukwuma Orji[3]
[1] Department of Geology, University of Port Harcourt, P.M.B 5323 Choba, Rivers State, Nigeria. [2] Pioneer Alfa Petroleum Ltd, Benin City, Nigeria. [3]Department of Geology, Federal University of Technology Minna, Nigeria.
**Corresponding author: okerekevictoria@gmail.com*

ABSTRACT
Palynostratigraphy is the application of palynology to stratigraphy. Sixty-four ditch cuttings, sampled at 20 meters intervals from V-well Offshore, Niger Delta were analysed. The aim was to utilized palynological principles to characterize the sediments recovered, and to reconstruct the paleoenvironment of deposition of the sediments in the studied well. Lithologically, the samples consist of predominantly of fine to medium grained sand with shale intercalation which conformed to the paralic Agbada Formation. The samples were subjected to the standard palynological laboratory processes which involved the maceration of samples with acids and bases. The recovered palynomorphs were abundant and diversified. Some of the recovered palynomorphs, such as; Zonocostites ramonae, Monoporites annulatus, Nympheapollis clarus, Stereisporites sp, Cyperaceoporites sp, Podocarpus milanjianus, Cincitiperiporites mulleri, Multiaerollites fomorsus, Echiperiporites echinatus, Gemmamonoporites sp, Peregrinipollis nigericus, Belskipollis elegance, Echiperiporites estelae, Botryococcus braunii, Dinoflagellate cysts, Spiniferites sp, Racemonocolpites hians and Echiperporites sp, were used in dating, zoning and interpreting the paleoenvironment of deposition of the studied section. Four subzones were identified based on the first appearance datum and last appearance datum of Nympheapollis clarus, Stereisporites sp, Peregrinipollis nigericus, and Cyperaceopolis sp. The stratigraphic intervals were assigned Late Miocene – Early Pliocene. The integration of land derived palynomorphs and marine indicators suggest that the sediments were deposited within the upper – lower shoreface (shallow marine).

Keywords: *Palynology, Lithology, Agbada Formation, Subzones, Miocene*

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I. INTRODUCTION

The Niger Delta Basin were V-Well Offshore is located, fig. 1, is situated in the Gulf of Guinea on the west coast of Central Africa, it lies at the southern region of Nigeria between latitude 3 ^{o} N and 6 ^{o} N, and longitude 5 ^{o} E and 8 ^{o} E (Nwachukwu and Chukwura, 1986). It is bounded at both the north and south, at the north it is bounded by older tectonic elements which include the Anambra Basin, Abakaliki Uplift and the Afikpo Basin, at the south it is bounded by the Gulf of Guinea fig. 1. It is also bounded by the Cameroon volcanic line at the east and the Dahomey Basin at the west (Short and Stauble, 1967). The development of the delta has been dependent on the balance between the rate of sedimentation and the rate of subsidence (Doust and Omosola, 1990). From Eocene to Recent, the delta has prograded southwards, forming depobelts that represents the most active portion of the delta at each stage of its development (Doust and Omosola, 1990). Some of the pioneer workers on the geology of the Niger Delta include those of Short and Stauble (1967), and Frankl and Cordry (1967), who first provided the initial information on the sediments and subsurface distribution of the stratigraphic units in the Niger Delta. Short and Stauble (1967) studied the outline of the Niger Delta and suggested that the major source rocks were shales of the Akata Formation. Well sections through the Niger Delta generally display three vertical lithostratigraphic subdivisions: an upper delta top facies; a middle delta front lithofacies; and a lower pro-delta lithofacies (Reijers *et al*, 1996). These lithostratigraphic units correspond respectively with the Benin Formation (Oligocene-Recent), Agbada Formation (Eocene-Recent) and Akata Formation (Paleocene-Recent) respectively.

The Akata Formation is composed mainly of marine shales, with sandy and silty beds which are thought to have been laid down as turbidites and continental slope channel fills.

It is estimated that the formation is up to 7,000 meters thick (Doust and Omatsola, 1990). The Agbada Formation is the major petroleum-bearing unit in the Niger Delta. The formation consists mostly of shoreface and channel sands with minor shales in the upper part, and alternation of sands and shales in equal proportion in the lower part. The thickness of the formation is over 3,700 meters. The Benin Formation is about 280 meters thick, but may be up to 2,100 meters in the region of maximum subsidence (Whiteman, 1982), and consists of continental sands and gravels. Oboh et.al, (1992), studied the palynology and lithology of Miocene of the Igbomoturu-1 Well, Coastal swamp and interpreted the environment of deposition as transitional with marine influence. The Niger Delta where V-well is located is considered as one of the most prolific hydrocarbon provinces in the world and recent giant oil discoveries in the deep-water areas suggest that the region will continue to remain a focus of exploration activities for a very long time. Because of its economic importance as a petroliferous province, it has been widely drilled by oil industries. This study was undertaken with a focused on documenting the recovered palynomorphs, among the recovered palynomorphs the diagnostic species was used to establish the stratigraphic intervals of the well, interpret the age, and paleoenvironment of deposition of sediments in the well sections under study, in the Niger Delta Basin, for the resolution of petroleum exploration.

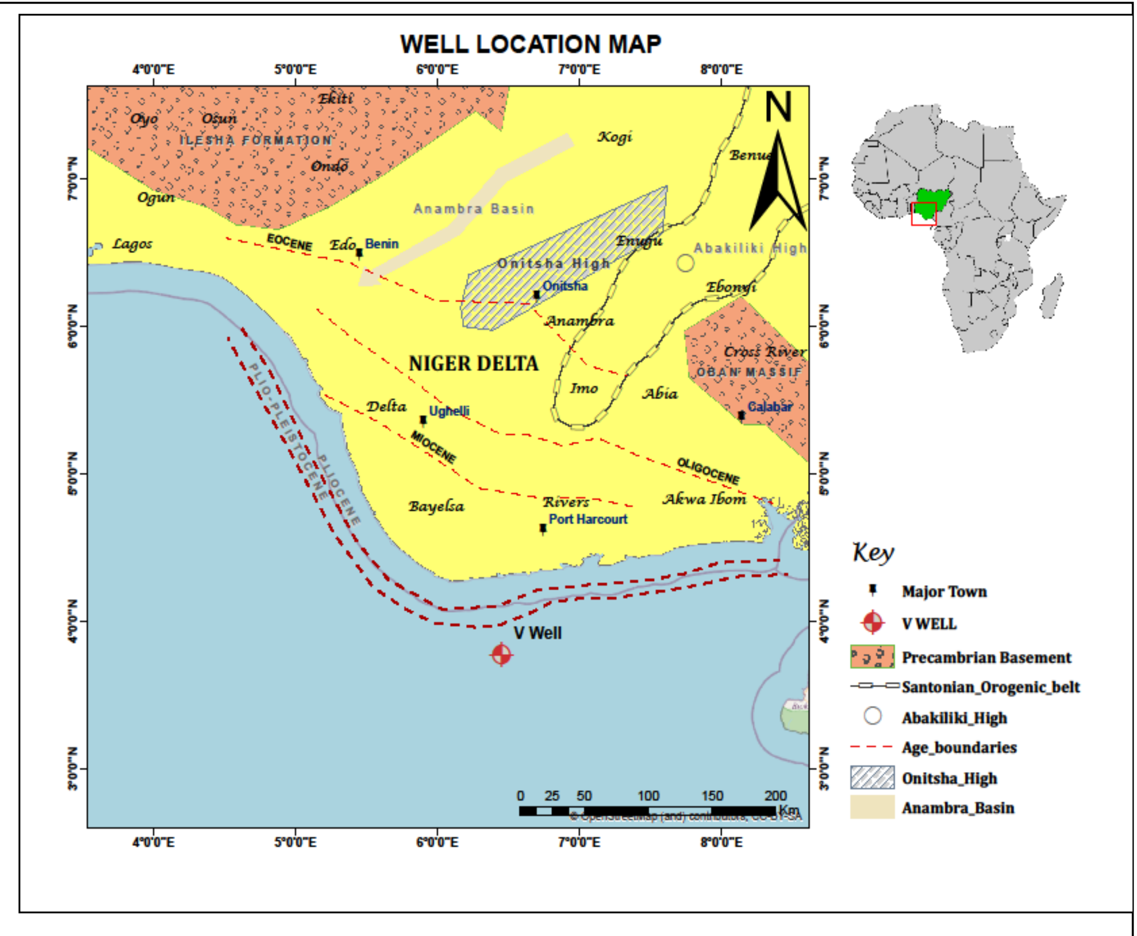

Fig. 1: Map of Niger Delta showing the studied well.

II. LITHOSTRATIGRPHY OF THE NIGER DELTA

The Tertiary Niger Delta was deposited in three major sequences which have been shown by well sections drilled vertically within these environments. The Niger Delta lithostratigraphic units have been reported to be strongly diachronous (Stacher, 1995). According to Short and stauble (1967), Hosper (1975), Avbovbo (1978), and Petters (1982), many other workers and multinational companies that carried out work in this area have recorded that the major lithostratigraphic sequences or units found within the Niger Delta include, the Benin Formation, Agbada and Akata Formations respectively Fig. 2. These formations showed intercalating of sand, shale, silt and/or sandstone facies equivalents which represent the delta plain, delta front and prodelta environments

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(i) Benin Formation: Directly overlying the Agbada Formation is the upper continental deltaic plain called the Benin Formation. It is mainly made of fresh water, fluviatile sands and gravels

with occasional coal seams, lignites and shale beds of about 2500 meters (8,250ft) thick. Evamy *et al.*, (1978) reported that this formation has 9:1 sand/shale ratio interbeds. The sand varies in grain size from fine to very coarse and sometimes pebbly in places. Sorting is more or less poor and grains are subangular to well rounded, yellowish brown to clean quartz grains, which are occasionally ferruginized (hematite stains).

Many companies exploring for oil in the Niger Delta had arbitrarily defined the base of Benin Formation by the deepest fresh water bearing sandstone that exhibits high resistivity. However, the base of this formation is defined by the first marine deposit (Short and Stuable, 1967) and this includes massive coarse-grained sands from the non-marine (Coastal deltaic) or continental environment that make up this formation. This formation is commonly cross-bedded and also seldomly faulted. However, Benin Formation is dated Oligocene to Recent in age (Short et al, 1967).

(ii) Agbada Formation: This formation is overlain by the continental sand sequence of the Benin Formation and is characterized by paralic to marine deposits mainly composed of sandstones and shales organized into coarsening (shoaling) upward off lap cycles. The Agbada Formation is diachronous with a thickness of about 4,500 meters (14,850ft). This formation ranges in age from Upper Miocene in the north to Pliocene – Pleistocene in the south. Avbovbo, (1978) and Oyofo (1983) documented that the sands of the Agbada Formation are the main reservoirs in the Niger Delta with shale providing lateral and vertical seal. The sediments vary from fine to very coarse grained, light to reddish brown (ferruginized), poorly to well sorted and unconsolidated to fairly consolidated. The shales on the other hand are dark to light grey, hard to moderately hard and subfissile to fissile with occasional shell fragments occurrences. However, Ekweozor and Okoye, (1980) reported that the shale of the lower Agbada Formation has the potentials for hydrocarbon generation.

(iii) Akata Formation: The basal sedimentary unit of the Niger Delta is the Akata Formation which includes at least 6,500 meters (21,400ft) of marine clays with silty and sandy interbeds (Whiteman, 1982). This formation is overlain by the paralic sand/shale sequence of the Agbada Formation representing 3:2 ratio of sand to shale (Evamy *et. al.*, 1978). The paralic sand/shale succession in this formation is attributed to the differential subsidence of these sediment and shifts of the delta depositional axes which cause local transgressions and regressions. In the same vein, Beka and Oti, (1995) reported that this formation has a clastic sediment thickness of about 6,000 meters (19,800ft). This formation is composed of shales, generally dark to light grey in colour and sandy to silty in (Asseez, 1976).

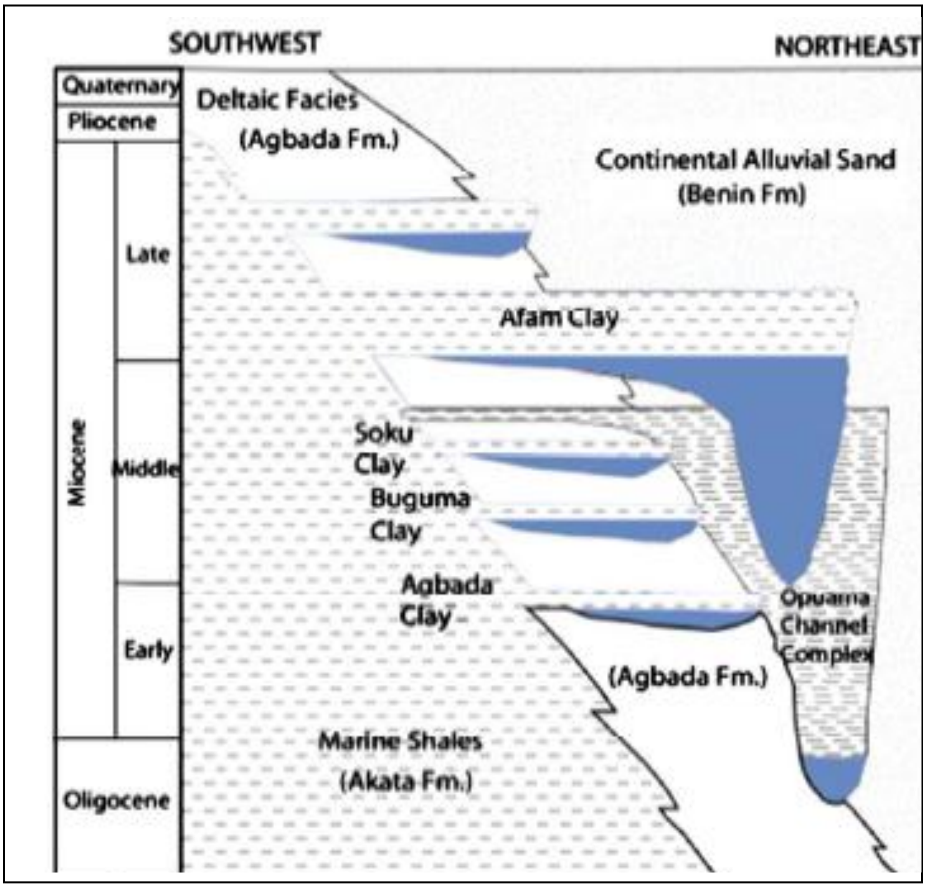


Fig. 2: Stratigraphic column showing the formations in the Niger Delta (Source: Doust and Omatsola, 1990).

III. METHODOLOGY

Sixty-four (64) ditch cuttings were disaggregated to increase its surface area. The samples were subjected to treatment with Hydrochloric acid (HCl) to remove carbonates, and then thoroughly washed with distilled water after decanting the HCl. Hydrofluoric acid (HF) was added to the samples to dissolve the silicates. The samples were stirred at regular intervals with a nickel rod and then left overnight in the fume cupboard then thoroughly washed with distilled water after decanting the HF. The samples were then treated first with warm 36% HCl and then cold HCl to remove fluoride gels and then thoroughly washed with distilled water. Then washed the samples with 0.5% HCl and then transfer the samples into small 15cc. centrifuge tubes. The 0.5% HCl was decanted after centrifuging and the Zinc bromide (s. g. 2.2) was added. This step separates the dense mineral fraction from the light organic residue and concentrates the organic residue. The floating top part consisting of palynomorphs was gently decanted into another tube. A small quantity of glycerine jelly was put in the centre of clean slides and a small quantity of organic residue was added and warmed. The mixture was spread out evenly, and covered with a cover slip, and the slides labelled. The slides were studied under a transmitted light microscope, palynomorphs assemblages were identified. The distinctive forms for age and environmental value were selected and captured. The data obtained was used to generate palynomorphs distribution chart, age and paleoenvironmental interpretation.

IV. RESULT AND DISSCUSSION

A lithostratigraphy is the classification of bodies of rock based on the observable lithological properties of the strata and their relative stratigraphic positions. The sediments of V well penetrated the Agbada Formation as observed apparently from the lithology, which are made up of paralic development of sands and shales with silt intercalations, Table 1. The sand is clean, white to milky white, fine to coarse grained, well sorted, sub-angular to sub-rounded and slightly ferruginized. The shale is light grey, sub-fissile to fissile, moderately hard, micromicaceous plus rootlets, and glauconites. Inference drawn from sediments showed that the deposits are characterized by fine to coarse grained sands, sandstones, shales and silt/siltstones intercalations.

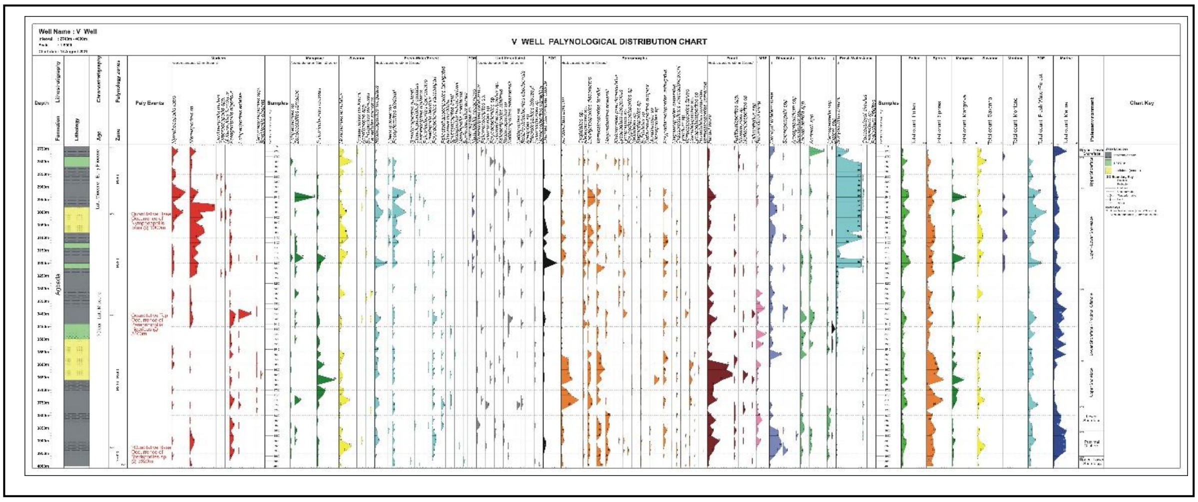
DEPTH (m)	***LITHOLOGY***	***LITHOSTRATIGRAPHY***
2740 – 2820	Predominantly shale/sand with intercalation of minor silt.	**AGBADA FORMATI ON**
2820 – 2920	Predominantly sand and shale with sandstone intercalations.	
2920 – 3060	Predominantly sand and shale	
3060 – 3640	Predominantly shale and sand intercalations.	
3640 – 4000	Predominantly shale/sand with silt intercalations.	

Table 1: Lithostratigraphic interpretation of V-well.

Biostratigraphy of V-Well.

The studied section of V well ranges from 2740-4000 m. The spread of palynomorphs varied from one depth to another. The analysed intervals yielded abundance and diverse land derive palynomorphs and marine forms such as: *Stereisporites* sp, *Monoporites annulatus, Rugulatisporites* sp, *Verrucatosporites tenellis, Gemmatricolporites* sp, *Elaeis guineensis, Psilatricolporites* sp, *Echitricolporites spinosus, Ipomaea digitate, Peregrinipollis nigericus, Belskipollis elegance, Psilatricolporites crassus, Retibrevitricolporites obodoensis/protrudens, Echiperiporites estelae/echinatus, Crassoretriletes vanraadshooveni, Verrucatosporites leavigatus, Aletesporites* sp, *Lygopodium neogenicus,* fungal spore, *Multiaerollites formusus, Smoothtrilete spore, Podocarpus milanjianus, Magnastraitites horwadi, Retitricolporites irregularis/amanzoensis, Nympheapollis clarus, Pachydermites diederixi, foraminiferal test linning, Dinocysts indeterminate, Spiniferites* sp, *Acritarch* sp, *Leiosphaeridia* sp, *Pterospermella* sp, *Concentricystes circulus* and *Botryococcus braunii*. Biozonation was established based on pollen and spores. Zonation scheme of Germaraad et al, (1968) and Evamy et al, (1978) was adopted for this study. Due to the rare occurrence of some marker species, some subzones were lumped together for a successful definition of the affected boundary (Figure 3 and Table 2). The sections encountered within this study belong to *Echitricolporites spinosus* zone of Germeraad et al, (1968). The recovered palynomorphs were used in zoning and dating the boundaries encountered within the intervals of the well sections. Four palynological subzones were defined, the P860, P850, P830-P840 and P820, Table, 2.

Using the Stratabugs software the distribution charts comprising of depth, formation, lithology, chronostratigraphy, palynological zones, marker species, palynological events, and palynomorphs abundance and diversity trends were plotted, Fig. 3.



Fig, 3. **Palynomorphs distribution, abundance, formation, age and paleoenvironment.**

From the analysis, the identified pollen and spores diversities were ninety two (92) species as illustrated in figure 3. The recoveries comprises of pollen, spores, algae, and dinoflagellates cysts, while the marker species were nine (9) namely; *Nympheapollis lotus, Stereisporites* sp, *Cinctiperipollis mulleri, Cyperaceopollis* spp, *Multiaerollites fomorsus, Peregrinipollis nigericus, Echiperiporites estelae, Gemmamonoporites* sp *and Belskipollis elegance* and more of the same shown in figures 4, 5 and 6 were identified respectively. Based on the distribution, diversity and abundance of pollen and spores identified, inferences were made from the plotted graphical chart figure 3. These include the age, palynozones and events by Evamy et al, 1978, miospores diversities and abundance as well as the environment of deposition of sediments.

Table 2: SEummary of Palynostratigraphic Succession Showing the Zones.

Interval (m)	*P-Zone*	*Age*	*Paly event*	*Remarks*
2740-3200	P860 and ?Younger	Late Miocene - Early Pliocene	Quantitative base occurrence of *Nympheapollis clarus* at 3200 m	The quantitative base occurrence of *Cyperaceopollis* sp was not observed, Therefore the P840 and P830 were made composite.
3200 – 3400	P850	Late Miocene and ?Older	Quantitative top occurrence of *Peregrinipollis nigericus* at 3400m	
3400 – 4000	P840 – P830		Base continuous occurrence of *Stereisporites* sp at 4000m	
4000	P820 and ?Older			The base of this subzone was not encountered under this study.

Using the zonation scheme of Evamy et al, 1978, four (4) subzones were established for this study. These include: the P860, P850, P840-P830 and P820 respectively, Table 2.

P-Zone: P860

Interval definition: The top of this subzone was not encountered in this study as *Retistephanocolpites gracillis* was not observed at all. The base was however placed at 3000 m utilizing the quantitative base occurrence of *Nympheapollis lotus* at this depth. The microfloral assemblage that support the existence of P860 within this interval of the well includes the absence of *Retistephanocolpites gracillis*, high percentage occurrences of *Stereisporites sp* and *Nymphaeapollis claus*, fairly rich occurrences of *Monoporites annulatus* and *Aletesporite* sp as well as the low occurrences of *Elaeis guineensis* and *Multiaerollites formosus*. The P860 subzone is dated Late Miocene – Early Pliocene by Evamy et al., (1978).

P-zone: P850

Interval definition:

The top of the P850 was defined by the base occurrence of *Nymphaeapollis clarus* at 3000 m while the base was delineated at 3400 m with the base occurrence of *Peregrinipollis nigericus*. The microfloral characteristics of the P850 subzone observed which support this interpretation are the high occurrence of *Stereisporites* sp, low occurrences of *Nymphaeapollis clarus, Peregrinipollis nigericus* and *Psilatricolporites crassus,* and the scarce occurrence of *Multiareolites formosus.* The P850 subzone is dated Late Miocene by Evamy et al., (1978).

P-zone: P830 – P840

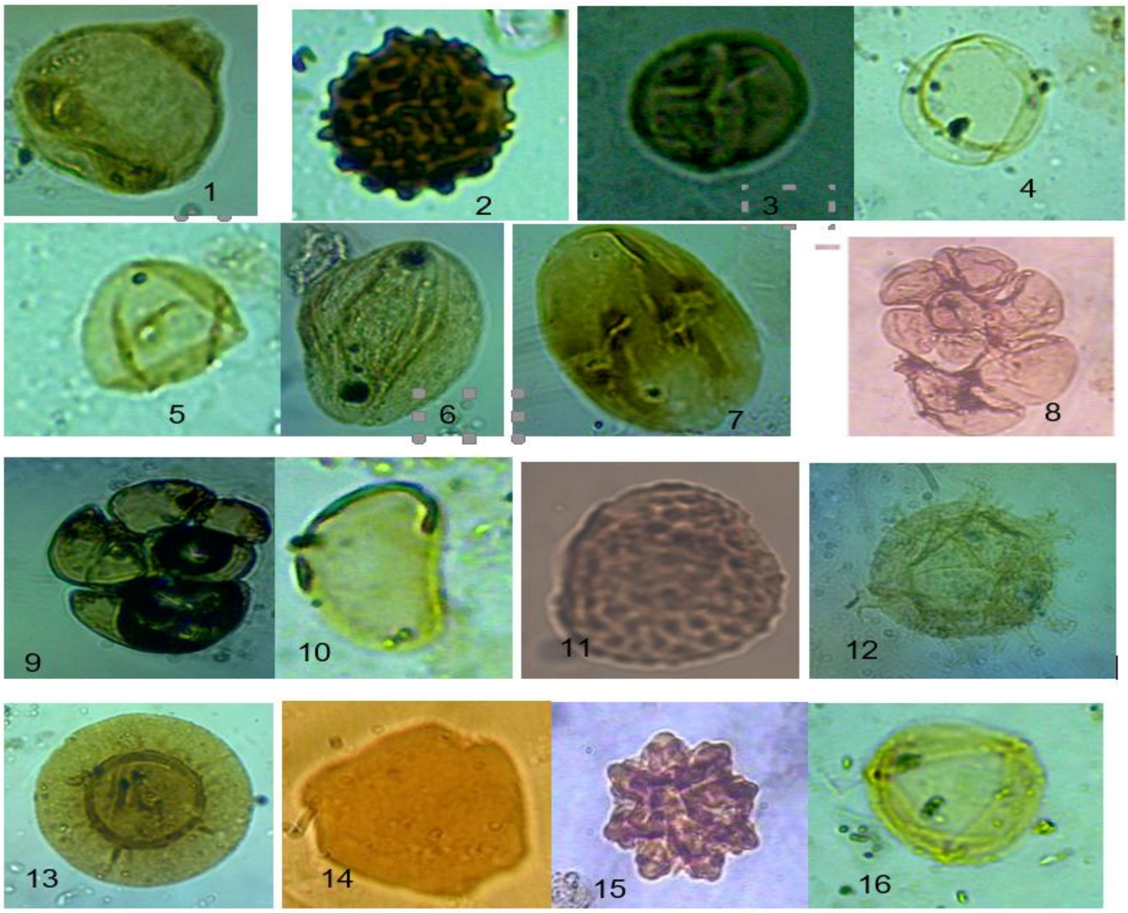
Interval definition:

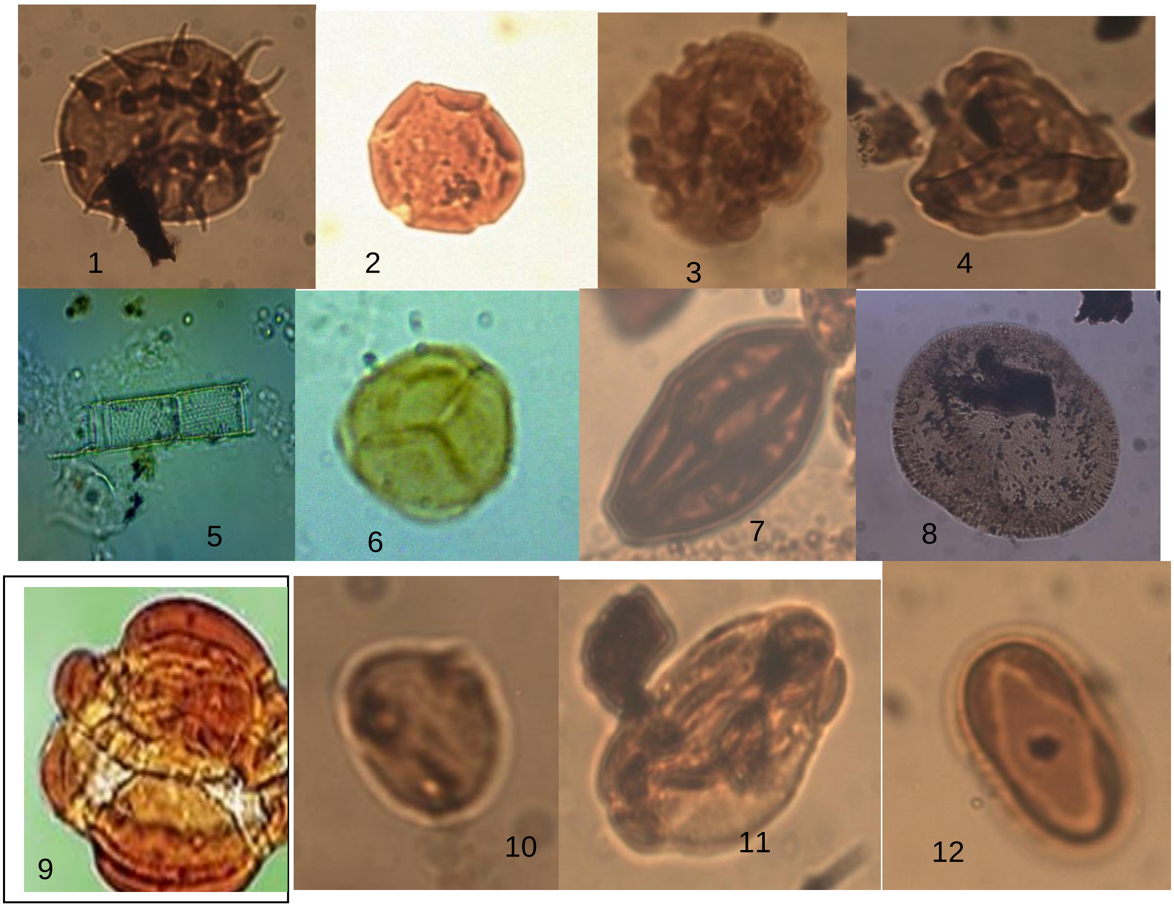
The top of the P830–P840 subzone was placed at the quantitative top occurrence of *Pereginipollis nigericus* at 3400 m while the base continuous occurrence of *Stereisporites* sp at 3920 m was used for the definition of the base. The quantitative base occurrence of *Cyperaceopollis* sp. which would have enabled the P830 and P840 boundary definition was not observed within this interval. Therefore, the two subzones were lumped in this interval. The fair presence of *Crassoretitriletes vanraadshooveni,* fairly rich of *Monoporites annulatus,* high occurrence of *Pereginipollis nigericus* and the presence of *Adenantherites simplex* support the penetration of P830–P840 subzones within this interval of the well. The P830 and P840 subzones are dated Late Miocene according to Evamy et al., (1978).

P-zone: P820

Interval definition:

The top of the P820 subzone coincides with the base of the overlying subzone defined at 3920 m. The base was not encountered in this study since the quantitative base occurrences of *Multiaerolites formosus* and *Echiperiporites estelae* were not observed within the interval of the well. The presence of *Alchornea cordifolia, Polyadopollenites vancampori* and the rare occurrence of *Crototricolporites crotonoisculptus* further support the existence of P820 subzone within this interval of the well. The P820 subzone was dated Late Miocene and? Older by Evamy et al., (1978).





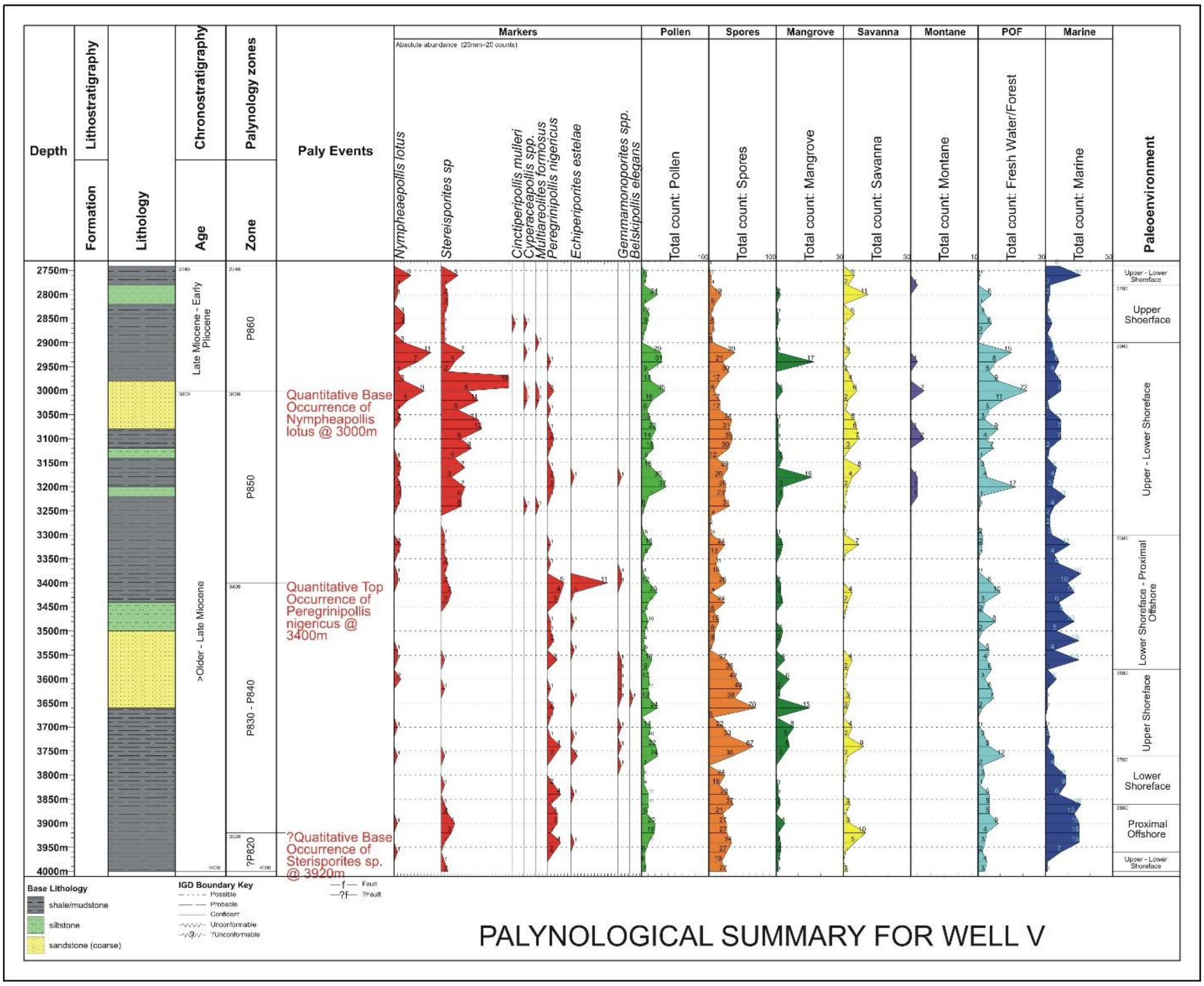
Fig, 5. Plate 2. Photomicrograph of pollen and spores collections (X1000).

1. *Echiperiporites echinatus*
2. *Pachydermites diederixi*
3. *Peregrinipollis nigericus*
4. *Lycopodium* sp
5. *Diatom frustule*
6. *Stereisporites* sp
7. *Fungal spore*

8. Diatom
9 &11. Marginipollis concinnus
10. Retibrevitricolporites protrudens
11. Multiaerollites formosus

Paleoenvironments

Paleoenvironmental analysis helps in reconstructing the biological, chemical, and physical nature of the environment at the time of deposition. Relative abundance of land derive pollen and spores and marine dinoflagellates cysts were used by Lawal, (1982); Schrank (1984); Edet and Nyong (1993); Ojo and Akande 2006. Fluctuations in the relative abundance and diversities of terrestrial palynomorphs as well as environmentally significant marine forms were integrated in the interpretation of the depositional environment of the sediments. The result revealed that the sediments were deposited within shallow marine settings.



Fig, 6. Various paleoecological group of the studied intervals.

From the above graphical plot figure 6, it shows that marine was the most dominance among the miospores followed by spores, freshwater algae, pollen, mangrove, savanna and least is montane elements. The dominance of marine and spores could be as a result of sea level rise and fall suggesting deposition within the upper - lower shoreface (shallow marine) settings.

V. CONCLUSION

Sixty-four ditch cuttings sampled at 20 m intervals were analysed. Quantitatively the samples yielded ninety-two species (92) species, marine forms were the dominance over other species recovered. The result of this analysis reveals that the sediments of V-well were deposited during Late Miocene - Early Pliocene. Using the approach of Evamy et al., (1978), four subzones were identified, the P860 (*Nympheapollis lotus*),

P850 (*Peregrinipollis nigericus*), P840-P830 (*Cyperaceopollis* sp), and P820 (*Stereisporites* sp). The subzones encountered in this study belong to Echitricolporites spinosus Pantropical zone of Germaraad et al, (1968). This study revealed that most of the species fall within the shallow marine based on the abundance and diversities of pollen, spores, and marine with their respective paleoenvironments.

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