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Paleoenvironment and Palynozonation of Osere-004 Well sequences, Niger Delta. Nigeria

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Abstract:- Paleoenvironmental interpretation and palynozonation was carried out using fifty ditch cutting samples ranging from 7020 ft – 10020 ft, with a total thickness of 3000 m from Osere-004 Well. The lithology of the ditch cuttings was described and analysed using wet-sieving technique. Palynological sample preparation was also carried out on the ditch cuttings following the non-mineral acid method and was analysed using transmitting light microscope. The lithologic description and wet-sieve analysis generated the lithology and sand-shale ratio/gradational plot. The palynological analysis indicated the palynomorphs recovered from the palynological sample preparation which were grouped in their paleoenvironments. The statistical analysis of the recovered palynomorphs indicated dominance in terrestrially derived palynomorphs (Pollen and spores) over marine derived palynomorphs. This indicated deposition within continental (fresh water to brackish water) environment to nearshore marine and open marine environment. The ditch cuttings were deposited during the late Miocene to early Pliocene times and corresponded to P870 to P860 of the SPDC palynological zonation.

Keywords:- *Paleoenvironment, Palynozonation, Lithostratigraphy, Sand-Shale Ratio, Gradation.*

I. INTRODUCTION

Osere-004 Well is one of the producing oil wells in the shallow marine fringes of the Niger Delta. It is located within the 100 m depth shallow water areas of the Niger Delta. The Niger Delta is one of the South-Eastern Nigeria sedimentary basins which are characterized by three major sedimentary circles following the separation of the South American plates from the African plate during the Jurassic to the middle Cretaceous (Lehner and De Ruiter, 1977). The first major sedimentary circle started in the Aptian/Albian with lithic sedimentary in-filling of the Benue Trough and the Calabar Flank which was truncated with the magmatism and folding of the Cretaceous deposits in the Santonian. The Trough represented the failed arm of the rift system that separated the South American plate from the African plate. The second phase of sedimentation which is post-Santonian, constituted the Campanian marine transgression (Nkporo Shale) that filled the Anambra basin and the Afikpo syncline and ended with a major transgression in the Paleocene with the deposition of the Imo shale in the Anambra basin and Akata Formation in the Niger Delta, leading to the growth of the proto-Niger delta. The continuous growth of the Niger delta giving rise to the present day Niger delta since the Eocene to present represents the third phase of sedimentation. The present day Niger delta is divided into three lithostratigraphic units, comprising the marine shale Akata Formation, the alternating marine shale and continental sand Agbada Formation and the topmost blanket of continental sand Benin Formation. Two of these lithostratigraphic units (Akata and Agbada Formations) are syn-sedimentary to southwestward prograding sedimentation cycles and faulting that gave rise to five depo centers. These depo centers referred to as depobelts were the result of differential responses of the denser Agbada Formation on a less dense, poorly compacted and over pressured clays of the Akata Formation as well as the lack of lateral basin-ward support (Ukpabi*et al*., 2020), giving rise to variable rates in subsidence and sediment accumulation (Doust and Omatsola, 1990).

Fifty ditch cutting samples ranging from 7020 ft – 10020 ft, with a total thickness of 3000 m from Osere-004 Well was prepared and analysed for paleoenvironmental interpretation and palynozonation. The Osere-004 Well is located at Longitude 6°20'3.978"E and Latitude 3°52'23.022"N (Fig. 1).

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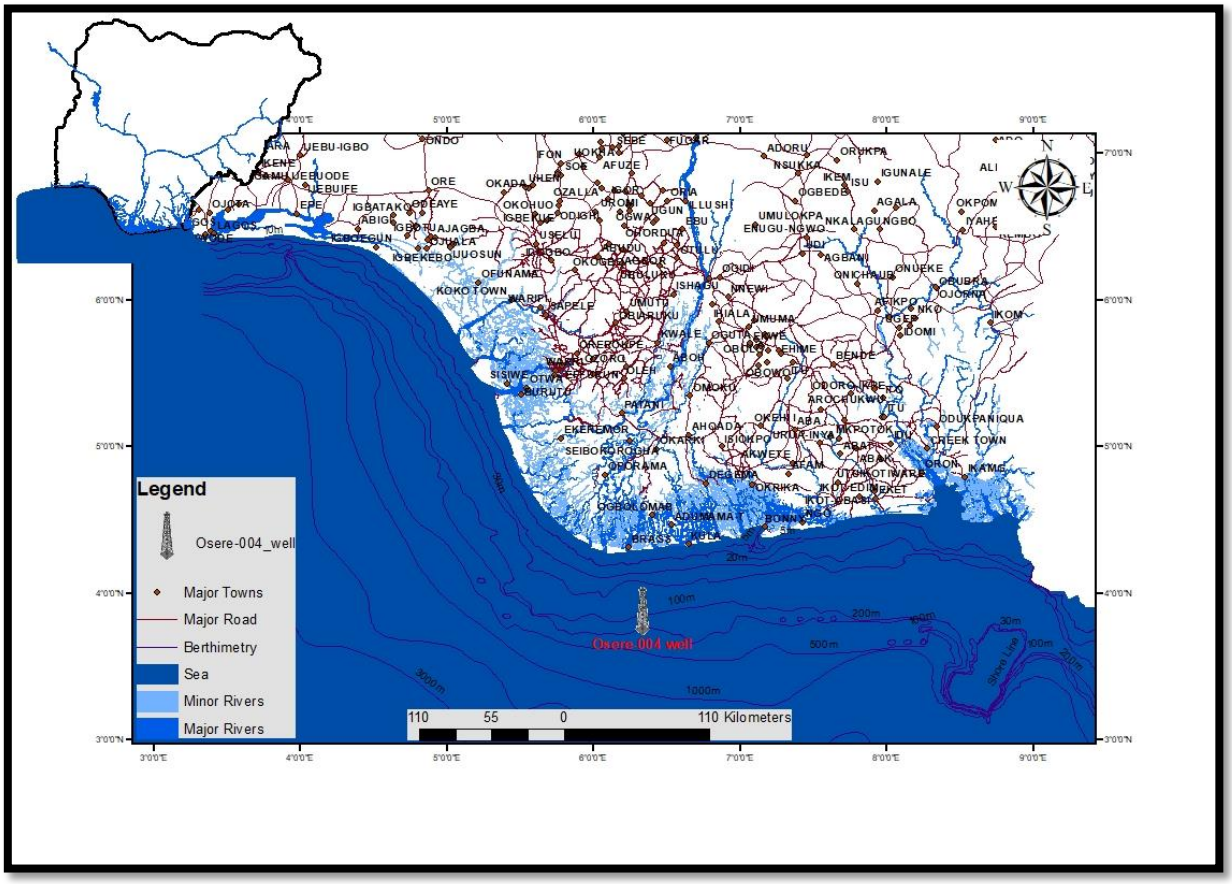

Fig. 1: Map of Osere-004 Well

II. METHOD OF STUDY

The fifty ditch cuttings recovered from Osere-004 Well were lithologically described to determine the samples lithological components such as grain sizes and shape, presence of carbonate materials etc. The samples were wet-sieved to determine the percentage passing of sample grains at different grainsizes corresponding to clay, fine, medium and coarse. The data generated from the lithologic description and wet-sieve analysis were used to generate lithologic log and sand-shale ratio/gradational plot. The samples were prepared into palynological slides following the standard non-mineral acid method using Sodium Hexametaphoste as deflocculant. The prepared palynological slides were analysed under a transmitting light microscope to identify the palynomorphs recovered in the palynological slides. The occurrence frequencies of identified palynomorphs were recorded, and the palynomophs grouped into their paleoenvironment. The result of the analyses was presented as charts using StrataBugs V2.0.

III. RESULTS

A. *Lithostratigraphy of Osere-004 Well sequences*

The lithologic sequence of Osere-004 well covered a depth range of 7080 ft – 10020 ft, with a total thickness of 3000 m (Tables 1, Fig. 2)

The upper 310 ft (7080 – 8080 ft) of the studied interval of Osere-004 well consists of sand with shale streaks, the sand ranged from very fine to medium grained in texture. The sand is grey, very fine to medium grained, very silty, very well sorted, clayey and loosely consolidated (Table 1). Accessory minerals in the section include few heavy minerals, rare mica flakes and pyrite.

Below the upper section is shale with sand streaks and minor silt band sequence measuring about 1940 ft (8080 – 10020 ft). The shale is dark grey very silty, calcareous and frangible with accessory minerals such as few pyrite and plant remains, rare mica flakes and shell fragments (Table 1).

The lithological description of Osere – 004 well ditch cutting sample is presented as a lithological log in figure 2, while the result of the wet-sieve analysis in table 2 was plotted into sand/shale ratio and gradational profile and presented in figure 3.

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Table 1: Summary of the lithostratigraphic description of Osere-004 well

Depth (ft)	Lithology	Lithostratigraphy
7080 - 8080	Sand with shale streaks.	Agbada Formation
8080 - 10020	Shale with sand streaks and minor silt band.	

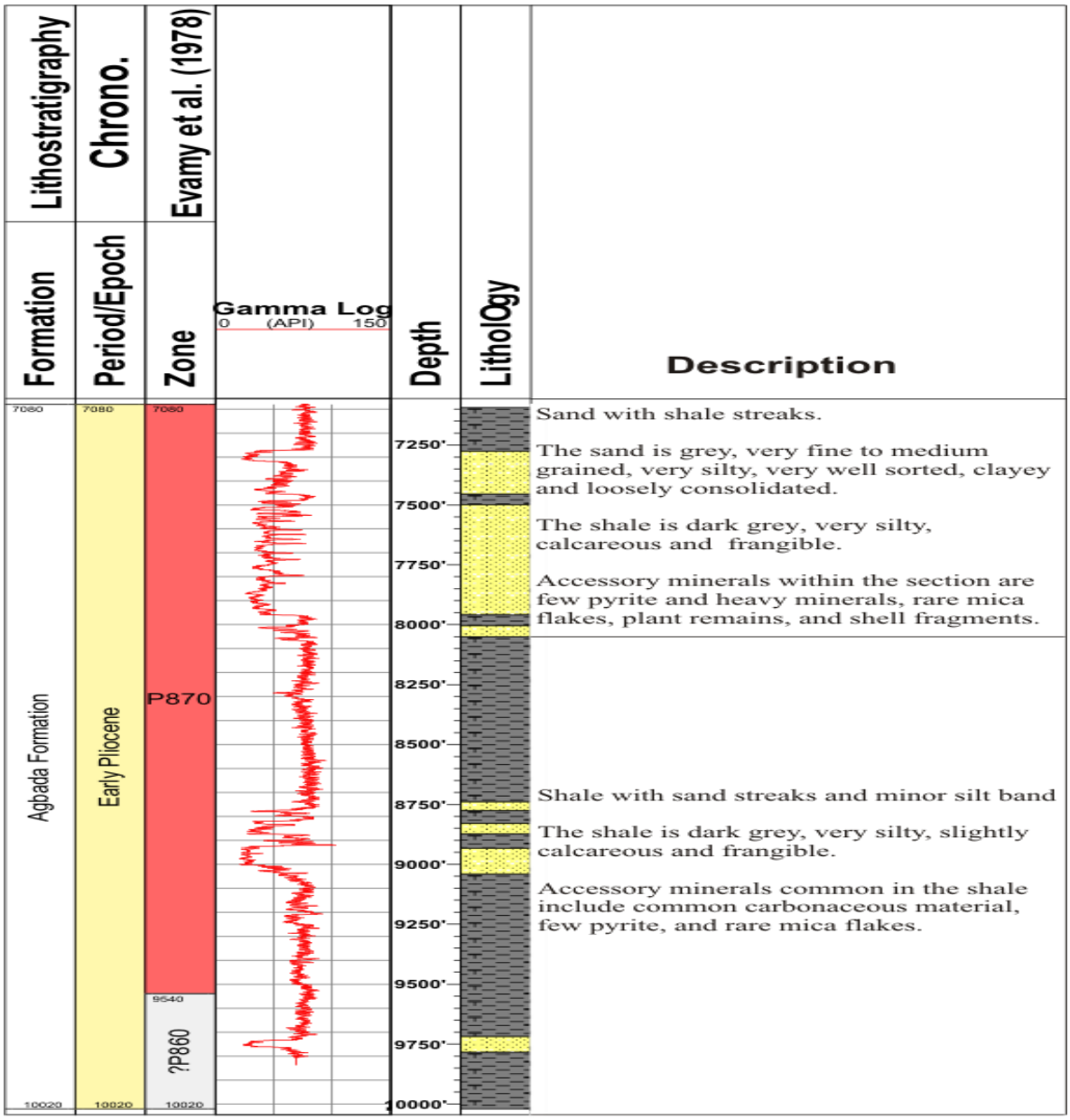

Fig. 2: Lithologic section showing lithostratigraphic description of Osere-004 well

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Table 2: Wet-sieve analysis result of Osere-004 well in grams and normalized percentage

Depth	Initial weight (g)	Weight Loss (g)	weight retained (g)			Total wt Retained	Weight Retained (%)		
		(<63 um)	(>500um)	(>250 - <500um)	(>63 - <250um)		% (>500um)	% (>250 - <500um)	% (>63 - <250um)
7080	30	9	6	8	7	21	28.57143	38.09524	33.33333
7120	30	17	5	4	4	13	38.46154	30.76923	30.76923
7180	30	21	4	1	4	9	44.44444	11.11111	44.44444
7240	30	20	5	3	2	10	50	30	20
7300	30	27.5	0.5	1	1	2.5	20	40	40
7360	30	28	0.5	0.5	1	2	25	25	50
7420	30	27.5	1	0.5	1	2.5	40	20	40
7480	30	29.5	0	0	0.5	0.5	0	0	100
7540	30	13	7	4	6	17	41.17647	23.52941	35.29412
7600	30	10	6	4	10	20	30	20	50
7660	30	10	3	3	14	20	15	15	70
7720	30	10	6	5	9	20	30	25	45
7780	30	13	4	3	10	17	23.52941	17.64706	58.82353
7840	30	12	2	4	12	18	11.11111	22.22222	66.66667
7900	30	9	7	3	11	21	33.33333	14.28571	52.38095
7960	30	29.5	0	0	0.5	0.5	0	0	100
8020	30	6	8	7	9	24	33.33333	29.16667	37.5
8080	30	19	1	1	9	11	9.090909	9.090909	81.81818
8140	30	21	1	1	7	9	11.11111	11.11111	77.77778
8200	30	21	1	1	7	9	11.11111	11.11111	77.77778
8260	30	19	1	1	9	11	9.090909	9.090909	81.81818
8320	30	23	1	1	5	7	14.28571	14.28571	71.42857
8380	30	20	1	1	8	10	10	10	80
8440	30	23	1	1	5	7	14.28571	14.28571	71.42857
8500	30	21	1	1	7	9	11.11111	11.11111	77.77778
8560	30	18	1	1	10	12	8.333333	8.333333	83.33333
8620	30	18	2	1	9	12	16.66667	8.333333	75
8680	30	20	2	1	7	10	20	10	70
8740	30	15	1.5	1.5	12	15	10	10	80
8800	30	22	1	1	6	8	12.5	12.5	75
8860	30	12	4	2	12	18	22.22222	11.11111	66.66667
8920	30	14	3	2	11	16	18.75	12.5	68.75
8980	30	8	5	5	12	22	22.72727	22.72727	54.54545
9040	30	9	4	6	11	21	19.04762	28.57143	52.38095
9120	30	13	1	4	12	17	5.882353	23.52941	70.58824
9180	30	13	1	3	13	17	5.882353	17.64706	76.47059
9240	30	15	1	3	11	15	6.666667	20	73.33333
9300	30	15	1	3	11	15	6.666667	20	73.33333
9360	30	16	1	3	10	14	7.142857	21.42857	71.42857
9420	30	14	1	3	12	16	6.25	18.75	75
9480	30	12	1	4	13	18	5.555556	22.22222	72.22222
9540	30	16	2	2	10	14	14.28571	14.28571	71.42857
9600	30	14	4	2	10	16	25	12.5	62.5
9660	30	22	1	2	5	8	12.5	25	62.5
9720	30	22	1	1	6	8	12.5	12.5	75
9780	30	11	1	3	15	19	5.263158	15.78947	78.94737
9840	30	16	3	2	9	14	21.42857	14.28571	64.28571
9900	30	14	3	2	11	16	18.75	12.5	68.75
9960	30	15	1	2	12	15	6.666667	13.33333	80
10020	30	17	2	1	10	13	15.38462	7.692308	76.92308

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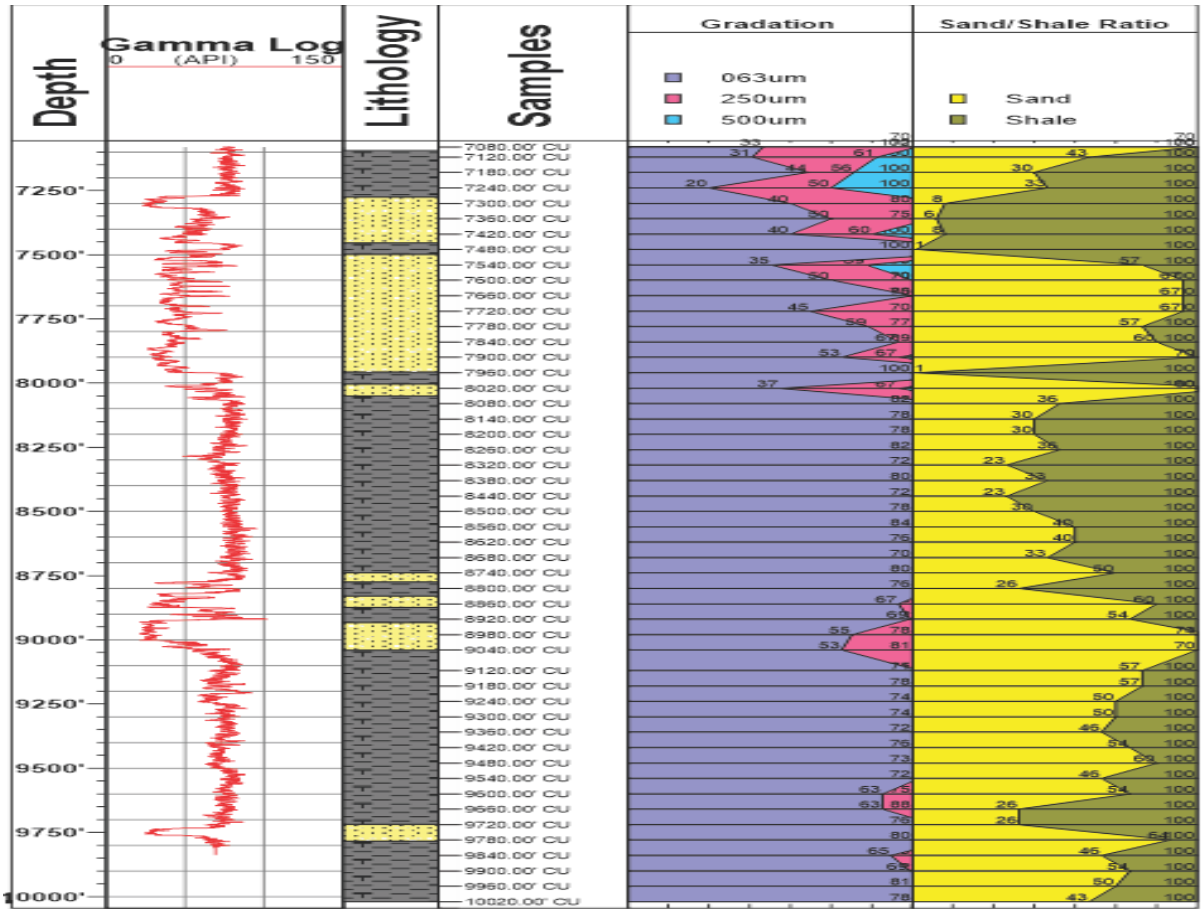

Fig. 3: Plot of sand / shale ratio per depth and gradational profile of Osere-004 well

B. Palynostratigraphy of Osere-004 well

Palynomorphs occurrence in Osere-004well include angiosperm and gymnosperm pollen, bryophyte and pteridophyte spores, fungal spores, dinoflagellates, diatoms, foraminiferal test linings and freshwater algae.

Statistical compilation of the palynomorphs indicated dominance in terrestrially derived palynomorphs (Pollen and spores) over marine derived palynomorphs (Fig. 4 and 5). The pollens are predominantly higher than all other palynological groups in most of the sampled interval as indicated in the following depths (7080 ft – 7360 ft; 7480 ft – 7600 ft; 8860 ft; 8980 ft – 9780 ft; 9900 ft – 1000 ft). Fresh water algae dominate in the following intervals 7420 ft; 7660 ft – 8800 ft; while spores dominate with highest occurrence at 8920 ft.

Terrestrially derived palynomorphs (pollen and spore) in the studied interval are significantly high ranging from 60% - 100% at various depths with significant drop between 7660 ft – 8800 ft ranging between 10% - 45% in occurrence. This interval with significant drop in terrestrial derived palynomorphs (Pollen and spore) show a marked increase in fresh water algae with occurrence ranging between 50% and 88%.

Marine derived palynomorphs (dinoflagellates and foraminiferal test linings) are very rare to barren with sporadic low occurrence. They constitute 0% of the total palynomorphs at many sampled depths and ranged between 0% to 4% in other sampled intervals, where they occurred sporadically.

Fungal spore occurrence is generally low in many of the sampled depths while diatom is rare to barren in many of the studied samples.

A cumulative of 35 (thirty-five) pollen species representing 35 (thirty-five) pollen genera were identified in the studied interval of Osere-004 well. These species occurred at varying counts at different depths in the studied well and include gymnosperm pollen *Podocarpidites sp.*, and angiosperm pollens such as*Cyperaceaepollissp,.Multiareolitesformosus, Nympheapollis lotus, Stereisporites sp., Retistephanocolpitesgracilis, Echiperiporites stelae, Peregrinipollisnigericus, Zonocostatitesramonae, Psilatricolporitescrassus, Monoporitesannulatus, Elaeisguineensis, Pachydermitesdiederixi, Psilastephanocolporiteslaevigatus, Striatricolpitescatatumbus, Retitricolporitesirregularis, Ctenolophoniditescostatus, Brevicolporitesguinetti, Margocolporitesrauvolfii, Psilatricolporitesannuliporis, Polyadopollenitesvancampori, Retimonocolpitesobaensis, Retitricolporitesamazoensis, Numulipollisneogenicus, Psilatricolporites sp., Echiperiporites sp., Alcornescordifolia, Gemmamonoporires sp. Psilatricolpites sp. Milfordia sp., Retibrevitricolporitesobodoensis, Polyadopollenites sp., Psilatriporites sp., Retimonocolpites sp.* and *Bombacaciditesceiba.*

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A cumulative of 19 (nineteen) pteridophyte and bryophyte spore species were identified in the studied interval of Osere-004 well. The spores consist of monoletes spores such as *Verrucatosporitesalienus*and*Verrucatosporitesfarvus*;trilete spores such as *Crassoretitriletesvanraadshooveni*, *Echitriletes sp.*, *Rugulatisporitescaperatus*etc. Others include *Acrostichumaurem, Laevigatosporitesdiscordatus, Lycopodiumsporites sp., Polypodiaceoisporitesretirugatus, Polypodiaceoisporites sp., Marathiacea sp., Lygodium sp., Klukisporitespseudoreticulatus, Matonisporites sp., Magnastriatiteshowardii, Distaverrusporites simplex, Lycopodium neogenicus*and*Lygodiumsporites sp..*, and *Aletesporites sp.* (Alete spores).

Other palynomorphs identified included freshwater algae such as *Concentricystescirculus, Pediastrum*and *Botryococcusbraunii*, anddiatom, fungi spore, foraminiferal test lining and dinoflagellate such as *Selenopemphix sp.* and dinocysts indeterminate.

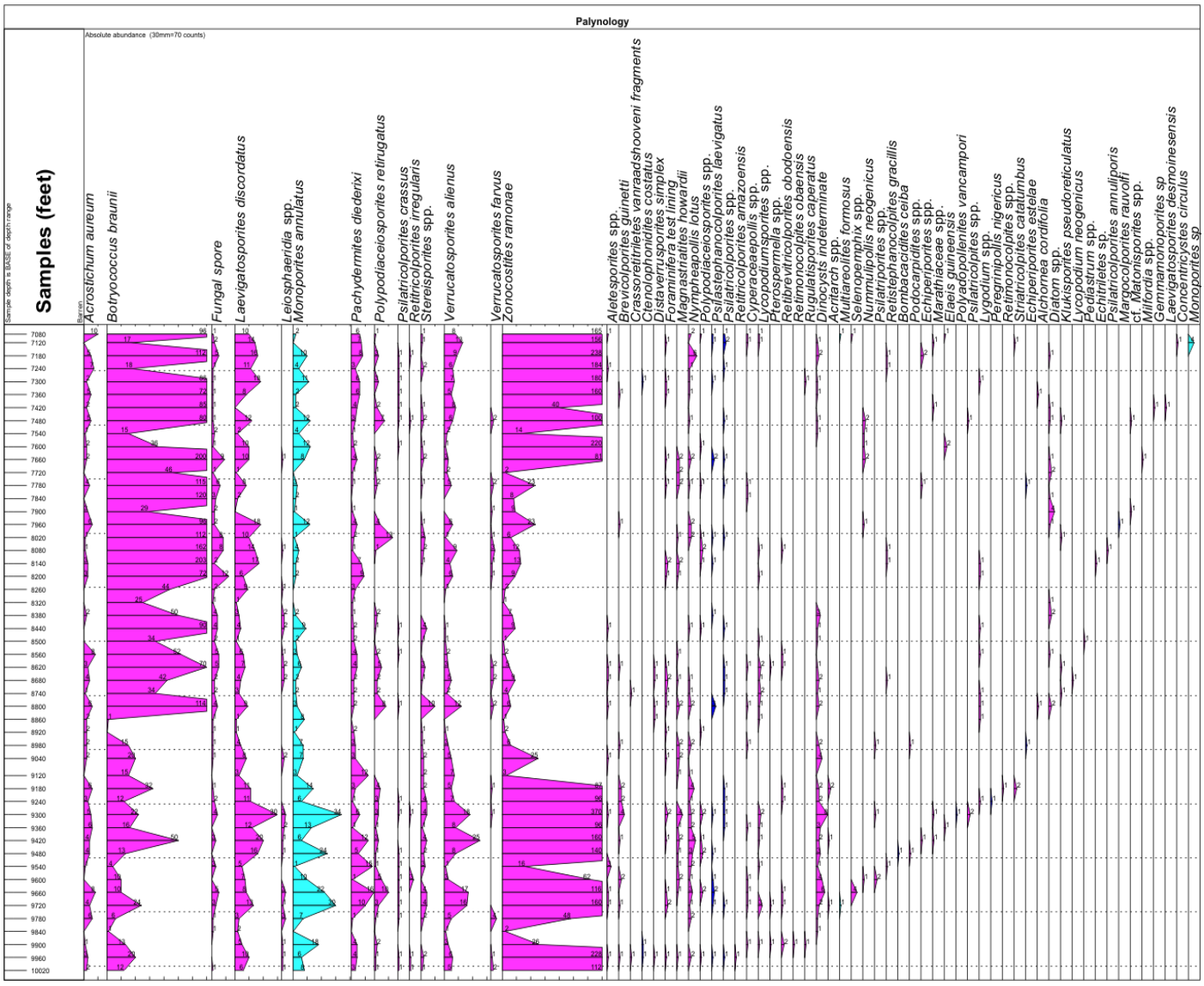

Fig. 4: The palynological distribution chart of Osere-004 Well with range and frequency of occurrence per sample depth

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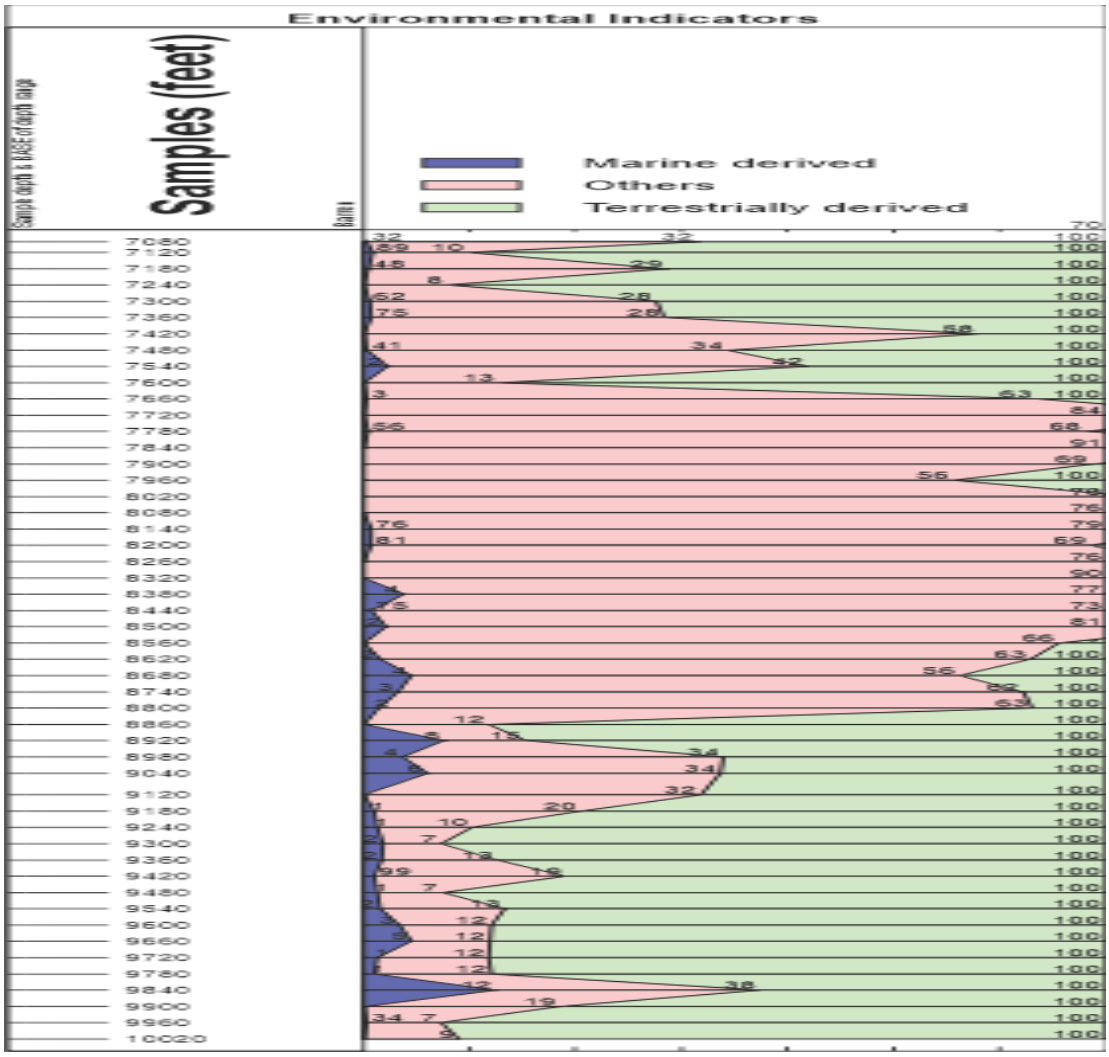

Fig. 5: Percentage quantitative composition of environmental indicators comprising of terrestrially derived palynomorphs, marine derived palynomorphs and other palynomorphs identified in Osere-004 well

IV. DISCUSSION

A. *Paleoenvironmental Interpretation*

The distribution of any particular fossil assemblage in any stratigraphic section may be controlled either by palaeoecological factors or as a result of evolution (Hamza *et al.*, 2002). Any change in fossil assemblage that corresponds with a change in lithology is probably due to the environmental tolerance of the fossil species rather than to evolution. Some fossils serve as environmental indicators and are used to interpretpaleoenvironment of deposition of ancient sediments. Also, the distribution of both body fossils and trace fossils depends on the environmental conditions that existed and the time organisms lived, died, or were buried.

The application of palynological data to paleoenvironmental reconstruction has been attempted by several authors (Battern, 1973, 1982; Van Bergen *et al*., 1990; Vadja-santivanez, 1998). Schrank (1984) in his organic-geochemical and palynological studies of the Late Cretaceous Dhakia Shale profile in South East Egypt concluded that pollen and spores decrease with distance from the shore; the palynofloral constituent of 0.0% - 35.0% reflects open marine; minimum of 35.0% to maximum of 60.0% reflects nearshore marine environment; while pollen and spore represented by a minimum of 80.0% to a maximum of 100% reflects continental conditions (fresh water to brackish water). For this work, the relative abundance of terrestrially derived pollen and spore and marine derived dinoflagellates and foram test linings (Figs. 4 and 5) are used to interpret the depositional environments of the studied wells following the scheme of Schrank (1984).

The interpreted paleoenvironments of deposition of the ditch cutting rock samples for the studied intervals in the three studied wells (Osere-004 well) are presented below in figure 6.

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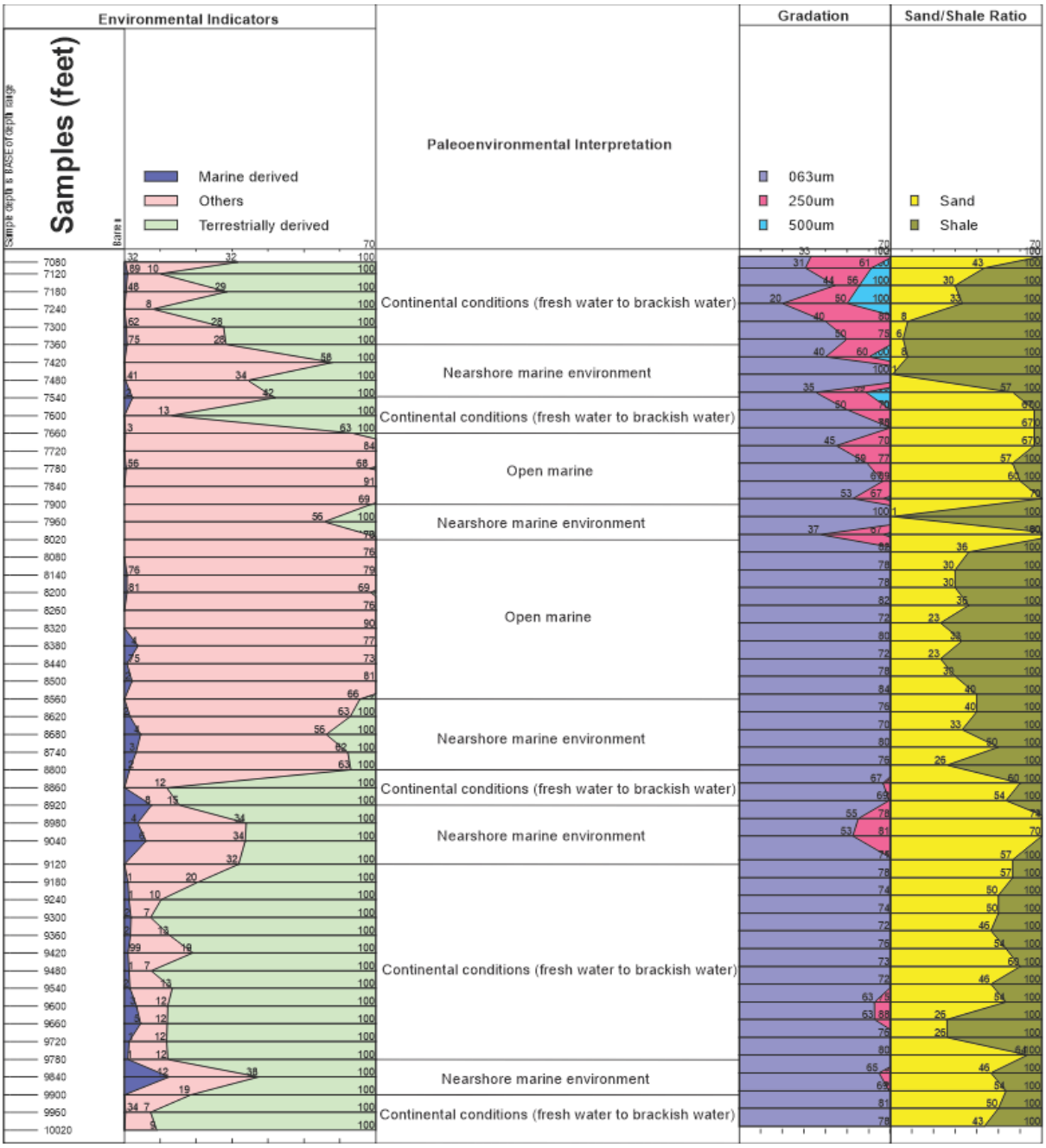

Fig. 6: Paleoenvironmental of deposition of Osere-004 wellditch cutting rock samples.

B. Biozonation

From the palynologicalanalysis and palynofloral distribution populated in the distribution chart of Osere-004 Well.?Late Miocene - Early Pliocene was interpreted for the interval studied.

Using the approach of Evamy*et al* (1978) the interval was divided into two subzones; P870 and P860, with the boundary between the two subzones placed at 9540ft utilizing the probable base occurrence of *Retistephanocolpitesgracillis* observed at 9540ft depth.

Below is the summary of the interpretation shown in a tabular form (Table 3) while the detailed interpretation is presented below:

Table 3: Summary of biozonation in Osere-004 Well

Interval (ft)	Age	P – Zone	Comment
7080 - 9540	Early Pliocene	P870	The index species used for this interpretation is *Retistephanocolpitesgracillis*. Because the occurrence of this species in the studied interval is rather sporadic, it is possible that the base observed is not its true base, therefore the base is questioned
9540 - 10020	?Late Miocene – Early Pliocene	?P860	

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Detailed Interpretation:
Interval: 7080 – 9540ft
P- Zone: P870
Age: Early Pliocene

Interval is defined by: ?base occurrence of *Retistephanocolpitesgracillis*at 9540ft.

The top of this P870 subzone is probably not encountered. The base was however delineated at 9540ft using the probable occurrence of *Retistephanocolpitesgracillis* at 9540ft depth.

Other characteristics of P870 observed within this interval include; moderate presence of *Retistephanocolpitesgracillis*, low occurrences of *Multiareolitesformosus*, *Elaeisguinetti*, *Nympheapollis lotus* and *Marathiaceaesp*, rich occurrences of *Stereisporites sp*. and *Psilastephanocolporiteslaevigatus* and the abundance of *Monoporitesannulatus* and *Zonocostitesramonae*.

This interval is dated early Pliocene(Evamy*et al*., 1978).
Interval: 9540 – 10020ft
P- Zone: ?P860
Age: Late Miocence - Early Pliocene

This interval is defined by: ?base occurrence of *Retistephanocolpitesgracillis*at 9540ft.

The top of this subzone coincides with the base of the P870 subzone above. The base was not encountered because there is no apparent quantitative base occurrence of *Nympheapollis lotus* encountered.

To support the interpretation of P860 subzone for this interval include low occurrence of *Multiareolitesformosus* and *Striatricolpitescatatumbus*, rich occurrences of *Stereisporites sp*., and *Retibrevitricolporitesobodoensis*,top rich occurrence of *Aletesporites sp*. and the abundance of *Zonocostitesramonae* and *Monoporitesannulatus.*

The P860 belongs to *Psilatricolporitesspinosus* Pantropical zone of Germeraad*et al*. (1968) and is dated Late Miocene – Early Pliocene.

V. CONCLUSION

The paleo environment of deposition of the studied samples of Osere-004 well indicated deposition within continental (fresh water to brackish water) environment to nearshore marine and open marine environment.

The study samples were deposited during the late Miocene to early Pliocene times and corresponded to P870 to P860 of the SPDC palynological zonation.

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