Geology, Palynomorphs distribution, Stratigraphy and Depositional Environments of Lewumeji ansd Idogun wells, Eastern Dahomey Basin Southwestern Nigeria

Abstract

Selected composited samples from Lewumeji (0-111m) and Idogun (0- 54m) Abeokuta Group, Eastern Dahomey Basin, were subjected to detailed lithologic and palynological studies. The studies aimed at determining the lithological sequence, relative age, palynological zone and paleoenvironments of deposition. The lithological description was done using hand lens, visual examination and dilute HCl. The palynologic sample preparation went through sample digestion, flotation and mounting on glass slides in order to determine palynomorphs contents such as pollen, spore and dinoflagellates present.

The lithologies from both wells revealed brownish clay, reddish to brown colour sandstone and dark grey shale denoting marine, fluvial, brackish and lagoonal environment. A total of 31 well preserved low to moderate diverse palynomorphs were recovered from the studied area. The palynomorphs frequency percentage distribution shows that both wells has a higher frequency of land derived pollen and spores to the marine dinoflagellates; (75%, 25% and 61%, 39%) for Lewumeji and Idogun wells respectively. The microfloral assemblages include abundant Cyathidites sp, Cyathidites minor, Tubistephanocolpites cylindricus, Proteacidites sp, Trilete spore, Foveotriletes margaritae, monocolpites marginatus, monoporites annulatus, pteris sp, Distaverrusporites simplex and Laevigatosporites sp. The dinoflagellates recovered were characterized by the likes of Leiosphaeridia sp, Senegalinium sp, Oligosphaeridinium sp, paleocytodinium sp, Cerodinium sp and Subtilisphaera sp. The wells fall within Cyathidites Minor zone, characterized by the diagnostic occurrence of Cyathidites minor, Cyathidites sp and monocolpites marginatus dated Upper Maastrichtian to Early Paleocene. Paleoenvironmental deductions based on abundance of freshwater swamps pollen and Spores, diagnostic dinoflagellates cyst and Palynomorphs marine Index (PMI) indicated a continental to brackish to shallow marine environment with minor influx of freshwater.

Keywords: Dahomey Basin, lithostratigraphy, palynology, Paleoenvironment,

Word counts: 269

1 Introduction

The applications of biostratigraphy in the palynological studies have become more valuable tools and universally accepted methods of evaluating the stratigraphy and source rock potential of sedimentary basins. These include the modern and fossil pollen, spores and dinoflagellates cysts. This marker species gives reliable and accurate information about past environments. When these markers are efficiently utilized, many of the hindrances encountered in paleoenvironmental synthesis can be avoided (Adegoke, 2012). The study area, Lewumeji and Idogun wells, falls within the Abeokuta group of the Eastern Dahomey basin (Fig.1, Fig. 2). The Abeokuta group is the oldest formation in the Dahomey Basin, Southwestern Nigeria, lying non-conformably on the basement (Jones and Hockey, 1964) and it is the thickest group within the basin, with an average thickness of 200m (Fayose, 1970). The basin is a pre-cratonic basin that was developed during the initiation of rifting associated with the opening of Gulf of Guinea in early creataceous to Late

Jurassic (Whiteman, 1982; Kingston *et al*., 1983). Agagu, (1985) illustrated and described the lithostratigraphy of the basin to be dominated by Monotony of Sand and shale alterations with minor proportion of Limestone and clay.

Several workers have carried out considerable and intensive researches to characterize and deduce the age of the sediments in the basin. (Omatsola and Adegoke, 1981; Salami, 1987; Obaje and Okosun, 2013, Adeigbe and Amodu, 2015). The stratigraphy of the Dahomey Basin has been well established by various authors, Jones and Hockey, (1964), Omatsola and Adegoke, (1981), Coker *et al*., (1983), Biliman (1992), Enu, (1990).

The studied wells are situated between latitudes $06^{0}30^{'}0^{"}$N - $06^{0}37^{'}0$"N and longitude $04^{0}45^{'}0^{"}$E - $05^{0}00$'0"E. and falls within the Abeokuta group of the Eastern Dahomey Basin (Fig.1 and Fig.2)

The present study focuses on using palynological and lithostratigraphic data to enhance the detailed general lithological description, deductions of age, varying depositional environment as well as to interpret the Biostratigraphy (biozones) of Lewumeji (0 – 111m) and Idogun wells (0 – 54m).

2 Sampling and Methods

The core samples used for this study were collected from the Bitumen project base Ore in Ondo state, Nigeria. The cores were sampled at every 3.0 meters interval from top to bottom of the Boreholes. A total of Four (4) composited samples from the Lewumeji well and five (5) composited sample from Idogun well were used for this study.

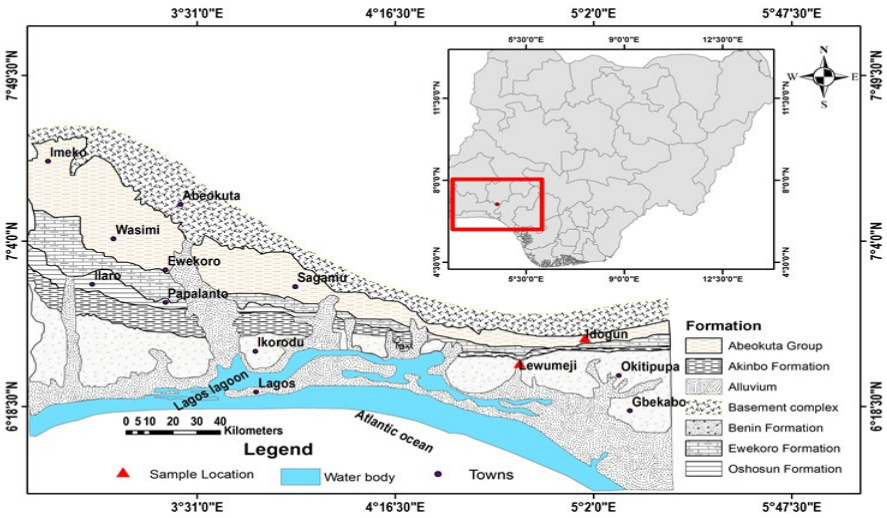


Figure 1: Map of Dahomey Basin showing the Study well (modified after Biliman, 1992)

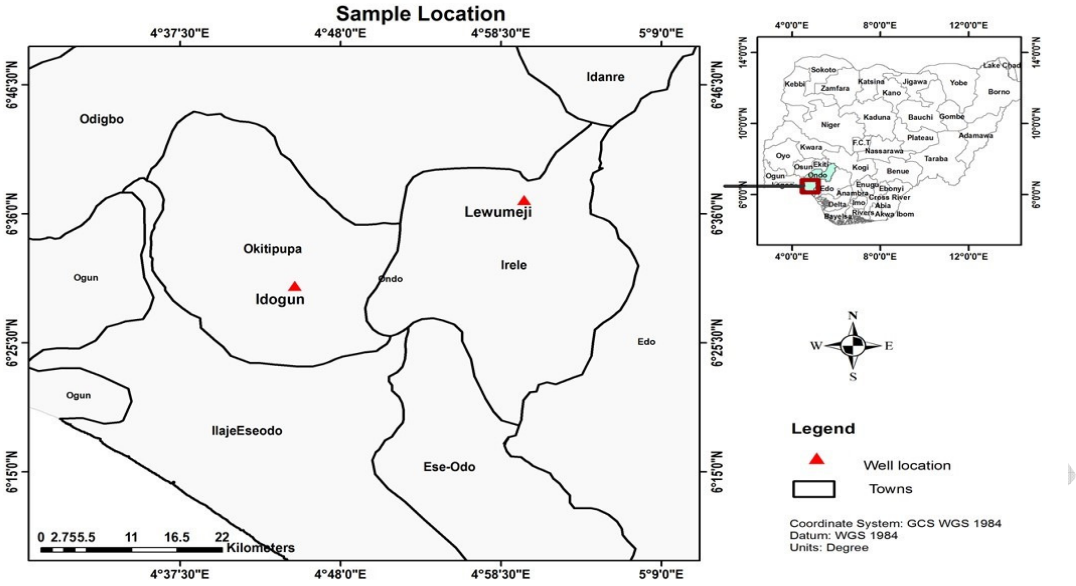


Figure 2: Location map of the exploration wells for this Study, Eastern Dahomey basin, Southwestern Nigeria. (Inset map illustrates the position of Dahomey basin in Nigeria)

2.1 Lithologic description

Detailed lithologic description was carried out on the core samples provided, by following the standard method of describing samples by using microscope hand lens, dilute HCl and physical examination. The description was based on their texture, Fissility, colour, and fossil content in term of plant remains and fossil fragment.

2.2 Palynological Analysis

The purpose of palynological preparation is to disaggregate the fossil palynomorphs from the rock or sediment matrix. Factors that can make samples unreliable, such as: Laboratory contamination, assemblages mixing in nature and misplacing of samples through human error were put into consideration during analysis for optimum retrieval of palynomorph. A standard extraction method was used. 10g of each sample was weighed, gently crushed to avoid deforming the palynomorphs, and poured into a well labelled plastic beaker and placed in a fume cupboard. Each samples was digested with 10% hydrochloric acid (HCl) for about 15minutes for carbonate removal and soaked overnight with 40% hydrofluoric acid (HF) for the removal of silicate. From the preceding preparatory stage a drop of potassium chlorate ($KClO_3$) was added, which was stirred and left for about 5minutes so as to react, it is then rinse twice to remove the $KCLO_3$. A 5 micron sieve was then used under a branson sonifier to wash out the inorganic matter (mud and clay). A drop of Norland Optical Adhesive was then deposited on the slides to be used. The slides were studied under a light transmitted microscope to obtain the palynomorphs.

3.0 Results

Interpretation and Discussion

3.1 Lithostratigraphy

The nine (9) composited samples of the studied sections of Lewumeji and Idogun wells, were carefully studied based on their Lithology, three (3) litho units were identified in the study wells. All the Three (3) unit occur in Idogun well with the alternation of shale and sandstone while two (2) units occurred in Lewumji well with a little clay intercalation. The three lithounits are sandstone, clay and shale. The description of the facie units are presented below while the litholog is shown in Fig. 3 and Fig.4

Lewumeji well

Litho unit 1 (0-15m)

This unit is on the topmost layer. The sandstone is reddish brown at the upper part of the unit then a light brown at the base of the layer. It has a fine to medium size grains. The unit is 15m thick and was deposited in a fluvialtile environment. This is further confirmed by the palynological study carried out which revealed the presence of an Angiosperm pollen Tubistephanocolpites Cylindricus

Litho unit 2 (15 – 111m)

This unit is 96m thick. It is composed of shally, dark to grayish, fissile to non- fissile, carbonaceous shale. Also the occurrence of Microforaminiferal wall linnng and Laevigatosporites sp within the interval suggested that it could have been deposited in a marine environment.

Idogun well

Litho unit 1 (0 -9m)

This units is 9m thick, it is reddish brown, non- carbonaceous clay. This litho unit portrays a mixed depositional environment in which there is strong influence of fluvial on lagoonal environment.

Litho unit 2 (9 – 15m)

This interval is composed of fine to medium grain sandstone with an evidence of shelly whitish material in some horizons. It is 6m thick and reddish brown to brown in colour. The sediment was deposited in a fluvial environment.

Litho unit 3 (15 – 24m)

This unit which is about 9m thick is shally, dark grey in colour, non- fissile and could have been deposited in a marine environment.

Litho unit 4 (24 – 42m)

This units is made up of grey coloured sandstone. Fine to medium grained. The occurrence of monocolpite marginatus, Tubistephanocolpites Cylindericus also suggests deposition in a fluvialtile environment.

Lithounit 5 (42 -54m)

This interval consists of a dark to greyish non- fissile shale. It is carbonaceous. The units is about 9m thick and the high occurrence of dinoflagellates cysts like Senegalinium sp, Paleocytodinium sp, subtilisphaera sp suggests position in a marine setting.

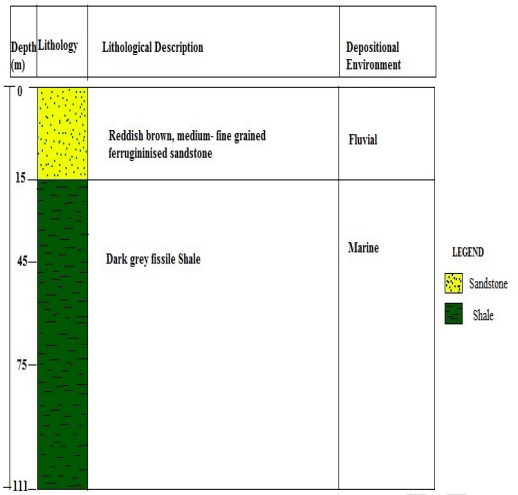


Figure 3: Litholog of the studied interval of Lewumeji well, Dahomey Basin.Nigeria.

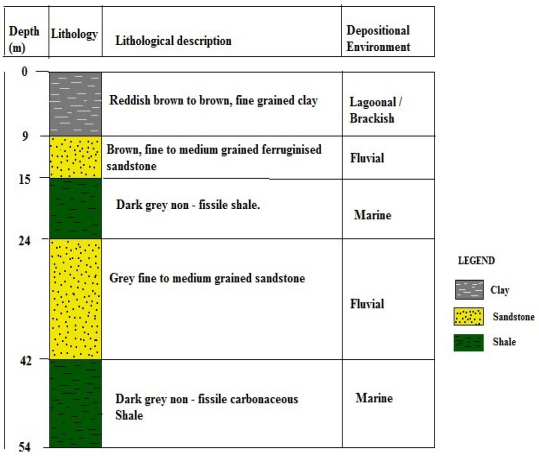


Figure 4: Litholog of the studied interval of Idogun well, Dahomey Basin, Nigeria

3.2 PALYNOLOGICAL STUDIES

Analytical breakdown of the palynomorphs showed that the samples are well preserved with a low to moderate occurrence and moderately diverse pollen, spores and the dinoflagellates. Some of the palynomorphs recovered in Lewumeji well are Tubistephanocolpites cylindricus, Proteacidites spp, Monocolpites marginatus, Cyathidites Spp, Laevigatosporites spp, Cyathidies minor, Leiosphaeridia Spp and marine diagnostic specie microforaminiferal wall lining were recorded. palynomorphs recovered in Idogun well are Monoporites annulatus, Monocolpites marginatus, Proteacidites Spp, Foveotriletes Margaritae, Mauritiidites lehmani, Tubistephanocopites Cylindricus, Cyathidites spp, Laevigatosporites spp, Trilete spore, Distaverrusporites simplex, Pteris spp, Leiosphaerida spp, Cerodinium spp, Oligosphaeridium spp, Paleocystodinium spp, Senegalinium spp Subtilisphaera spp and marine diagnostic specie microforaminiferal wall lining. The marine dinoflagellates cyst makes up to 39%, while the

pollen and spores makes up to 27.77% and 33.3% respectively of the total palynomorphs in Idogun well while the marine dinoflagellates cysts makes up about 25%, while the pollen and spores makes up about 33.33% and 41.66% respectively of the palynomorphs in Lewumeji well.

3.2.1 Palynological zones and Correlation

The erection of biozones is dependent of the evolution, extinction and quantitative occurrence of marker forms present in the sediments (Ola- buraimo, 2012).The palynological interpretation of the analyzed interval was based on diagnostic marker species. For the entire section of the Lewumeji (0 – 111m) and Idogun (0 -54m) wells, the recovered palynomorphs enabled the delineation of one major zone which is the Cyathidites Minor Assemblage zone, based on the occurrence of Cyathidites minor, Cyathidites sp and Monocolpites marginatus this erected zone can also be correlated with spinizonocolpites Bacculatus zone of Lawal and Moullade, (1987). The details of the palynological zones recognized for lewumeji and Idogun well are discussed below and shown graphically in the palynology distribution chart (Fig. 5 to Fig. 8). The chart shows the ages of the recovered palynomorphs and the Index palynomorphs which marked the zones as recorded in the bioevent section of the chart. The basis of characterization of Lewumeji and Idogun well is given below:

Zone: Cyathidites Minor Assemblage zone

Interval: 0.00m – 111.0m; 0.00m – 54.0m

Age:? Upper Maastrichtian – Early Paleocene

Characteristics

For the Lewumeji well, the zone is marked at the base (75.00-111.00) by the occurrence Cyathidites sp, Cyathidites minor, Tubistephanocolpites cylindricus, and the acritarch Leiosphaeridia Sp. The part near the base (45.00- 75.00) is characterized by the new appearance of Monocolpites Marginatus, Laevigatosporites spp, Microforaminiferal wall linning and continuous occurrence of Leiosphaeridia Spp. Close to the top of the well (15.00- 45.00) is the new appearance of Proteacidites sp, continuous occurrence of Laevigatosporites sp and Cyathidites sp. while the topmost part (0.00-15.00) is very sparse in spores and dinoflagellates cyst but marked by the single occurrence of an angiosperm pollen which is Tubistephanocolpites cylindricus (table 1). A considerable amount of palynomorphs assemblage found in this well have been reported for late maastrichtian to Paleocene sediment in the basal part of Araromi (Salami 1984, Adeigbe and Amodu, 2015), for the Paleocene sediment of Pan tropical area (Germeraad *et al.*, 1968), for the cretaceous sediment of upper Benue trough (Lawal

and molluade, 1986; Awad, 1994), Major forms present in the upper maastrichtian facies are often present in Paleocene sediments. (Ola-Buraimo, 2012; Ayinla *et al*., 2013).

For Idogun well, the interval study also belong to the Cyathidites minor assemblage zone. Dinoflagellates cyst dominate the basal part (42.00-54.00m) of the well which is an indication of more marine influence, these include the assemblages of Senegalinium sp, Oligosphaeridinium sp, Subtilisphaera sp, Cerodinium sp and relative high frequency of Paleocytodinium sp. The diagnostic marker forms present are Cyathidites sp, Monoporites anulatus and Monocolpites Marginatus. At depths 24.00 to 42.00m there is re-occurrence of Monocolpites Marginatus and new forms that are diagnostics of late maastrichtian age, emerged, they include Mauritiidites lehmani, Tubistephanocolpites Cylindricus, and Pteris Sp. the overlying interval (15.00 – 24.00) is characterized by occurrence of new forms Distaverrusporites simplexwhich supports the late Cretaceous age (Durugbo and Aroyewun, 2012). The overlying interval 9.00m – 15.00m is relatively rich in palynomorphs, it is composed of continuous occurrence of Cyathidites sp. Miospores and dinocysts that appear for the first time are Leiosphaeridia sp, Trilete Spore, Microforaminiferal wall lining, Foveotriletes Margaritae, and Laevigatosporites sp. The topmost interval 0.00m -9.00m is characterized by the re occurrence of Cyathidites sp and new appearance of Proteacidites sp as shown in table 2

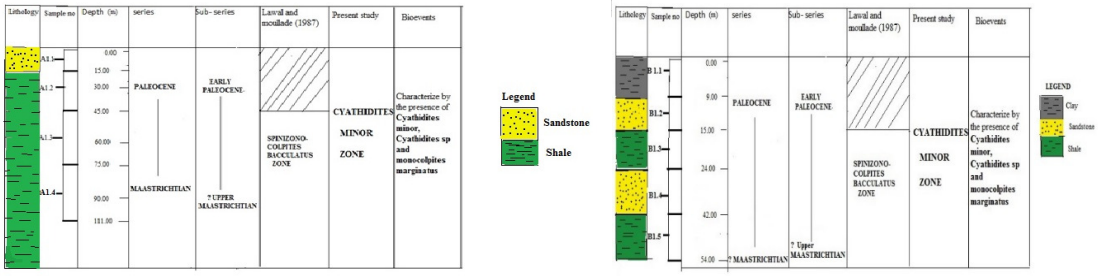
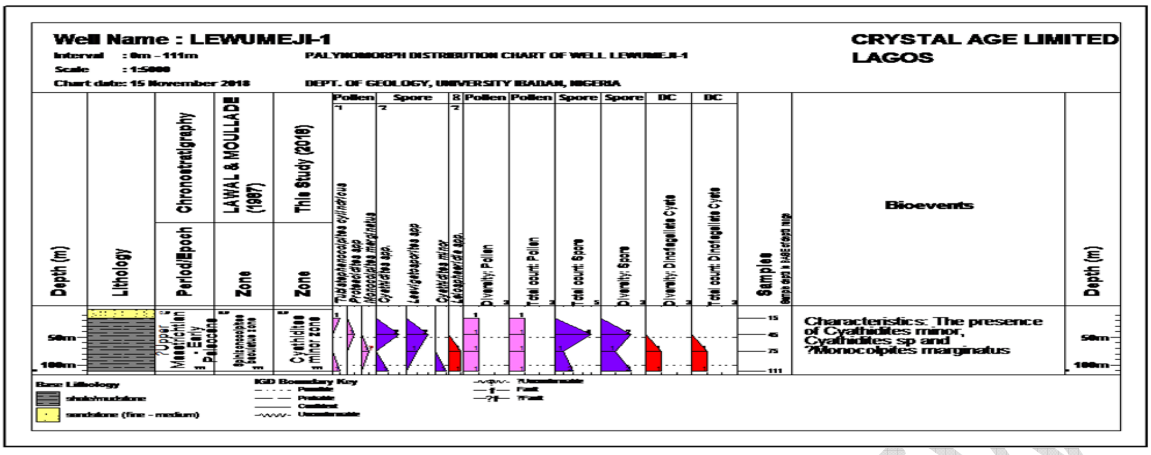


Fig 5: Palynomorphs zones recognised in Lewumeji well.

Fig 6: Palynomorphs zones recognised in Idogun well.



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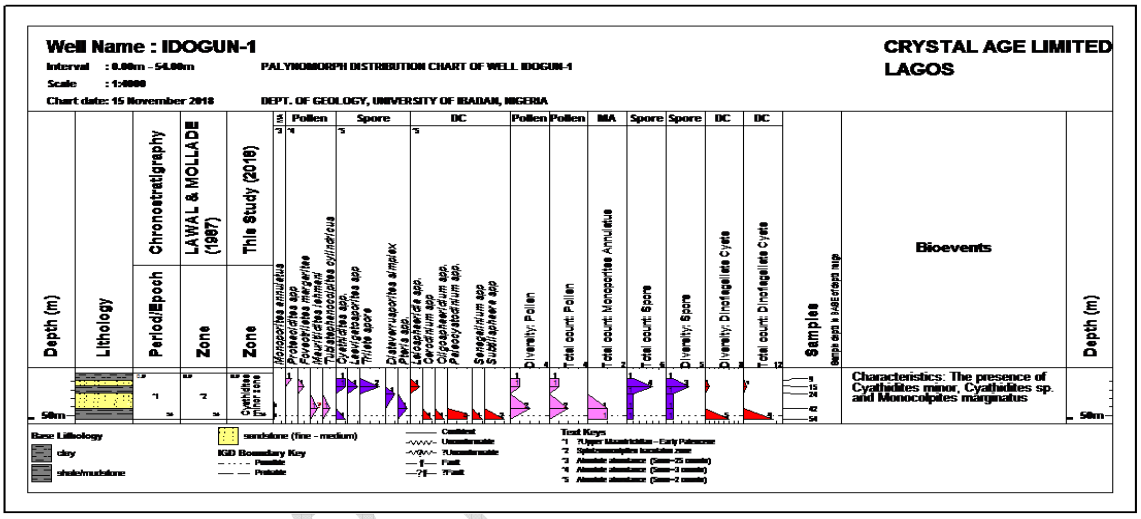
199 Figure 7: The palynomorph distribution Chart of Lewumeji well (0.00 – 111m).



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201 Figure 8: The palynomorph distribution Chart of Idogun well (0.00 – 54m).

202 Table 1: The distribution of palynomorphs species recovered in Lewumeji well and the number
203 counts for specie type

SAMPLE NO	Depth (m)	Lithology	Palynomorphs recovered	Counts/Species Type
A1.1	0 - 15.00		Tubistenphanocolpites Cylindricus	1 (P)
A1.2	15 - 45		Cyathidites sp Proteacidites sp Laevigatosporites sp	2(S) 1(P) 2(S)
A 1.3	45 -75		Monocolpites Marginatus Leiosphaeridia sp Microforaminiferal wall lining Laevigatosporites sp	1 (S) 1 (DC) 1 (DC) 1(S)
A 1.4	75 -111		Leiosphaeridia sp Cyathidites sp Cyathidites Minor Tubistephanocolpites Cylindricus	1 (DC) 1 (S) 1(S) 1(P)

Legend
P - Pollen
S - Spores
DC - Dinoflagellates
Sandstone
Shale

204

Table 2: The distribution of palynomorphs species recovered in Idogun well and the number counts for specie type

Sample no	Depth (m)	Lithology	Palynomorphs Recovered	Counts/ Species Type
B1.1	0 - 9.00		Cyathidites sp Proteacidites sp	1(S) 1(P)
B1.2			Leiosphaeridia sp , Trilete spores Microforaminiferal wall lining , Cyathidites sp Foveotriletes Margaritae, Laevigatosporite sp	1 (DC) , 2(S) 1 (DC) , 1 (S) 1(P) , 1 (S)
B1.3	9.00 -15.00		Distaverrusporites simplex	1 (S)
B1.4	15.00 - 24.00		Monoclpites Marginatus Mauritiidites Lehmani Tubistephanocolpites Cylindricus Pteris sp	1(P) 1(P) 1(P) 1(S)
B1.5	24.00- 42.00 42.00 - 54.00		Senegalinium sp Paleocytodinium sp Subtilisphaera sp Cyathidites sp Monocolpites Marginatus Cerodinium sp Oligosphaeridinium sp Monoporites Annulatus	1 (DC) 4 (DC) 2(DC) 1 (S) 1(P) 1 (DC) 1(DC) 2(P)

LEGEND
S - Spore
P - Pollen
DC -Dinoflagellates cysts
Clay
Sandstone
Shale

Correlation of intervals (fig.9) within both wells using terrestrially sourced spores and pollen shows alots of similarities, this suggests that the sediments were deposited under the same conditions and the miospores might have come from the same origin during the same period and sediments were partly deposited under the same condition.

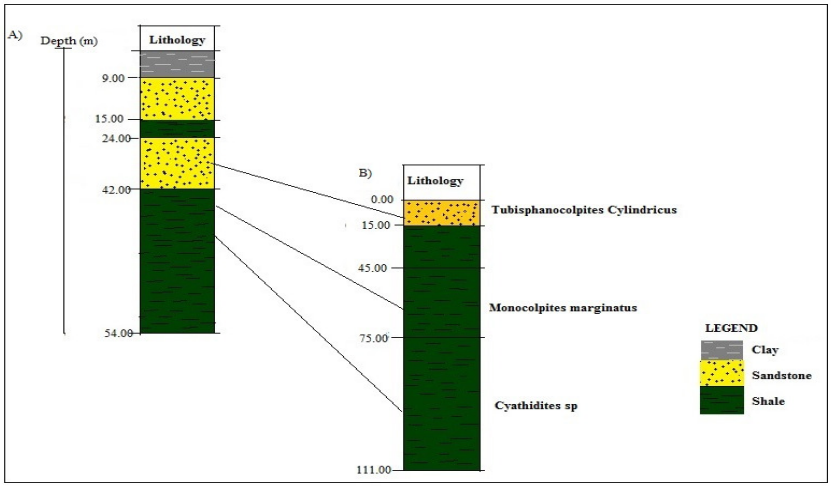


Figure 9: Correlation chart of the study sections using the recovered palynomorphs from both wells (a) Idogun well (b) Lewumeji well

3.2.2 Environment of deposition

Deduction of Paleoenvironment of deposition was carried out using different means based on preferable environment of deposition of environmentally indicative forms, palynomorphs frequency distribution, and comparison of land derived forms to marine source. The palynomorphs frequency percentage distribution shows that both well has a higher frequency of land derived miospore to the marine dinoflagellates; (75%, 25% and 61%, 39%) for lewumeji

and Idogun well respectively. This suggests that the source of organomacerals are plants and environment of deposition is likely to be from a continental to brackish environment of deposition (Adeigbe et al., 2013).

The occurrence of environmentally indicative forms in lewumeji and Idogun well such as Leiosphaeridae Sp indicative of neritic environment (Ayinla et al., 2013), monocolpites marginatus suggestive of coastal plain habitat (Adeigbe and Amodu 2015), foraminifera wall linings suggestive of nearshore environments .However, the moderate records of fern spores such as Cyathidites sp, Cyathidites minor are indicative of open fresh water swamps (Lawal and moullade 1987). And the presence marine loving forms such as Cerodinium sp, Paleocystodinium sp, and Senegalinium sp and subtilisphaera sp in Idogun well are indicative of shallow marine environments. This suggest a depositional environment that vary from continental to brackish to shallow marine environment with minor influx of freshwater.

The Palynomorphs marine Index which is a semi quantitative interpretation technique was employed to further determine the Interval of ldogun (0.00-54.00m) and Lewumeji well (0.00-111.00m). This method depends on the amount of terrestrial and marine palynomorphs separately, to deduce the paleoenvironments of fossil forms in respect of fluvial and marine environment. Helenes *et al*., 1998 define PMI (Palynological Marine Index) as:

PMI = Rm/Rt +1 *100

Range of classification follows

>100 = Fluvial environment

100-200 =Fluvial/ marine environment

>200 = Marine environment.

Where Rt = Richness/number of terrestrial palynomorphs (pollen + spores + Fungal remains)

Rm = Richness/number of aquatic palynomorphs (Dinoflagellates+ Acritarch + foraminifera wall linings + Prasinophytes). High, Low and nil values of palynomorph marine index (PMI) indicate a marine, brackish and fresh water environment respectively (Chukwuma-Orji *et al.,* 2017).

Quantitative interpretation technique applied using Palynomorph Marine Index (PMI) values show that in Lewumeji well (table 3) PMI value of about 100, indicative of interval 0.00-111.00m which are equivalent to fluviatile deposit due to dominance of land derived palynomorphs.The PMI values (table 4) show that in Idogun well, intervals with PMI values of about 100, indicative of interval 0.00-9.00m, 9.00-15.00m, 15.00-24.00m, and 24.00 -42.00m are equivalent to fluviatile deposits, while the lowermost part with the depth range of 42.00 –

54.00m has a PMI value between 100-200 which is indicating an alternation of continental and marine deposits. Therefore, from the general view of the PMI values against analyzed stratigraphic interval (fig 10, fig.11), a brackish to Shallow marine environments with minor freshwater incursions is suggested for the study area.

Table 3: Paleoenvironment Interpretation of Lewumeji well from P.M.I. Value of the Palynomorphs Distribution.

Sample No	Depth (m)	Pollen	Spores	Dinoflagellate Cyst	Total	PMI	Paleoenvironment
A1.1	0.00 - 15.00	1	0	0	1	0	Fluvial Deposit / Freshwater environment
A1.2	15.00 - 45.00	4	1	0	5	0	Fluvial deposit /Freshwater environment
A1.3	45.00 - 75.00	1	1	2	4	67	Fluvial deposit /Brackish environment
A1.4	75.00 - 111.00	1	2	1	4	25	Fluvial deposit/ Brackish environment

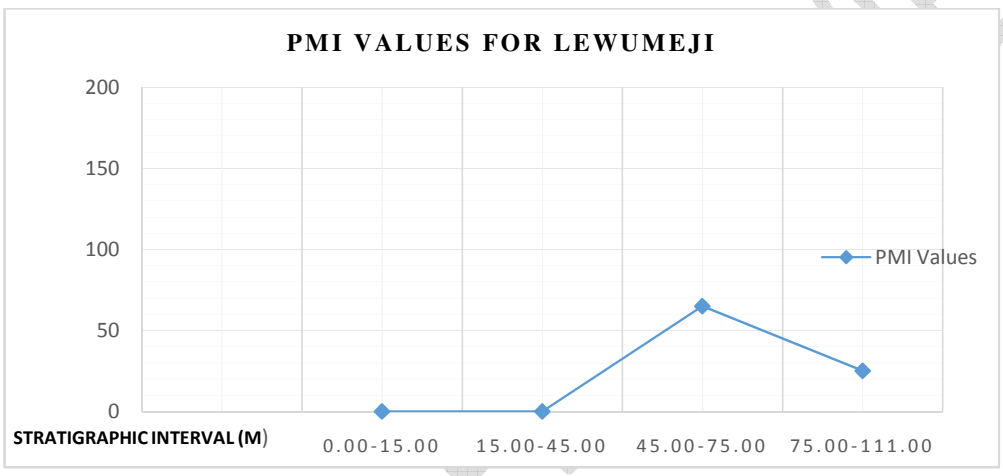


Figure 10: Palynomorphs Marine Index (PMI) chart of Lewumeji well

Table 4: Paleoenvironment Interpretation of Lewumeji well from P.M.I. Value of the Palynomorphs Distribution.

Sample No	Depth (m)	Pollen	Spores	Dinoflagellate Cyst	Total	PMI	Paleoenvironment
B1.1	0.00 - 9.00	1	1	0	2	0	Fluvial Deposit / Freshwater environment
B1.2	9.00 - 15.00	1	4	2	7	34	Fluvial deposit/ brackish environment
B1.3	15.00 -24.00	0	1	0	1	0	Fluvial deposit / Freshwater environment
B1.4	24.00 -54.00	1	2	1	4	0	Fluvial deposit/ freshwater environment
B1.5	**42.00 - 54.00**	**3**	**1**	**9**	**13**	**180**	C/Marine deposit/ marine environment

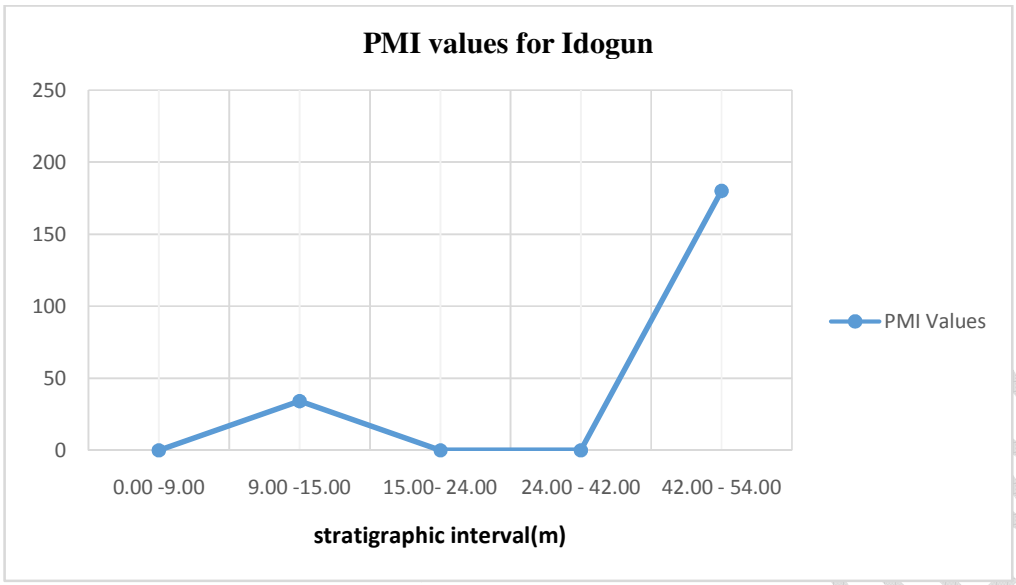
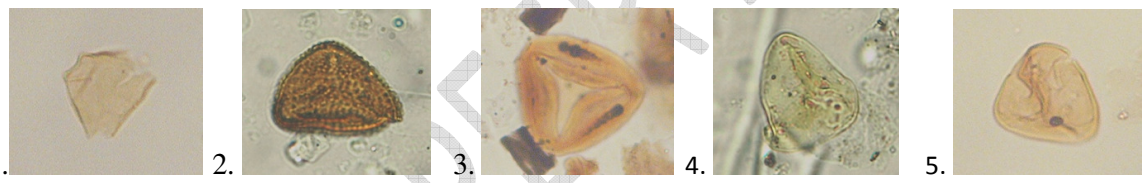


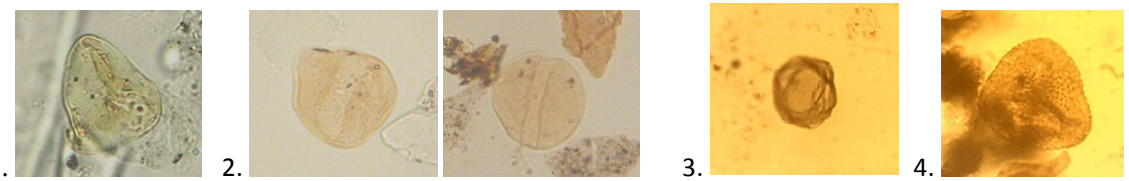
Figure 11: Palynomorphs Marine Index (PMI) chart of Idogun well

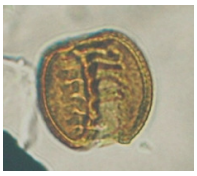
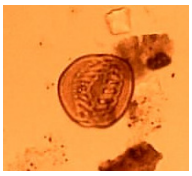
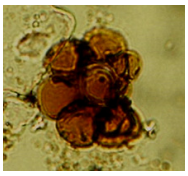
Plate 1: Some selected Palynomorphs photomicrographs recovered from Idogun well



1. Proteacidites sp 2. Foveotriletes margaritae 3. Pteris sp 4 &5. Cyatidites minor 6. Laevigatosporites sp 7. Monocolpites marginatus 8. Microforaminiferal wall linnings 9. Distaverrusporites simplex 10. Oligosphaeridium sp.

Plate 2: Some selected Palynomorphs photomicrographs recovered from Lewumeji-1 well



5.   6.   7. 

1. Cyatidites minor 2. Monocolpites marginatus 3. Leiosphaeridia sp 4. Foveotriletes margaritae 5. Tubistephanocolpites cylindricus 6. Laevigatosporites sp 7. Microforaminiferal wall linings.

Conclusions

The palynological and Lithostratigraphy studies has been appropriately employed to study the sediments of Abeokuta group a part of Eastern Dahomey basin through the use of nine (9) composited core samples from Lewumeji and Idogun well with depth ranging from 0 -111m and 0-54m respectively.

The wells were examined lithologically and five units were delineated which can be further grouped into three for Idogun well two units of shale, two units of sandstone and a clay unit while the lewumeji well has a lithology of sandstone and shale. Both well are dominated by fissile to blocky, light to dark grey colour shale and the sand grain varies from medium to fine grained texture and the clay unit covers a small interval having a reddish brown colouration. This lithology denote Marine, fluvial and Lagoonal or brackish environment respectively. The thirty-one (31) palynomorphs recovered within the two well are well preserved with low to moderate diverse pollen, spores and the dinoflagellates cysts. The microfloral assemblages include abundant Cyathidites sp, Cyathidites minor, Tubistephanocolpites cylindricus, Proteacidites sp, Trilete spore, Foveotriletes margaritae, monocolpites marginatus, monoporites annulatus, pteris sp, Distaverrusporites simplex and Laevigatosporites sp. The dinoflagellates recovered were characterized by the likes of Leiosphaeridia sp, Senegalinium sp, Oligosphaeridinium sp, paleocytodinium sp, Cerodinium sp and Subtilisphaera sp. The palynological assemblage zone identified within the two wells is the Cyathidites minor zone, these zone is correlatable with the Spinizonocolpites Bacculatus zone of Lawal and moullade, (1987). The zone is characterized by the presence of Monocolpites marginatus, Cyathidites minor and Cyathidites Sp. The studied sediments from the wells were deposited in a continental to brackish to shallow marine environment with minor freshwater incursions during the Upper Maastrichtian – Early Paleocene period based on environmental diagnostic species, palynomorphs marine index and frequency distribution of palynomorphs.

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