International Journal of
Science Inventions Today
www.ijsit.com
ISSN 2319-5436
Research Article

APPLICATION OF STRATIGRAPHY PALYNOLOGY TO PETROLEUM EXPLORATION: A CASE STUDY OF NIGER DELTA BASIN

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ABSTRACT

Palynological biostratigraphic studies were carried out on ditch cutting samples obtained from wells L-1 and L-2, offshore deep water area, Niger Delta. The focus of these studies, using convetional acid maceration was to establish a Palynological biozonation for age determination and carry out correlation across the study wells which is imperative in petroleum exploration and production. Lithologically, the study sequences composed of shales, siltstones / mudstones which are grey, with intercalation of thin-bedded sandstones. Fairly diverse palynological assemblages were recovered. The samples yielded 35 dinocyst genera and 56 species. Palynological Zones were established based on first and last occurrences of readily identifiable marker species and their relative abundances The palynostratigraphic subdivisions observed consist of, *Multispinula quanta*, Chytrioeisplaeridium sp and Tuberculodinium vancampoae . These zones aided the age assignment of Early Pliocene through to Middle Miocene to the studied sections.

INTRODUCTION

Palynology is becoming increasingly important in basin analysis worldwide in modern research for petroleum exploration and production activities. It has become an important tool in resolving many age and facies correlation problems. Being mostly allochtonous, palynomorphs are common, they occur in abundance in both continental and marine deposits. Hence, they can be treated statistically to reveal the degree of correlation in onshore and offshore sediments.

Unfortunately in the Niger Delta Basin, information on palynology is still scanty. The most comprehensive work to date on the palynology of the Niger Delta is that of (Germeraad &Muller 1968). A few forms were illustrated by (Oboh 1992] and (Oloto 1994).

Biffi and Grignani (1984) defined morphological criteria for speciating the Lejeunecysta cysts from the Oligocene of the Niger delta in order to identify potential useful stratigraphic markers amongst this group but did not elaborate on their biostratigraphic use and distribution.

This paper is an attempt to date the sediments using the recovered palynomorph assemblage, evaluate their species diversity to generate a palynomorphs data base and correlate the studied wells to have a better understanding of stratigraphic distribution during the period the sediments were deposited. It is hoped that the results so obtained will be useful in addressing stratigraphic and correlation problems in the Niger Delta Basin.

AIM AND OBJECTIVES OF THE STUDY

The aim of this study is to carried out age determination and correlation of wells using palynology and document their assemblages (Niger Delta PALY Album) for the purpose of academic, industry research and consultancy work.

Location of studied wells:

The study wells are located offshore, off the Nigerian coast, at a distance of 120km southwest of the Niger Delta. . The field covers approximately 60 km^2 in an average water depth of 1,000 metres (3,300 ft). The field produces both *petroleum* and *natural gas* (**See figure 1**.*)*

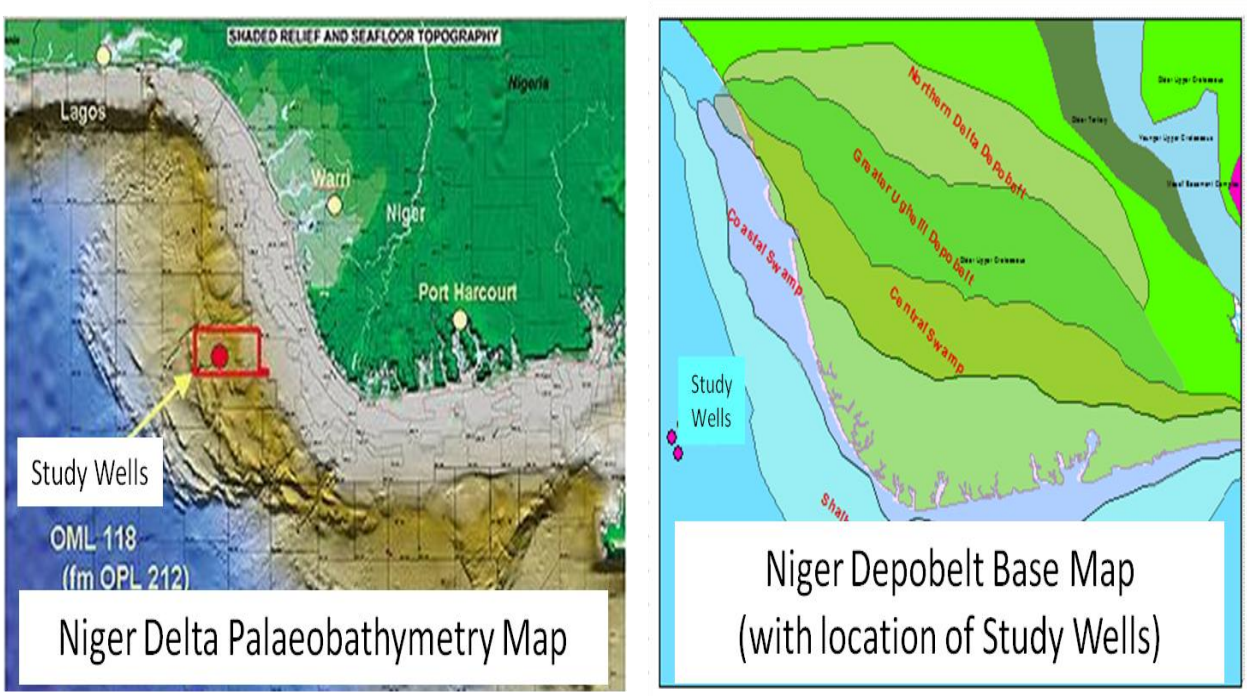


Figure 1: Niger Delta Paleobathymetry and Depobelt base map (showing location of study wells)

Geology and Stratigraphy Of The Niger Delta:

According to Short and Stauble (1967), Frankl and Cordry (1967), and Avbovbo (1978), the lithostratigraphy of Niger Delta is represented by three (3) major diachronous formations stretching in age from Paleocene to recent and comprising from base to top - the Akata, Agbada and Benin Formations; the formations were placed beneath marine, transitional (paralic) and continental environments respectively(figure 2)

The lithostratigraphic build-up of the Niger Delta basin was accompanied by synsedimentary tectonics normal to the progradation, resulting in a series of parallel, fault-bounded depobelts, which become progressively younger from north to south, as the delta progrades southward (Stacher, 1995). These depobelts are: Northern depobelt, greater Ughelli, central swamp, coastal swamp and the offshore depobelt (Figure 3).

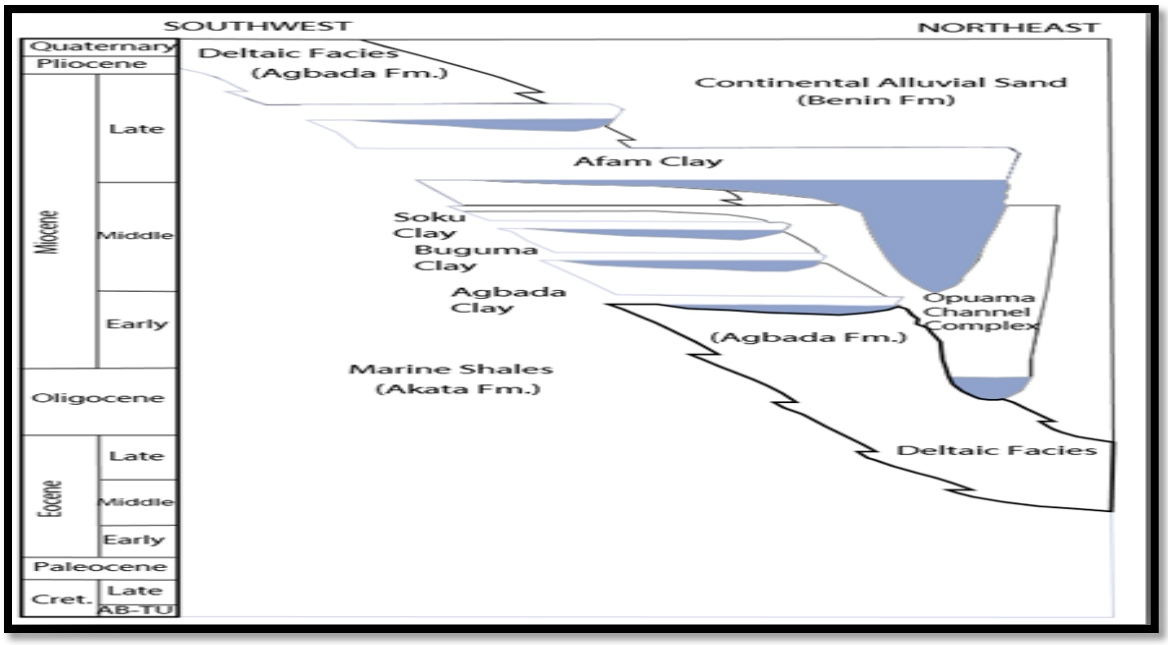


Figure 2: The Niger Delta lithostratigraphic section showing the three lithologic units

(Adapted from Doust and Omatsola, 1990).

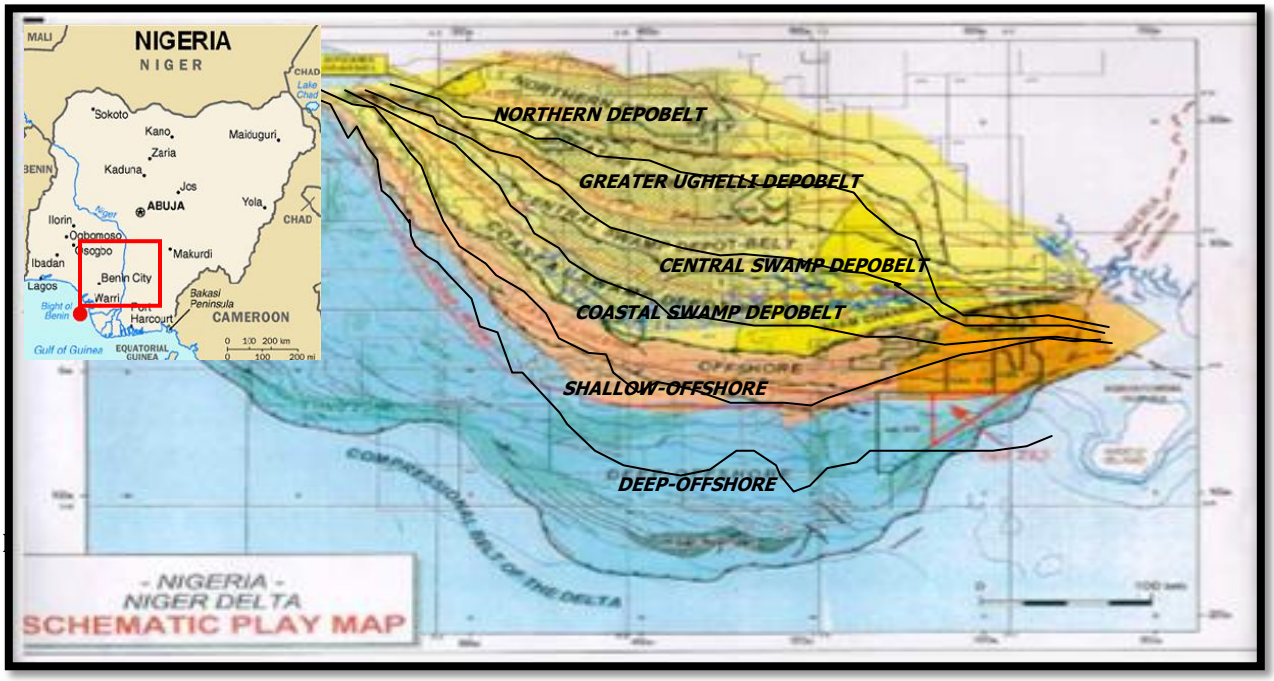


Figure 3: Showing Niger Delta Depobelt and Spatial Distribution of Studied Wells (Modified from Reijers, 1997)

AKATA FORMATION: The lowermost lithological division of the Niger Delta consists of basically marine

shales with clay and silt intervals in places. This Lithostratigraphic unit is taken as the prodelta megafacies of the Niger Delta complex, formed during lowstand when terrestrial organic matters and clays were conveyed to deep water areas chiefly epitomized by low energy conditions and oxygen deficiency (Stacher, 1995).The Akata Shale is under-compacted and over-pressured (Merki, 1972).

According to Beka and Oti (1995), turbidity currents likely deposited the turbidity sands within the upper Akata Formation of the Niger Delta. The Akata Formation ranges in age from Paleocene – Recent and grades into the Agbada Formation.

AGBADA FORMATION: The Agbada Formation overlies the Akata Formation and underlies the Benin Formation. It is the second of the three strongly diachronous Niger Delta multifaceted formations(Short and Stauble, 1967; Frankl and Cordry, 1967). The interbeded shales are supposedly taken as source rocks for some of the petroleum pools and fields in these areas (Evamy1978).The Agbada Formation spans over 3500 m (11,500 ft.) in thickness. (Corredor et al, 2005)..

BENIN FORMATION: The Benin Formation lies uppermost in the Niger Delta lithostratigraphy and it is made up of very poorly consolidated sandstones, with little shale lenses, coals and conglomerates from continental and delta plain. According to Allen (1965), the thickness of the Benin Formation lies within 2000m. Oemkens (1974) established the fact that the late Quartenary post-glacial transgressive deposits take place locally inside the upper 0-30m of the Benin Formation in lower delta plains of the study area.

METHODOLOGY

Data for this study was generated from 96 ditch cutting samples from offshore Niger Delta . Samples were collected at 120ft interval which was obtained from two wells, coded namely L-1, and L-2, with depth range of 5650ft-12596ft, 6830-11220ft respectively. Lithologic interpretation of the well L1-1 and L-2 were made from the wire line logs of the two wells.

PALYNOLOGICAL PREPARATION:

A total of 96 ditch cuttings samples were prepared for palynological studies.

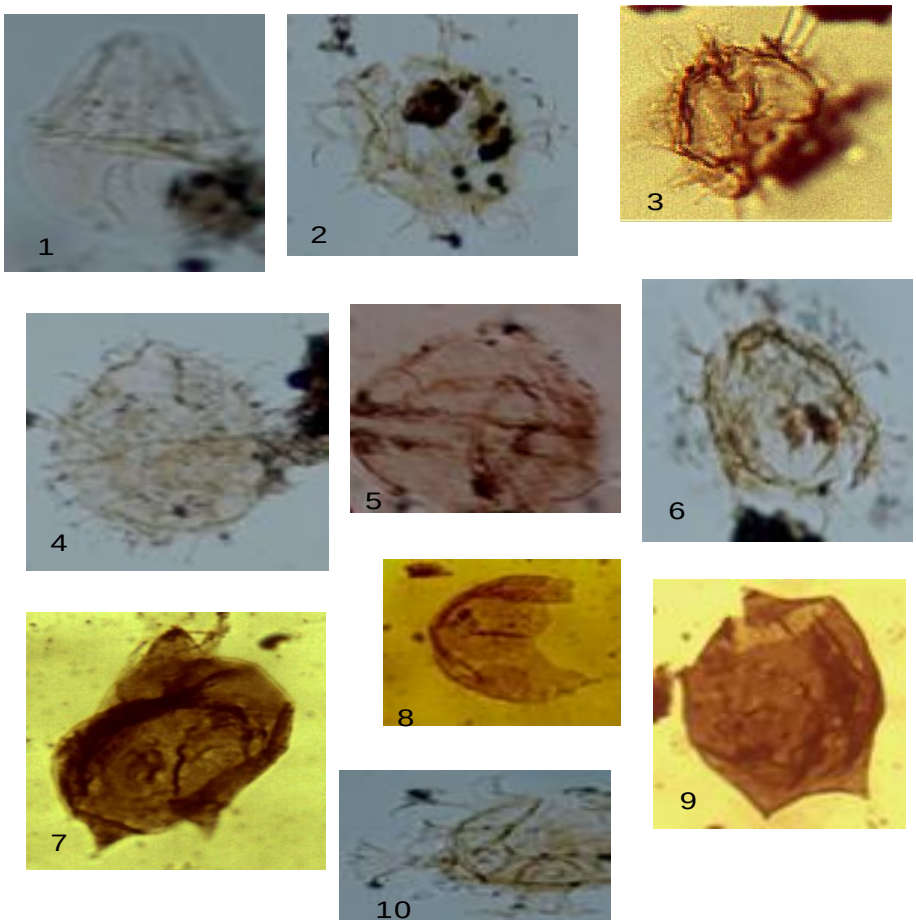
The procedure is as follows:

- Ninet -six ditch cuttings Samples were prepared for Paly slides analysis from two wells namely L-1 and L-2. (**See plate.3-7 at the appendix**).
- The supplied ditch cuttings were logged and composited at interval of 120ft.
- 5 gram of each sample was placed in a labeled cup in which 100ml of 70% hydrofluoric acid (HF) was added with the aim of separating the palynomorphs from the other rock debris by digesting the silica in

sample.

- Samples were then washed and the slides prepared. A portion of the kerogen was mixed with 0.1% PVA solution, pipette onto a cover slip and allowed to dry
- the remainder of the kerogen was sieved at 20µ.
- Cover slip was then mounted on a labeled glass slide using two drops of the Norland optical adhesive.
- Resulting suspension was pipetted on a microscope glass slide, place on a hot plate and gently dried.
- The slides were properly labeled and observed under research microscope through which snapshot was taken.
- Prepared slides were examined under transmitted light microscope at x1000 magnification.
- Detailed identification (to species level where possible) was made by consulting the Published monographs works on palynomorphs.

Plate 1:

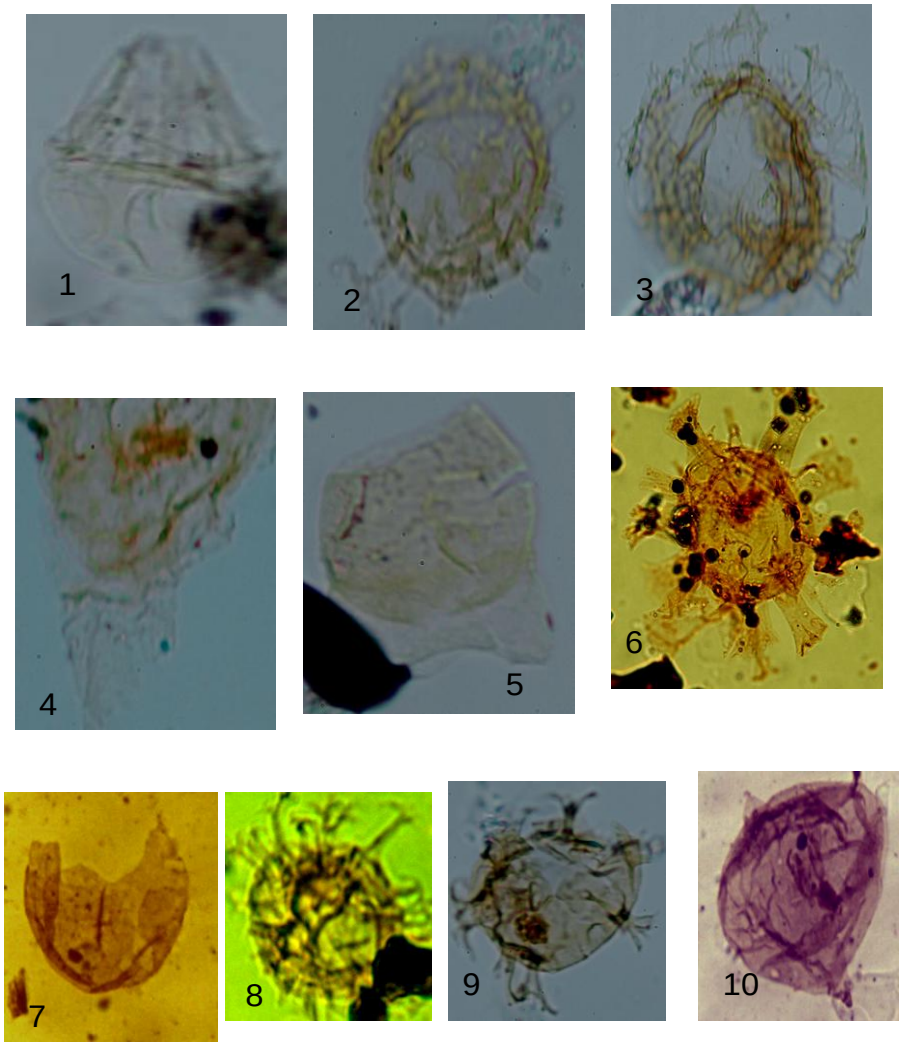


1. Dinogymnium acuminatum 2. Oligosphaeridium complex 3 .Exochosphaeridium muelleri 4. Palaeohystrichophora infusorioides 5. Cribroperidinium Edwards 6. Multispinulosa quanta,

7. Senegalinium laevigatum 8Canningia acuminate 9. Isabelidinium amphiatum

10. Oligosphaeridium albertense

PLATE 2



1. Dinogymnium acuminatum, 2. Indeterminate Dinoflagellate cyst , 3. Nematosphaeropsis sp., 4. Odontochitina operculata , 5. Sutilisphaera inaffecta, 6. Kallosphaeridium sp, 7. Canningia acuminate, 8. Tuberculodinium vancampoae *9. Oligosphaeridium complex, 10. Senegalinium bicavatum*

APPENDIX

Work Flow: Sequence of Research Events

Plate 3: Bagged Samples displayed on displayed on Laboratory table

Plate 4: Soaking and maceration of samplea using Hydrofluoric acid of (38%) concentration

Plate 5: palynorphs sieves with vary meshes of different degree

Plate 6: Paly-Solution stored in test tubes

Figure 7: Palynomorph slides being displayed on the electric stove

PRESENTATION OF RESULTS:

Sedimentology:

The studied intervals range from 5650-12596, for well L-1 and L-2 6830-10970ft respectively. A lithologic framework for the section was established as follows (Figure 4)

The base of the section below 12596ft consists of brown to grey Claystone which is Calcareous. The depth range between 12596 and 9560 ft is observed to consist of brown to dark brown Siltstone which is friable, spotted, fine to medium grained and highly calcareous. The grains on microscopic analysis were found to be poorly sorted, angular to sub-angular and sub-rounded in some depths. Very minute quantity of pyrite is observed to occur as an assessory mineral. Beyond the depth of 8550ft, Siltstone is observed to grade into Claystone which is brown to grey, soft to moderately hard and flaky. The depth of 7430ft consists of dark grey, sticky shale grading into fissile and calcareous shale at the depth of 6550 ft and beyond. Shale characters are found to vary across the section.

The depth range between 6650 and 6010ft consists of Shales that are dark grey, sub-fissile to fissile and lacking carbonaceous materials. The trend however changes from the depth 6010 to 5700ft where they are moderately hard, fissile and carbonaceous. The depth 5700 to 5650 ft consists of light grey, hard, sub-fissile to fissile shale. Generally, the section is seen to consist mainly of shale, claystone and siltstones that are partly calcareous

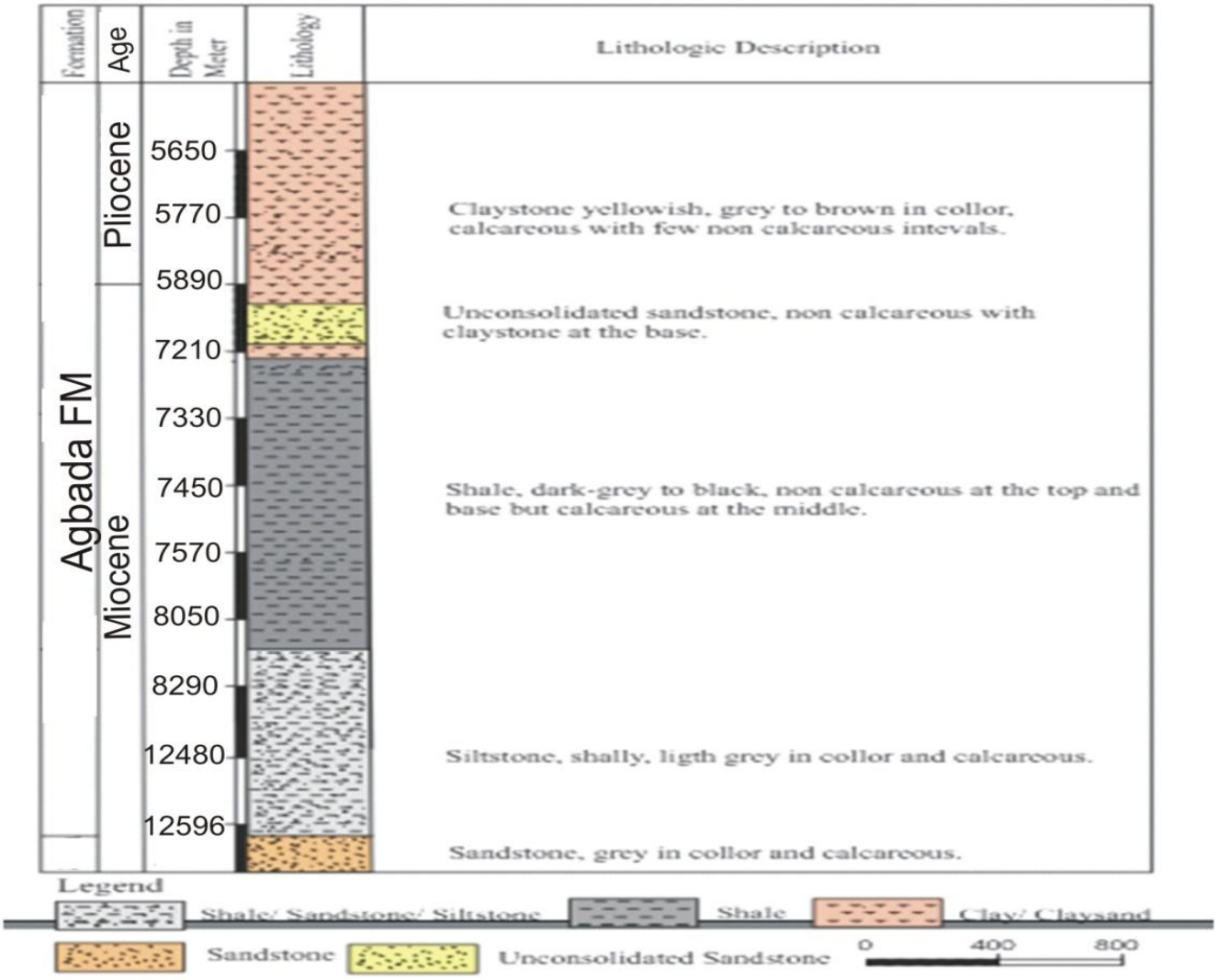


Figure 4: A lithologic framework for the study Well interval

Palynology:

The Results of the identified Palynomorphs for samples from the wells are shown in Palynology distribution Table for Wells L-1 and L-2 (see Tables 1 and 2). The pictures of some of the different forms of palynomorphs encountered during the study are also displayed. (See plate 1 and 2). The palynological

results were used for age determination and correlation of the two wells.

Most of the species observed show a rare to common occurrences within the studied intervals. The flora assemblage-Stratigraphic important zonal markers of chronostratigraphic values recorded consist of *Spiniferites pseudofurcatus, Multispinula quanta*, Chytrioeisplaeridium sp and Tuberculodinium vancampoae.

Some of palynomorphs encountered in the study were displayed on the distribution table and the recovered forms were used to plot distribution charts. (See Table 1). A distribution charts shows the distribution of the palynomorphs against their depth occurrence; Some of the recovered forms in the study area are; *Multispinula quanta*,, *Saeptodinium sp., Tectatodinium sp*. *Selenepemphix selenoides, Impagidinium cf. patulum, Hystrichosphaeropsis obscura, Lejeunecysta sp., Hystrichokolpoma sp. Lejeunecysta sp. Polysphaeridium subtile, Batiacasphaera hirsuta, Impagidinium patulum, Tuberculodinium sp.* Sumatradinium *hispidum* , *Chiropteridium sp., Hystrichokolpoma poculum, Hystrichokolpoma sp, Pentadinium sp*., Lejeunecysta *brassensis, Impagidinium sp. Lingulodinium sp. Trivalivadinium Plenum, Concentricytes rubinus, Tuberculodinium sp., Spiniferites sp*. *Chiropteridium sp., Hystrichokolpoma Poculum, Hystrichokolpoma sp. cf. Pentadinum sp., Impagidinium sp., Lingulodinium sp., Dapsilidinium pesudocolligerum, D.pastielsii, Quinquecuspis Concretum, Spiniferites lazus, Cordosphaeridium of cracenospinosum, Impagidinium sp., Lingulodinium sp.*

Selenepemphix nephroides, *Saeptodinium sp., Tectatodinium sp. Selenepemphix selenoides, Impagidinium cf. patulum, Hystrichosphaeropsis obscura, Lejeunecysta Hystrichokolpoma sp., Lejeunecysta sp. Polysphaeridium subtile, Batiacasphaera hirsuta, Impagidinium patulum,*. Sumatradinium *hispidu Spiniferites pseudofurcatus, Multispinulosa quanta, Depsilidinium pseudocolligerum. Operculodinium gigateum, Nematosphaeropsis Labyrinthea, Chytroeisphaeridium Sp, Sumatradinium Hispidum, Lingulodinium macheorophorum, dapsilidinium pastielsii, Tuberculodinium vancampoae, Lejeunecysta globosa*, *Operculodinium giganteum, Tuberculodinium vancampoae.*

L-1 Depth interval	***Selenepemphix nephroides***	***Impagidinium cf. patulum***	***Multispinula quanta***	**Chytrioeisplaeridium sp**	***Sumatradinium hispidum***	***Tectatodinium sp***	***Poculum, Hystrichokolpoma sp.***	***Dapsilidinium pesudocolligerum,***	***Lejeunecysta globosa,***
5650	6	5		4	3				
5770		2				2			
5890				1				2	3
6010									
6130		2		1					

6250	5									3		
6370			4	3				1			1	
6490												
6610										2		
6730												
6850												
6970						5					3	
7090										2		
7210	1	2										
7330								4				
7450				6							1	
7570										2		
7690												
7810	4											
7930						2						
8050	3											
8170				3						1	3	
8290						4						
8410										1		
8530												
8650											2	
8760										4		
8880	1		7			5						
9000						2						
9120	2		3	3								
9240							5					
9360				3								
9480												

9600				5			
9720					5		
9840		1		2		1	
9960							
10080		2			5		
10200							
10320		6				4	
10440			1	3	4		
10560							
10680							
10800		1					
10920							
11040					4		
11160		3		6		1	
11280							
11400						3	
11520							
11640							
11760							
11880					5		2
12000							
12120	2		3				
12240					2		
12360		3					
12480							
12596					1		5

Table 1: Palynology Distribution For Well L - 1

L-2 Depth interval	*Sumatradinium hispidum*	*Chytrioeisplaeridium sp*	*Multispinula quanta,*	*Polysphaeridium subtile,*	*Impagidinium patulum*	*Lingulodinium macheorophorum,*	*Tuberculodinium vancampoae*	*Lejeunecysta sp.*	*Hystrichosphaeropsis obscura,*
6830	3			2					
6950			4		2	6			
7070									
7190									
7310	1								
7430	3				5				
7550	5						3		
7670									
7790									
7880									
8180									
8300	2								
8420									
8540								1	4
8660		5			3				
8780									
8900									
9020		3							

9140		4	5		
9260					
9380					6
9500					
9650					
9770			2		
9890	3				
10010					
10130					
10250			1		
10370					
10490					
10610					
10730					
10850					
10970					

Table 2: Palynology Distribution For Well L-2

DISCUSSION OF RESULT

Palynological Biozonation:

The age delineation in this study interval of the well was attempted using palynological information obtained. Specific age determination were base on stratigraphic first appearance Datum (FAD) and last appearance Datum (LAD) of flora index marker fossils of palynomorphs assemblages. The presence of Radiolaria and Diatom clearly showed that the Formation is of deep marine environment

The well was sectioned using the globally recognized Zonation scheme of Germerad et al (1968) and also Reference to Zonation of Oloto, (1994.). Three major (3) zones were identified belonging to the Middle Miocene, late Miocene and early Pliocene. The zones are *Multispinulosa quanta Chytroeisphaeridium*

chytroides, Tuberculodinium vancampoae Zones;

1. **Well Name:** L-1

Zonal Description:- **:** Tuberculodinium vancampoae

Age: Early Pliocene

Stratigraphic Interval: 11880-12596 feet

2. Well Name: L-1

Stratigraphic Interval: 8880 to 11880 feet

Zonal Description:- *Chytroeisphaeridium chytroides* Zone

Age: Middle Miocene

3. Well Name: L-2

Stratigraphic Interval: 8540 -11220 feet

Zonal Description:. **:** Tuberculodinium vancampoae Zone

Age: Early Pliocene.

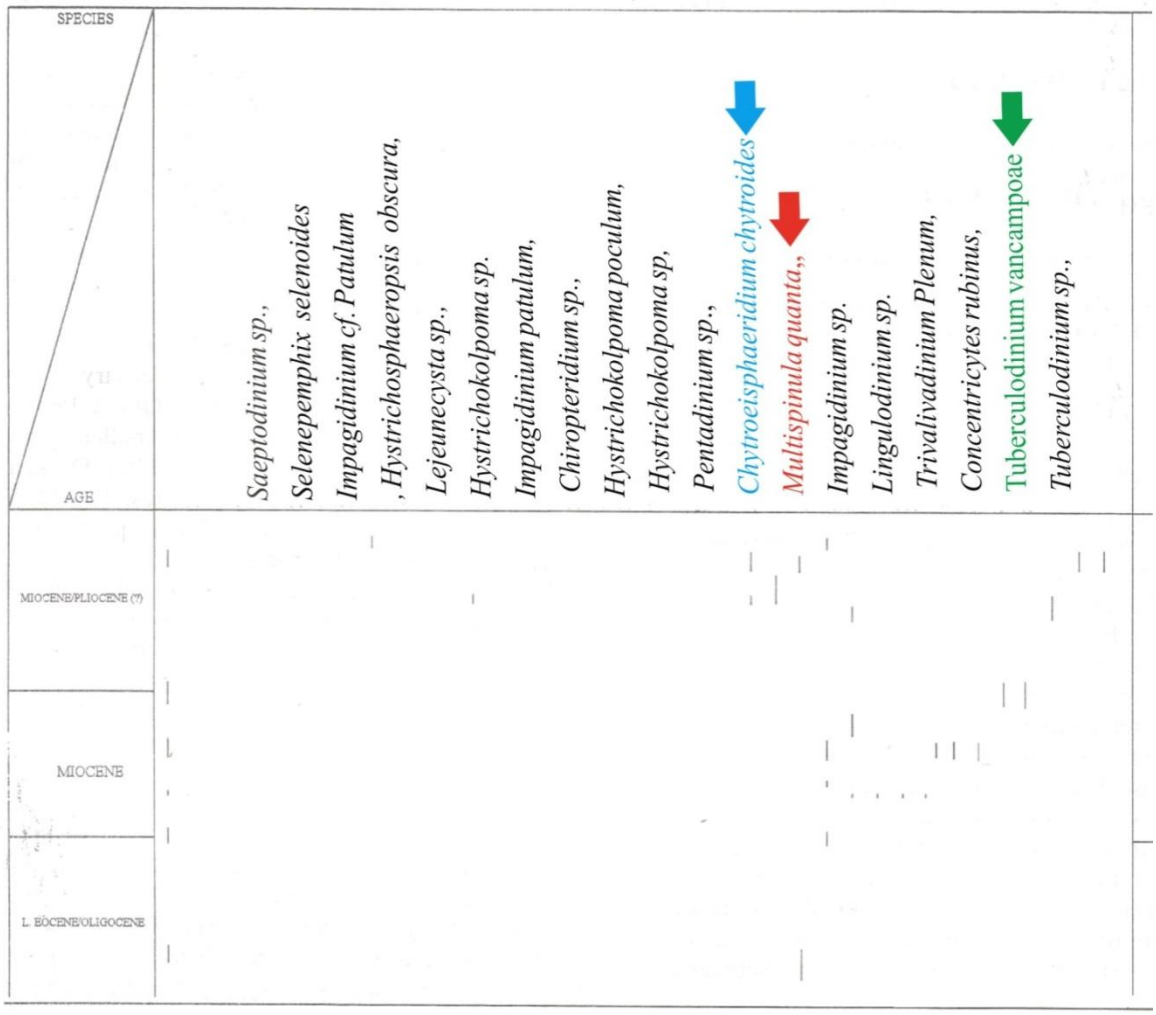


Figure 5: Stratigraphic ranges of dinoflagellate cysts in the study wells

4. Well Name: L-2

Stratigraphic Interval: 6830 - 8540 feet

Zonal Description *Multispinulosa quanta,* Zone

Age: Middle Miocene

AGE DETERMINATION: The known ranges of the biotratigraphically significant dinoflagellate taxa and the distribution of these taxa in the L-1 and L-2 wells section and the age determinations are discussed below.

The sequence between 12480-5650 feet yielded stratigraphically significant species whose age

ranges in literature include *Multispinula Quanta* (Miocene – Recent), *Nematosphaeropsis labyrinthea* (Middle Miocene – Pliocene),

Tuberculodinium vancampoae (Middle Miocene – Pliocene), *Ligulodiniunm macheoropheorumn* (Miocene – Pliocene), *Spiniferites Lazuss* (Middle Miocene – early pliocene), *Selenepemphix nephroidees* (Middle Eocene –pliocene), *Impagidinium patulum* (Middle Miocene- pliocene).

The overlapping ranges of these species, their co-occurrence in this section and their stratigraphic position above the lower Pliocene sequence (8540-11220) indicate an Upper Pliocene age for the sequence between 7510 and 9530 feet.

The boundary between the Upper Pliocene and the overlying sequence 11880-12596 is placed at the unconformity recognized at the 8050feet. The unconformity is recognized by the presence of pebbles overlain and underlain by shale, which is interpreted ad indicating the termination of a cycle of sedimentation. The sequence between 6130-7090 yielded, at scattered intervals, stratigraphically significant taxa and their age ranges in literature include *Impagidinium patulum* (Middle Miocene- Pliocene)

The presence of Tuberculodinium vancampoae established in Well L-1 suggests an age of not younger than Early Pliocene.

In addition, the observation of *Multispinulosa quanta* in Well L-2, further strengthen the age assignment to be older than Early Pliocene corresponding with the Early Pliocene – middle Miocene. *Multispinulosa quanta* is noted in both wells supporting that the age of the well has to be not younger than Middle Miocene, Zone, (Gemeraa et al 1968). The species is recorded in both wells giving the credence for correlation between the two wells.

Correlation:

Multispinulosa quanta Zone was established in both wells. These zones observed were used for correlation of the two wells, (See figure 5-correlation panel) the deduction from the correlation implies that the sequence of the two wells at that depth interval has an age range most likely of Middle Miocene this agrees with the previous Calcareous naanofossils research work done in the Niger Delta (Omoboriowo, & Okewale 2017). The age range is within the hydrocarbon generation and occurrences in commercial quantities in Niger Delta Basin.

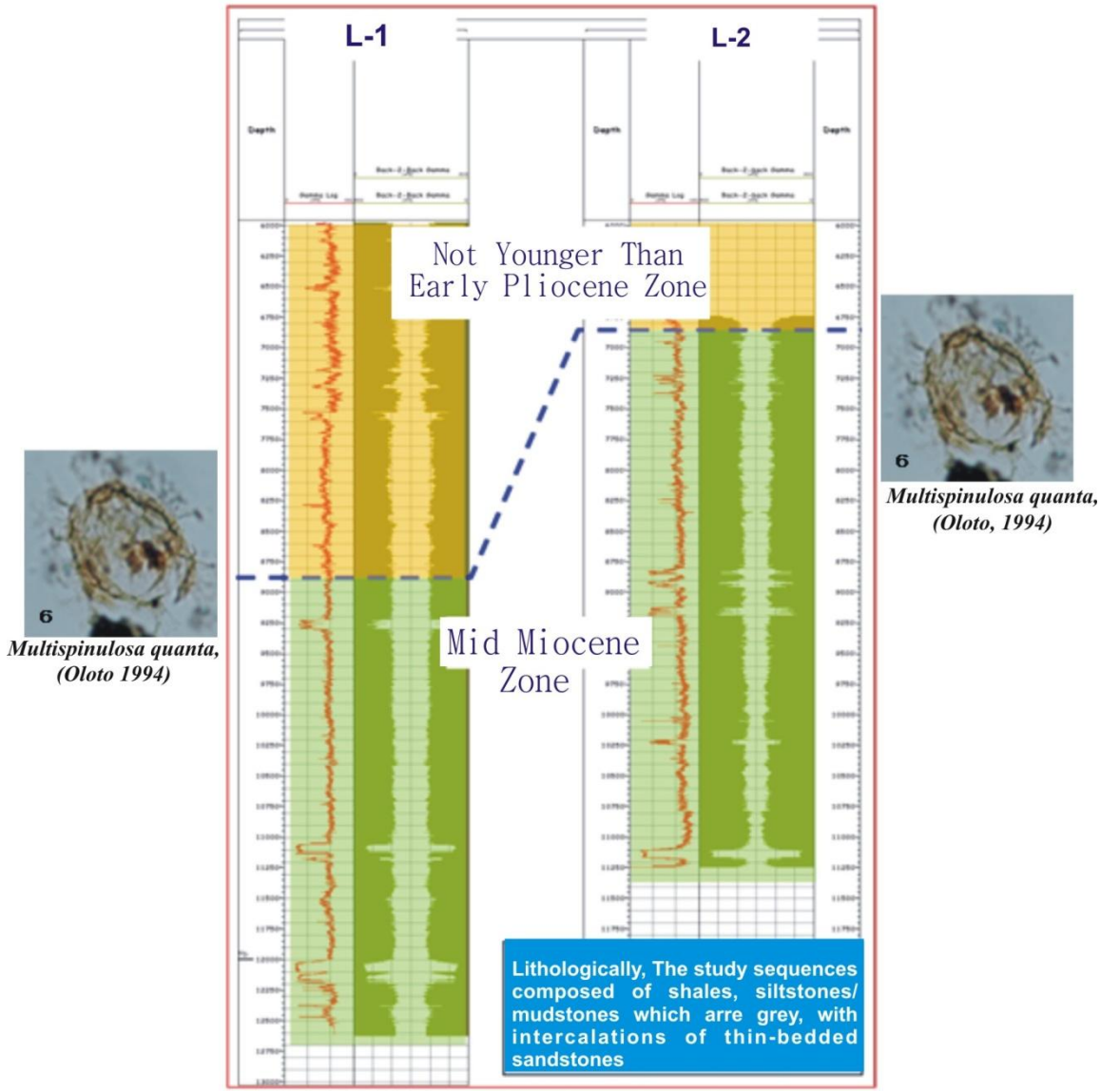


Figure 6: Correlation Panel of the study Wells

CONCLUSION

The data set obtained has demonstrated that the studied wells are thus dated from Early Pliocene through to Middle Miocene in age. The lithology of the well consists of silty shale to shale and sandatone units. The Lithology shows a coarsening upward sequence, which is typical of a delta. The boundaries are marked by unconformities recognized by the presence of gravel horizons in a predominantly silty shale sequence. It is interpreted as indicating the termination of a cycle of sedimentation when regression of the sea resulted in conditions favourable for the deposition of terrestmaterial.

Recommendation:

It is recommended that more funding should be made more available so that the further study of Palynology should be done to accommodate more wells for age assignment and correlation so that we can generate holistic regional data bank of Palynology which will serve as a source of stratigraphic information for oil industry exploration and production activities, as well as erecting a more refined and high resolution Palynology Zonation Scheme for the Niger Delta .

Acknowledgement:

1. The Researchers would like to express appreciation to **Tertiary Education Research Fund (TETFUND)** for providing a research grant to under the platform of **Institution Based Research Intervention fund** to carry out this research work.
2. The Researchers are also grateful to Drs. Soronnadi-Ononiwu, G.C and . Yikarebogha. Yinbudhogha for their critical appraisal of the manuscript and providing unpublished information on the Miocene dinoflagellate cysts of Niger Delta.

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