Palynology And Sequence Stratigraphic Analysis of OL-A Well Eastern Niger Delta, Nigeria

UJOH O.L.[1], CHUKWUMA-ORJI J.N.[2]
[1, 2] *Department of Geology, Federal University of Technology, Minna, Nigeria*

Abstract- Palynology and Sequence stratigraphy analyses of the strata penetrated by OL-A well was investigated in other to decipher the age, biozone, and sequence stratigraphic framework using data sets from palynology. A total of thirty-three (33) ditch cutting samples within the intervals of 7810-3340 ft were analyzed. Acid method was used for the palynomorph recovery. A total of fifty-five (55) palynomorph species were recovered. The section was dated Oligocene-early Miocene due to the occurrence of the diagnostic maker species such as Cicatricosisporites dorogensis, Arecipites exilimuratus, Echiperiporites estelae. A taxon range zone of Cicatricosisporites dorogensis, concurrent range zone of Arecipites exilimuratus-Striatricolpite catatumbus Zone and interval zone of Pachydermites diederixi-Peregrinopollis nigericus Zone were established. Condensed sections and maximum flooding surfaces were observed from the palynological results and were integrated with the well log to delineate system tracts and other stratigraphic surfaces. The shales of the TST could form potential reservoir seals, while the LST and HST could form good exploration target during hydrocarbon exploration.

Indexed Terms- International stratigraphic guide, Miocene, Oligocene, Palynomorph, Palynostratigraphic zone, Stratigraphic surfaces,

I. INTRODUCTION

Palynology, which is the study of the entire acid-resistant microscopic organic matter recovered from sedimentary rock finds its use in petroleum exploration both in terrestrial and marine environment. Palynology is useful for chronostratigraphic correlation, paleoenvironmental studies, evaluation of potential source reservoir and sealing rocks when integrated with well logs and seismic stratigraphy (Copestake, 1993).

Sequence stratigraphy is the study of rock relationships within a chronostratigraphic framework of repetitive, genetically related strata bounded by surfaces of erosion or non-deposition or their correlative comformities (Van Wagoner *et al.*, 1987). It has gained wide acceptance and recognized as an effective tool for predicting stratigraphic traps, reservoir quality and continuity by oil and gas industries. The arrival of sequence stratigraphy has made a major force to furthering biostratigraphy studies (Simons and Williams, 1996; Emery and Myers, 1996). This is because time is the framework of sequence stratigraphy. Essentially, this means that sequence stratigraphic studies require a biostratigraphy framework in which to place the organization of sequence boundaries, maximum flooding surfaces and system tracts. The aim of this work is to integrate stratigraphic tools such as palynology and well log in order to establish stratigraphic surfaces and system tracts of the strata penetrated by OL-A well.

- *Location of the studied well*

The Niger Delta Basin is located between latitudes 4º and 6º N and 3º and 9º E in Southern Nigeria. OL-A well is situated at the onshore part of Eastern Niger Delta in the Greater Ughelli Depobelt. It is located on latitude 5º43'00"N and longitude 6°33'00"E. (Fig.1)

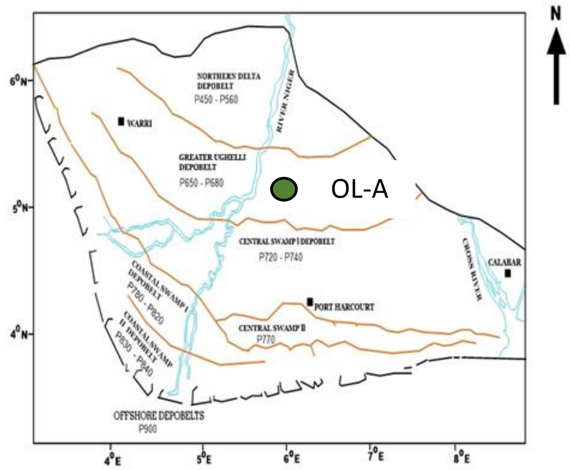

Fig1. Location of OL-A Well, on Greater Ughelli Depobelt, Eastern Niger Delta, Nigeria. (Modified after Doust and Omatsola, 1990)

- *Geology of the Niger Delta*

The stratigraphy and geology of the Tertiary Niger Delta has been described by Short and Stauble (1967). They described three formation in ascending order, these are the Akata Formation, Agbada, and Benin Formations. The Akata Formation generally consist of marine prodelta shales. The prodelta shales are dark grey with lenses of silistone and sandstone (Allen, 1965). The Akata Formation is considered to be the main source rock in the Niger Delta (Evamy *et al*., 1978). The Agbada Formation consist of cyclic coarsening –upward regressive sequences. The coarsening upward sequences are composed of shales, siltstones, and sandstones which include delta front and lower delta plain deposits (Weber, 1971). The Agbada Formation forms the hydrocarbon reservoir in the Niger Delta. The Benin Formation is the topmost unit which comprises a succession of massive poorly indurated sandstones, thin shales, coals and gravels of continental to upper delta plain origin.

Doust and Omatsola (1990) recognized depobelts in the Niger Delta which are distinguished primarily by their age and most importantly their location. These are Northern Delta, Greater Ughelli, Central Swamp, Coastal Swamp, and Offshore depobelts (Fig1). An individual depobelt is usually fault bounded both

II. MATERIALS AND METHODS

2.1 Palynological Preparation Method

A total of thirty-three (33) ditch cutting samples within the interval of 7810-3340 ft from OL-A well collected from Addax Nigerian Petroleum Limited (ANPL) Lagos, were subjected to palynological analysis. The sample preparation and analysis were done in Mosunmolu Laboratory Nigeria Limited, Lagos. Standard laboratory technique was involved which include weighing and cleaning of the sample, followed by digestion of the sample in hydrochloric and hydrofluoric acids for carbonates and silicates removal respectively (Ediger, 1986). Separation and sieving were done using brason sonifier for removal of clay and silt particles. Controlled oxidation was carried out on the sieved residue using concentrated nitric acid (HNO_3). The residue were then stained with Safranin O to enhance the appearance of any dinoflagellate cyst. Afterwards, the residue were then spotted on cover slips of 22/32mm and allowed to dry for mounting; Loctite (impruv) was used as the mounting medium. Forms viewed were identified and named using palynological albums and also different systematic publications of Cenozoic palynomorphs such as Van Der Hamman and Wymstra (1964), Germeraad *et al*. (1968), Evamy *et al.* (1978), and Legoux (1978). The identified forms were counted using tally system and recorded on the analysis sheet. The process was repeated for all the slides and the result inputted into the stratabug software to prepare the palynomorphs chart.

2.2 Sequence Stratigraphic Method

The sequence stratigraphic interpretation was carried out by integrating the palynological data with the well log to establish stratigraphic surfaces and system tract.

The sequence stratigraphic analysis involved the following stages;

1. Interpretation of the lithology from the gamma ray log and ditch cuttings.
2. Flora abundance and diversity peaks were used to determine condensed sections with depths
3. Maximum flooding surfaces were determined from the log character with the highest gamma ray reading showing shaliest point
4. System tracts and sequence boundaries were established based on characters observed from the

biostratigraphic results and well logs at the proximal and distal limits and essentially filled with paralic sediment. The deposition of paralic sediments in each depobelt results from eustatic sea level changes active within the development of a depobelt. The sea level oscillation are the result of alternating transgression and regression depending on either rise or fall of the sea level. Growth fault, rollover anticlines and antithetic faults are the commonest structure in the Niger Delta. Other structures include crestal faults, flank faults, shale diapirs (Doust and Omatsola, 1990).

III. RESULT AND DISCUSSION

A total of fifty-five (55) species of Palynomorphs were recovered from OL-A well. Pollen and spores were good, with a total species count of forty-two (42), Dinoflagellates were fairly represented with ten (10) species found in well OL-A well. Algae were poorly recovered with only three species. The recovered palynomorph are represented in fig 2

- *Palynological Zonation and Age Dating*

Zone I: *Arecipites exilimuratus- Striatricolpite catatumbus* Zone
Zone type: Concurrent Range Zone
Depth: 7810-6190 ft.
Age: Middle Oligocene
Diagnosis: The top of this zone is marked by the FDO of *Arecipites exilimuratus* at 6190 ft and at the base by the LDO of *Striatricolpite catatumbus* at 7810 ft.
The base of this zone is characterized by the LDO of *Monocolpite*sp., *Pachydermites diederixi*, pollen indeterminate, *Verrucatosporite* sp., *Zonocostite ramonae, Monoporite annulatus, Sapotaceoidaepollenites* sp., *Psilatricolporites crassus*, *Spiniferites* sp. Within the zone are the FDO and LDO of *Nematosphaeropsis* sp. Also found in this zone is the single occurrence of *Spiniferites pseudofurcatus, Spiniferites ramosus, Botryococcus braunii, Praedapollis flexibilis, Psilatricolpites* sp., *Recamonocolpites* sp., and *Retimonocolpites* sp. The top of this zone is marked by the abundant/increase occurrence of marker species *Retibrevitricolporites obodoensis/protrudens* at 6190 ft as it relates to the P560 subzone of Evamy *et al*. (1978).

Zone II: *Cicatricosisporites dorogensis* Zone
Zone type: Taxon Range Zone
Depth: 6190-4150 ft
Age: Late Oligocene
Diagnosis: This zone is marked by the FDO and LDO of *Cicatricosisporites dorogensis*. The base is characterized by abundant/increase of marker species *Retibrevitricoporites obodoensis/protrudens.* Other associated species within the zone are *Lingulodinium machaerophorum*, *Arecipites crassimuratus, Concentricytes circulus, Echiperiporites* sp., *Aletesporites* sp., *and Echiperiporites estelea*. Other long ranging species running through this zone are dinocyst indeterminate, *Selenopemphix nephroides, Inaperturopollenites* sp., *Monocolpites* sp., *Pachydermites diederixi, Recamonocolpites hians, and Retitricolporites* sp. The zone correlates with the P580 subzone of Evamy *et al*. (1978) which is marked by top occurrence of marker species *Cicatricosisporites dorogensis.*
Zone III: *Pachydermites diederixi- Peregrinipollis nigericus* Zone
Zone type: Interval Zone
Depth: 4150-3340 ft
Age: Early Miocene
Diagnosis: The top of this zone is marked by the FDO of *Pachydermites diederixi* at 3340 ft and the base is marked by the FDO of *Peregrinipollis nigericus* at: 4150 ft. Other species marking their FDO at the top of this zone are *Zonocostite ramonae*, *Monoporite annulatus, Sapotaceoidaepollenites* sp., *Laevigatosporites* sp., *Retitricolporites irregularis*, dinocyst indeterminate, *Leiosphaeridia* sp., *Psilatricolporites* sp. and fungal spores and hyphae. Species with their FDO at the base of this zone include *Canthiumidites* sp., *Cicatricosisporites dorogensis*, *Inaperturopollenites* sp., *Monocolpite* sp., and pollen indeterminate. Species marking their only occurrence within this zone include *Pediastrum* sp., *Nympheapollis* sp., *Psilatricolporites operculatus, Proteacidtes cooksonni* and *Echiperiporite icacinoides.* This zone corresponds with P620 of Evamy *et al.* (1978), as it is bounded at the base by the top occurrence of marker species *Cicatricosisporites dorogensis*.

The biozones established from OL-A well was found to correlate to P560, P580, and P620 of Evamy et al. (1978). These palyzones fall within the Oligocene–Early Miocene Epoch with different ages. The palyzone P560 (Middle Oligocene) falls within the Rupelian stage ranging from 31.8-29.3 Ma, the P580 palyzone (Late Oligocene) falls within the Chattian stage with age range from 29.3 to 25.8 Ma and P620 pollen zone (Early Miocene) which falls within the Aquitanian stage and ranging between 25.8 to 22.5 Ma. This is further supported by the presence of Oligocene-Early Miocene marker species such as *Cicatricosisporites dorogensis* (Late Eocene to Oligocene), *Arecipites exilimuratus* (Oligocene to Miocene), *Echiperiporites estelae* (Oligocene to Miocene), *Crassoretitriletes vanraadshooveni* (Oligocene to Miocene), *Spirosyncolporites bruni* (Oligocene to Miocene), *Praedapollis flexibilis* (Eocene to Pliocene), *Peregrinipollis nigericus* (Eocene to Pliocene), *Recamonocolpites hians* (Oligocene to Miocene), *Gemmatricolporites* sp., (Early Miocene), *Zonocostite ramonae* (Early Miocene to Pleistocene). The presence of the above mentioned palynomorphs at different levels in OL-A well is an indication that the stratigraphic interval under investigation was deposited during the Oligocene to Early Miocene Epoch.

- *Sequence Stratigraphy Interpretation*

The well log, palynological data were used to carry out the sequence stratigraphic analysis to delineate stratigraphic surfaces and system tracts.

- *Condensed Section and Maximum Flooding Surface*

Condensed sections are stratigraphic unit that are mainly marine, pelagic, bio-rich sediment which are deposited slowly and are linked to periods of transgression. The continual deposition of this bio-rich sediment over time produces sequences characterized with different flora and fauna types.

The condensed section were identified in OL-A well with stratigraphic intervals that made up of abundant and diverse palynomorphs. OL-A well has a condensed section identified at the interval of 4150-3340 ft

Maximum flooding surface (MFS) represents the peak point of major condensed section. These surfaces are usually characterized by high abundance and diverse palynomorph peaks. The MFS are also identified by high gamma, low resistivity, and sonic peaks characterized by the shaliest part of the major condensed sections (Catuneanu, 2006). The maximum flooding surfaces for OL-A well were identified at 4528 ft. The identification were based on the following observation

- Abundant and diverse palynomorphs at 3580 ft
- Points of high gamma ray reading showing shaliest point in the section with API of 145
- Peak abundance of dinocyst at 3580 ft
- Highest population of mangrove swamp species which is an indication of sea level rise
- MFS depth recorded low PMI value which was interpreted as depth having marine intrusion.

- *Sequence Boundary (SB)*

Sequence boundaries are tied to periods of regression. They are usually identified in depths with low palynoflora or absent of flora which correspond to low gamma ray reading. The point of change between coarsening upward (forestepping) and fining upward (backstepping) are referred to as sequence boundaries. The sequence boundary was established at a depth of 6130 ft and dated 23.3 Ma.

- *Trangressive System Tract (TST)*

Trangressive system tract is usually deposited during periods of relative sea level rise and persist until the maximum relative rise of the sea level is realized at MFS. TST fining upwards sequence have been recognized as excellent seal for hydrocarbon reservoirs. The TST was established for OL-A well at depth interval of 5860-3580 ft. This interval was described as TST because of the following observations;

- Generally, a fining upward sequence was observed from the gamma ray log with an observable increase in gamma ray readings from base to top in the section
- There is an evident of higher mangrove swamp floras which is an indicator of sea level rise
- The TST ends with a condensed section which is an evident of flora abundance and high gamma ray reading
- Abundant increase in dinocyst

- *Highstand System Tract (HST)*

Highstand System Tract is characterized by a set of prograding coarsening upward and shallowing upward that terminates at SB. The HST was marked at the interval of 4560-3700 ft because of the following criteria;

- It is the stratigraphic interval above SB when sediment have moved the greatest distance landwards (Catuneanu *et al*., 2012)
- General coarsening upward sequence and shallowing upward parasequence that terminates at SB.
- There is an increase in freshwater palynomorphs and open forest floras which increase until there is a fall in sea level (Morley, 1995)

- *Lowstand System Tract (LST)*

At the initial stage of the Lowstand System Tract, the sea drops rapidly, resulting to erosion and incision of lower coastal plain (Adojoh *et al*., 2015). They have an overall coarsening upward parasequence set with slow sedimentation rate in excess of the rate of accommodation. Lowstand System Tracts are shown in some wells in the Niger Delta to be consists of shoreface sand with shale bands. The LST was marked at the stratigraphic interval of 6130 ft- 5860 ft because of the following observations;

- Low abundance of mangrove species which is an indication of sea level fall.
- Low gamma ray readings were observed from the log
- The lithology penetrated as shown from the log indicate a general coarsening upward sequence.
- Presence of fungal spores which is an indication of sea level fall

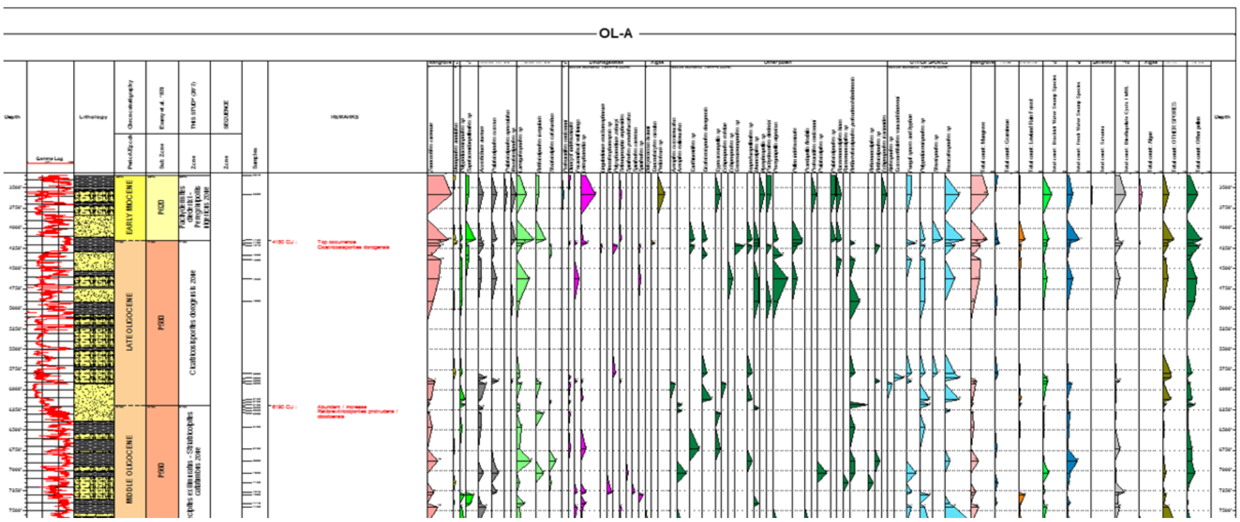

Fig 2 Palynomorph distribution chart of OL-A well

ACKNOWLEDGMENTS

The authors thank Prof. E. A. Okosun for constructive comments and suggestions which help us improve our manuscript. Our sincere gratitude goes to the Department of Petroleum Resources (DPR) and Addax Petroleum Development Nigeria Limited for the provision of well log and ditch cutting samples, used for this research work. They staff members of Mosunmolu Nigeria Limited are also appreciated for assisting in carrying out the palynological analysis.

REFERENCES

[1] Adojoh, O., Lucas, F. A., & Silas, D. (2015). Palynocycles, paleoecology and system tracts concepts. A Case Study from the Miocene Okan-1 well, Niger Delta Basin, Nigeria. *Applied Ecology and Environmental Sciences*. *3*(3), 66-74.

[2] Allen, J. R. L. (1965). Late Quaternary Niger Delta and adjacent areas: Sedimentary Environment sand lithofacies. *American Association of Petroleum Geologist* Bulletin, 49, 547-600.

[3] Catuneanu, O., Galloway, W. E., Kendall, G. S. C., Miall, A. D., Posamenteir, H. W.,Strasser, A., & Tucker, M. E. (2012). Sequence stratigraphy: Methodology and nomenclature. *Newsletters on stratigraphy*. *44*(3), 173-245.

[4] Copestake, P. (1993).Application of micropaleontology to hydrocarbon exploration in the North Sea Basin. In: Jenkins, D.G. (ed.), *Applied Micropaleontology*, 51, 93-152.

[5] Doust, H., & Omatsola, E. (1990).Niger Delta Divergent/passive Margin Basins.*Ame-rican Association of Petroleum Geologist Memoir*, 48, 239-248.

[6] Ediger, V. S. (1986).Sieving technigues in palynological sample processing with special reference to the MRA system, *Micropaleontology, 32* (3), 256-270.

[7] Emery, D. & Myers, K. J. (1996). *Sequence stratigraphy*: Oxford Blackwell science.

[8] Evamy, D. D., Haremboure, J., Kameling, P., Knaap, W. A., Molleoy, F. A., & Rowla-nds, P. H. (1978). Hydrocarbon Habitat of the Tertiary Niger Delta. *American Association of Petroleum Geologist Bulletin.* 62, 1-39.

[9] Germeraad, J. H., Hopping, C. A., & Muller, J. (1968). Palynology of Tertiary Sediments from Tropical areas .*Revised Palaeobotany and Palynology*, 6, 189-198.

[10] Legoux, O. (1978). Quelques Espèces De pollen Caractéristiques Du Néogéne Du Nigeria. Centre for Research and Exploration Production, *Elf Aquitane*, 2, 265-317.

[11] Morley, R. J. (1995). Biostratigraphy characterization of system tracts in Tertiary sedimentary basins. *Proceeding of the Internatinals Symposium on Sequenc Stratigraphy in South east Asia*, 49-71.

[12] Murphy, G., & Salvador, A. (1999). International stratigraphic guide – An abridged edition. *Internatonal Subcommission on Stratigraphic Classification of IUGS Inernational Commission on Stratigraphy, 22*(4), 255-271.

[13] Rull, V. & Poumot, C. (1997). Oligo-Miocene palynology of the Rio Chama Sequence (Western Venezuela), with comments on fossil algae Palaeoenvironmental indicators. *Palynology*. 21 213-229.

[14] Simmons, M. D. & Williams, C. L. (1996) Sequence stratigraphy and eustatic sea level change: the role of Micropaleontology, *Journal of Micropaleontogy*, 11, 112-120.

[15] Van der Hammen, D., & Wymstra, T. A. (1964). A palynology study on the Tertiary And Upper Cretaceous of British Guiana. *Leidse Geologische Mededelingen*, D1.30, 183-241.

[16] Weber, K., (1971). Sedimentological aspects of oil fields in the Niger delta. *Geology EnMijnbow*, *50* (3), 559-575.