Available online www.jsaer.com

***Journal of Scientific and Engineering Research*, 2018, 5(11):1-14**

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Maastrichtian to Danian Sedimentary Biozonation and Sequence Stratigraphy in Alo-1 Well, Anambra Basin, Southeastern Nigeria

Lucas, F. A.*[1], Osezele, E. I.[2]

[1]Department of Geology University of Benin, Benin City, Nigeria
[2]Geology and Geophysics Department, Skangix Development Limited, Lagos, Nigeria

Abstract A biozonation and sequence stratigraphic study of Maastrichtian to Danian sediment from Alo-1 well in the Anambra Basin, Nigeria was carried out using One hundred and five (105) ditch cutting samples recovered from depths ranging from 540ft to 8,600ft. A total of 81 species of miospores and 19 dinocysts were identified, evaluated and appraised for their biostratigraphic content. Maastrichtian to Danian age was assigned for the succession penetrated. The Cretaceous –Tertiary (K-T) boundary is delineated by both the FAD of a dinocyst species, *Damassadinium californicum* and LAD of a pollen species, *Constructipollenites ineffectus* at intervals 3,600ft and 4,360ft respectively. Palynomorph abundance pattern and the age of the succession penetrated were used to delineate stratal surfaces: two maximum flooding surfaces (MFS) and one sequence boundary (SB) were defined in the Danian, three maximum flooding surfaces (MFS) and two sequence boundaries (SB) were defined in the Maastrichtian. Based on the age established for the succession penetrated, the formations likely penetrated by the well were established to be the Imo (Danian) from 540ft-3600ft and Nsukka (3600ft-4570ft) -Ajali (4570ft-5170ft) and the Mamu (5170ft-8600ft) these have been dated Maastrichtian to Danian.

Keywords Dinocysts, Miospores, Sequence stratigraphy, Maastrichtian, Danian

1. Introduction

The Anambra Basin is basically characterized by sediments of Cretaceous and younger ages. The total thickness of the Anambra Basin is about 9km. The basin which ranges from Campanian to Recent has attracted interest lately due to its rich coal and petroliferous deposits. Lucas and Ishiekwene [1] described the Basin as a Cretaceous/Tertiary basin, consisting of a structural link between the Cretaceous Benue Trough and the Tertiary Niger Delta basin. The distribution of sand and shale within the basin is characterized by alternating sequences derived from a variety of paleoenvironmental settings. The presence of interbeded shales and sandstones with occasional limestones [2] resulted in an initial interest in search for oil and gas within the Lower Benue Trough (including the Anambra Basin) of Nigeria. Hydrocarbon exploration in the Anambra Basin has been dependent on the abundant Maastrichtian coal deposits. The Anambra Basin was long abandoned due to its fruitless and unrewarding effort for the exploration of petroleum [3]. The exploration for coal and petroleum in the Anambra Basin culminated into commercial production of coal in 1916 while oil exploration was abandoned as the efforts ended in a number of non-commercial discoveries.

A hundred and five (105) samples were described to establish a lithologic model. Forty (40) of the total samples were taken at varying intervals of depth and prepared using standard preparation techniques [4-5] for palynological analysis. Eighty one miospores and nineteen dinocysts species were recorded and their distribution plotted. The study area Alo-1 well is situated in the Anambra Basin, Southeastern Nigeria

between Latitude 06^{O} 43'58'' N and Longitude 7^{O} 18' 11''E. Alo-1 well is a well drilled to a total depth of 8600ft.

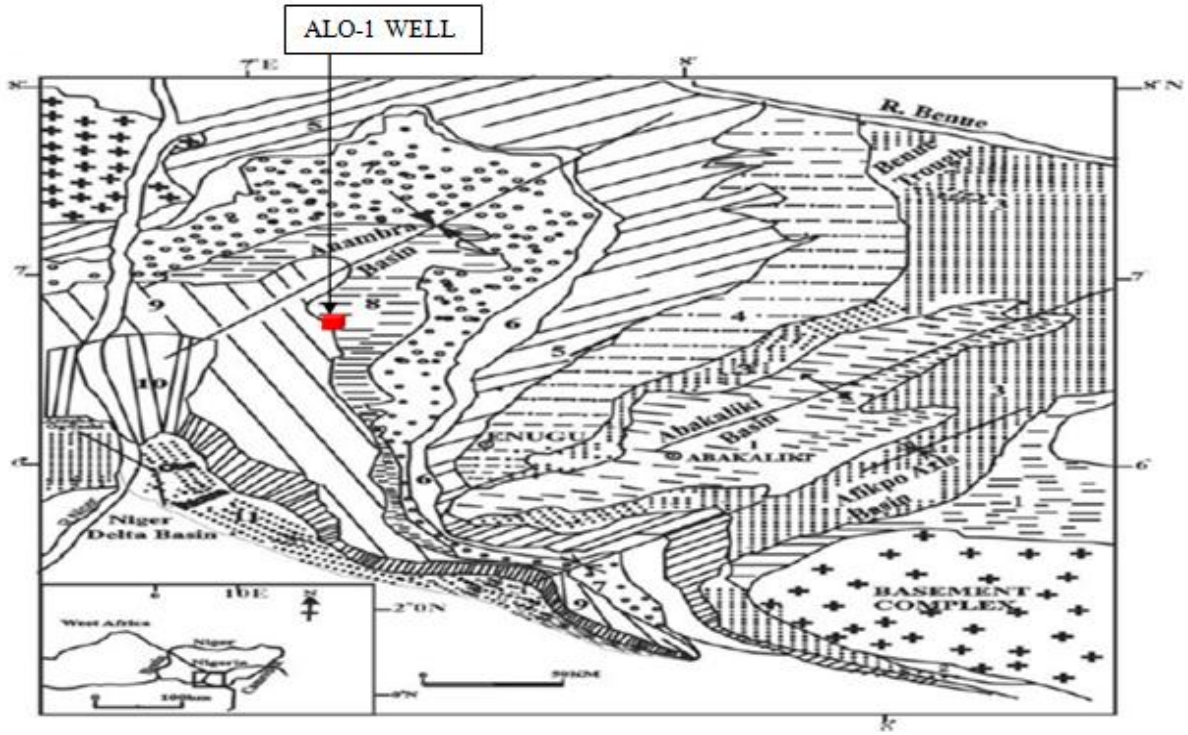


Figure 1: Map showing Location of Alo-1 Well, Anambra Basin, Southeastern Nigeria

Materials and Methods

A total of one hundred and five ditch cutting samples were collected from Alo-1 well, drilled in the Anambra Basin, South Eastern, Nigeria. The Samples ranged in depth from 540ft (180m) – 8600ft (2866m) and were carefully arranged from top to base of the well. Each sample was recorded and a detailed sedimentological description was carried out using a reflected light binocular microscope. From the sedimentologic description, a lithologic model was established. Forty (40) intervals of interest were selected for palynological analysis.

Sedimentological Description

A detailed sedimentological description using the reflected light binocular microscope was carried out documenting the ratio of sand-shale in percentage, texture (grain size, sorting, and degree of roundness), as well as accessory minerals found in the samples. Dilute HCl was used to test for presence of carbonate in sample; effervescence indicates the presence of carbonate in sediments. Photomicrographs were taken at some depths. In the absence of a wire-line gamma ray data, the ratio of sand-shale percentages was very useful in establishing a GR log using Petrel Software 2013.

***Palynological Sample Preparation*:** The samples for palynological analysis were selected from the lithologic model. From the sedimentological description, forty (40) samples were picked from varying intervals of interest and processed following standard palynological preparation techniques.

According to Wood *et al* [5], Palynological samples are better concentrated when processed using standard palynological techniques involving the use of Hf, HCl and HNO_3 including heavy-liquid separation ($ZnBr_2$) and sieving of the residue with a 20 µm sieve. Counting and logging of each palynomorph specie was done by straight transects across each slide and coordinates. The recovered palynomorphs species were identified using the Shell palynological photo album. Morphological characters of the pollens and spores such as the size, exine, structure, shape, sculpture and aperture type provided the basis for the identification of the forms. Species name and the number of times they were encountered were recorded in the analysis data sheets. Light photomicrographs were taken using an Olympus CH30 light microscope, equipped with a camera.

Results and Discussion

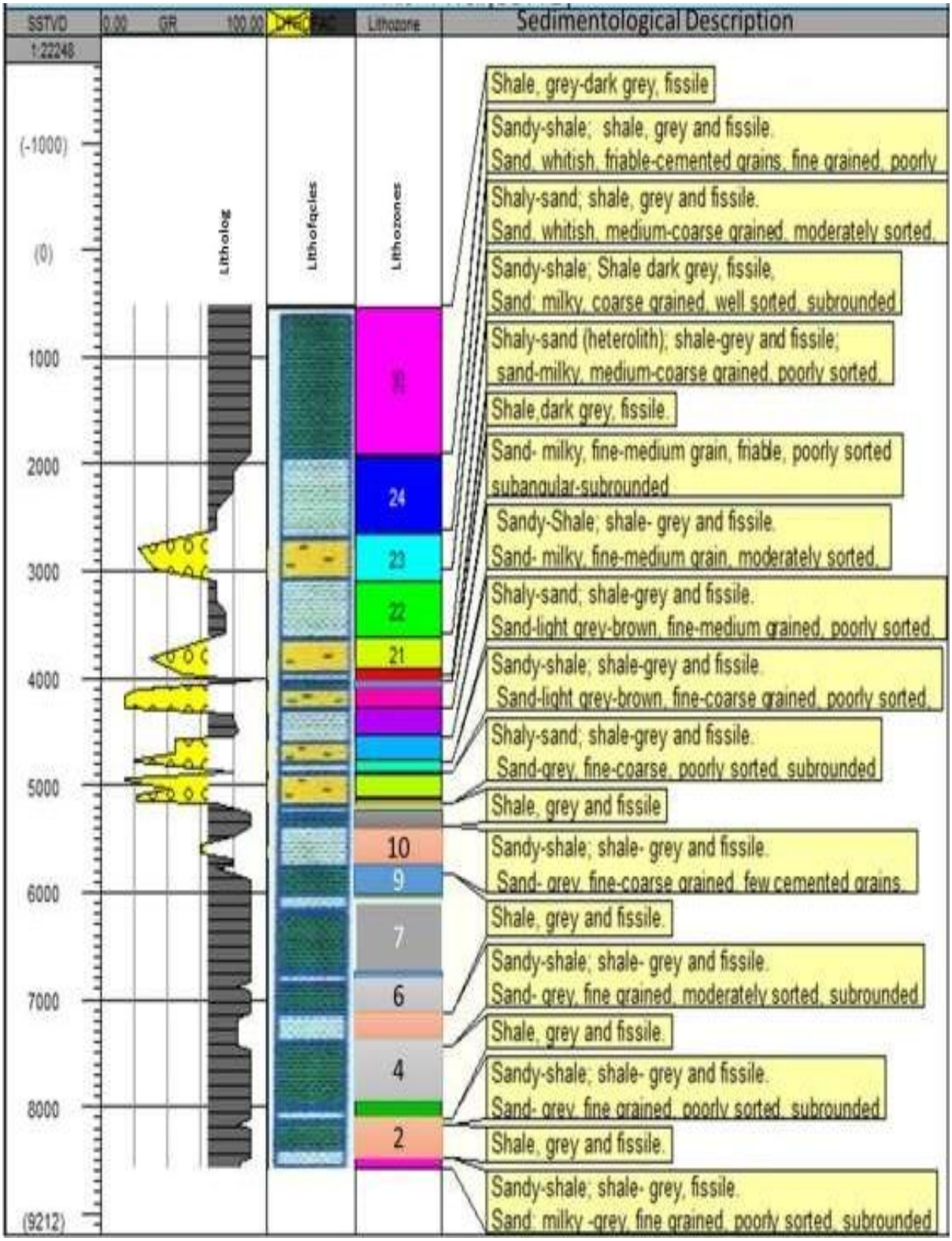


Figure 2: Lithologic description for Alo-1 Well

Palynology

Palynological sample analyses yielded a hundred (100) palynomorph species, these included; eighty one (81) miospores and nineteen (19) dinocysts respectively.

Recovered Miospores include: *Afropolis jardinus, Monocolpites marginatus, Anacolosidites spp., Arecipites spp., Auricullopollenites echinatus, Aquipollenites minimus, Belkispollis elegans, Buttinia andreevi, Cingulatisporites ornatus, Constructipollenites ineffectus, Retidiporites magdalenensis, Crototriocolpites crotonisculptus, Cretacaeiporites scrabatus, Concavissimisporites spp., Cyathidites australis, Deltoidsporites spp., Dictyophyllidites harrisii, Echitricolporites spinosus, Ephedripites costaliferous, Elaeis guineeses, Echiperiporites estalae, Echitriporites trianguliformis, Ephedripites ambonoides, Gematricolpites scrabatus, Gleischenidites spp., Polypodaceiosporites spp., Laevigatosporites spp., Lycopodium spp., Longapertites marginatus, Inaperturopollenites spp., Longapertites vaneendenburgi, Longapertites microfoveolatus, Monoporites annulatus, Leitrioletes spp.., Mauriitidites crassibaculatus, Monosulcites spp., Matonisporites spp., Praedapollis africanus, Momipites africanus, Proxapertites cursus, Psilamonoporites spp., Proxapertites operculatus, Psilatricolporites spp., Psilatricolpites spp., Proxapertites tertiaria, Proteacidites longispinosus, Pereglinipollis nigericus, Retidiporites miniporatus,Retibrevitricolpites triangulates, Retimonocolpites spp., Retitricolpites americana, Spinizonocolpites baculatus, Sartuna enigmaticus, Retitricolpites irregularis, Rugulatisporites caperatus, Retitricolpites clarensis, Retitricolporites crassicostatus, Striatricolpites catatumbus, Retistephanocolpites spp., Syncolporites marginatus, Steevesipollenites orbiculatus, Verrucatosporites tenellis, Zlisvisporites blanensis, Taxodiaceaepollinites hiatus, Tricolpollenites spp., Tetrad spp., Triplanosporites spp., Verrucatosporites usmensis.*

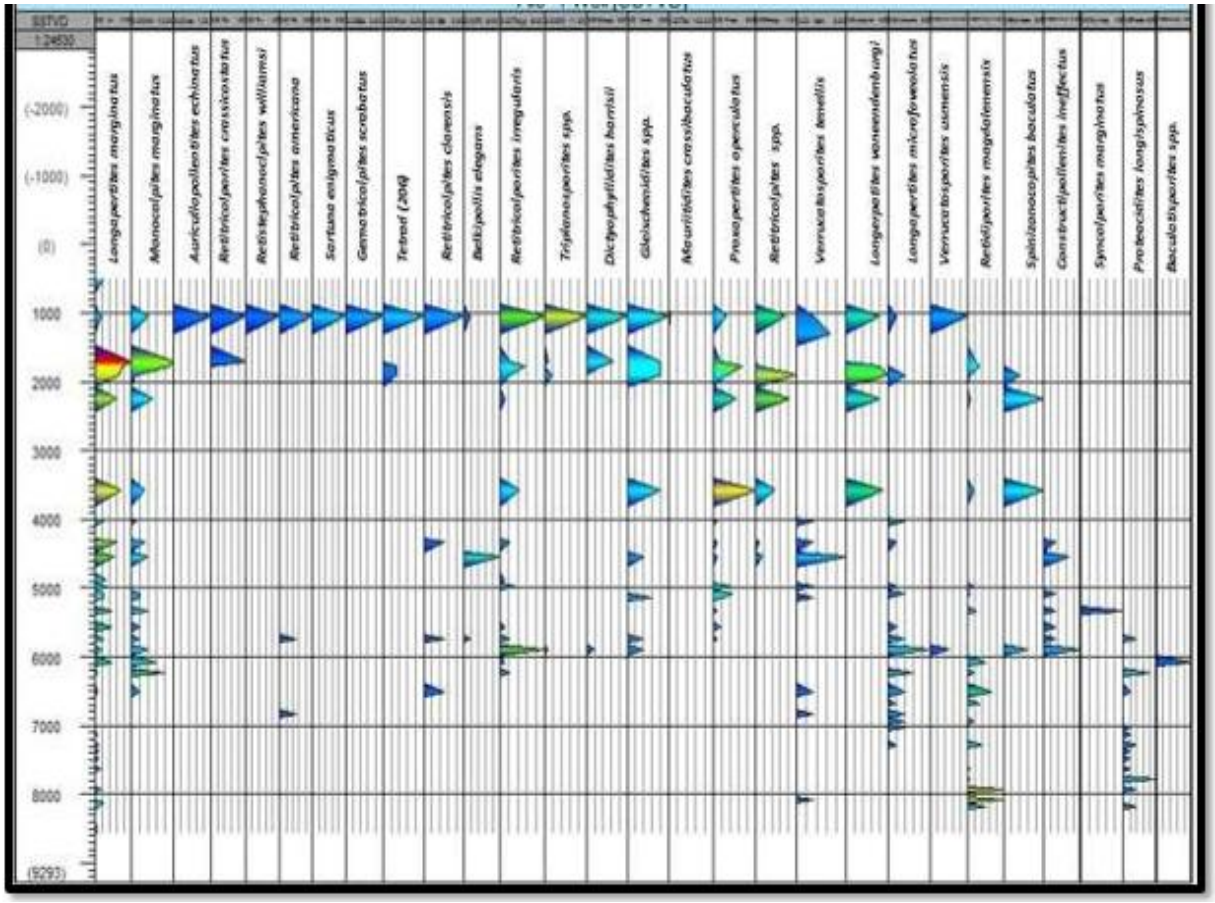


Figure 3: Miospore Range Chart for Alo-1 Well

Recovered Dinocysts include: *Cerodinium bolonensis, Cerodinium debeilii, Damasadinium californicum, Paleocystodinium australis, Eocladophyxis peniculatum, Fibrocysta lapacea, Fibrocysta bipolar, Muratodinium fimbriatum, Homotribilium paLast appearance datumium, Spiniferites cingulatus, Kallosphaeridium yorubaensis, Leiosphaeridia spp., Paleocystodinium golzowense, Spiniferites ramose, Selenopemphix spp., Systematophora spp., Fungal spores, Foraminiferal test lining* and *Tasmanite species.*

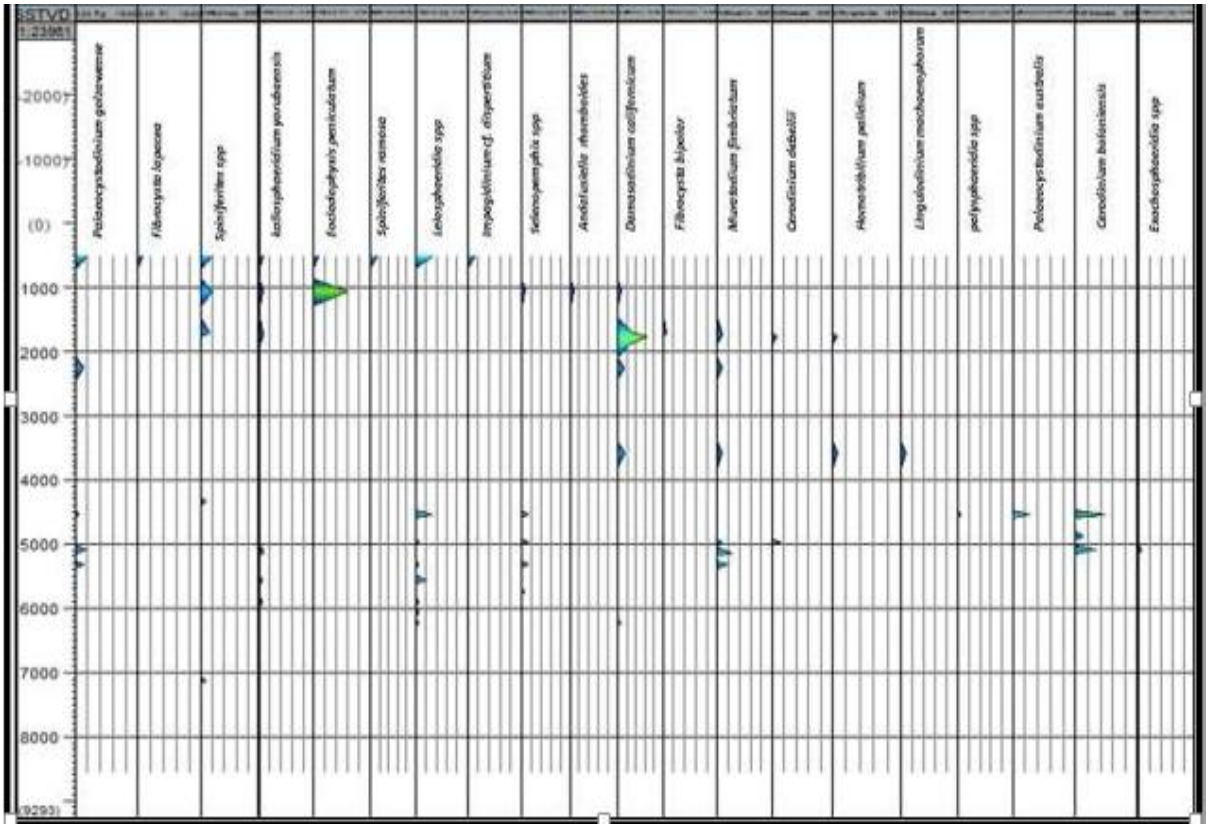


Figure 4: Dinocysts Range Chart for Alo-1 Well

Palynostratigraphy

Age Subdivision

Two chronostratigraphic stages were delineated in the well, a Danian stage in the Paleocene and a Maastrichtian stage in the Cretaceous.

The Danian stage (540ft-4360ft) was established based on the first appearance datum of *Damasadinium californicum* and last appearance datum of *Constructipollenites ineffectus. Damasadinium californicum* is a global microphytoplankton marker, it has been used to define the lower Paleocene (Danian) in other parts of the world for example in the Gulf of Mexico and in Northwest Tunisia to delineate the Cretaceous- Tertiary boundary. The dinocyst specie *Muratodinium fimbriatum* was seen to extend from Mid-Maastrichtian to Danian within the well section. The Danian within the well was further subdivided into zones using other dinocysts species recovered.

The Cretaceous-Tertiary (K-T) boundary (4360ft) was delineated based on the last appearance datum of the pollen *Constructipollenites ineffectus.* Van Hoeken- Klinkenberg [6] in his work using bore samples from Owan-1, Egoli-1 and Gbekebo-1, Nigeria; showed that the stratigraphic range of *Constructipollenites ineffectus* does not exceed the Maastrichtian. The age Danian has been assigned to intervals above this boundary at (540ft-4360ft) while a Maastrichtian age has been assigned to intervals below the boundary at (4360ft-8600ft).

A Maastrichtian age (4360ft- 8600ft) was established based on the continuous downhole occurrence of key miospores such as *Constructipollenites ineffectus, Buttinia andreevi, Cingulatisporites ornatus, Syncolporites marginatus.* The Maastrichtian was also further subdivided into zones.

Biozonation

The biozonation of the succession was carried out using age diagnostic palynomorph species. It was established based on the last appearance datum (LAD) of these species. Eleven miospores zones and five dinocysts zones were delineated.

Dinocysts Assemblage Zones

The *Kallosphaeridium yorubaensis* Assemblage Zone

Age: Danian (540ft -1080ft)

Definition: The top of this zone was marked using the last appearance datum of *Kallosphaeridium yorubaensis* at (540ft) and the base of this zone is marked using the last appearance datum of *Damasadinium californicum* at (1080ft). The last appearance datum of species *Paleocystodinium golzowense, Fibrocysta lapacea, Spiniferites spp., Impagidinium spp., Leiosphaeridia spp., Euclydophyxis peniculatum, Spiniferites ramose, Selenopemphix warensis* and *Andalusiella rhomboides* occurs within this zone. Acme occurrence of *Euclydophyxis peniculatum* was recorded within the zone.

The *Damasadinium californicum* Assemblage Zone

Age: Danian (1080ft-1740ft)

Definition: The top of this zone is defined by the last appearance datum of *Damasadinium californicum* at (1080ft) and the base of the zone is defined by the last appearance datum of Muratodinium *fimbriatum* at (1740ft). The last appearance datum of *Fibrocysta bipolar* is the only event found within this zone.

The *Muratodinium fimbriatum* Assemblage Zone

Age: Danian (1740ft-1800ft)

Definition: The top of this zone is marked by the last appearance datum of *Muratodinium fimbriatum* at (1740ft) and the base of the zone is marked by the last appearance datum of *Lingulodinium machaerophorum* at (1800ft). Events within this zone include the last appearance datum of *Cerodinium diebeilli* and acme occurrence of *Damasadinium californicum.*

The *Lingulodinium machaerophorum* Assemblage Zone

Age: Late Maastrichtian-Danian (1800ft-4570ft)

Definition: The top of this zone is marked by the last appearance datum of *Lingulodinium machaerophorum* at (1800ft) and the base of the zone is marked by the last appearance datum of *Paleocystodinium golzowense* at (4570ft). Events within this zone include the last appearance datum of *Polysphaeridia spp.* and acme occurrence of *Leiosphaeridia spp.*

The *Paleocystodinium australis* Assemblage Zone

Age: Late Maastrichtian (4570ft-5110ft)

Definition: The top of this zone is marked by the last appearance datum of *Paleocystodinium australis* at (4570ft) and the base of the zone is marked by the last appearance datum of *Exochosphaeridia spp.* at (5110ft). Events within this zone include the consistent and acme occurrence of *Cerodinium boloniensis.*

Miospores Assemblage Zones

The *Longapertites marginatus* Assemblage Zone

Age: Danian (540ft-1080ft)

Definition: The top of this zone is marked by the last appearance datum and consistent occurrence of *Longapertites marginatus* at (540ft) *and* the base of the zone is defined by the last appearance datum of *Monocolpites marginatus* at (1080ft). Events within this zone include the occurrence of *Monoporites annulatus, Deltoidspora spp., Gematricolpites scrabatus,Inaperturopollenites spp., Laevigatosporites spp., Lycopodium spp., Proxapertites curcus, Retitricolpites americana, Auricullopollenites echinatus, Retitricolporites crassicostatus, Retistephanoclpites williamsi, Sartuna enigmaticus, Tetrad (206), Rretitricolpites clarensis* and *Belkipollis elegans.*

The *Monocolpites marginatus* Assemblage Zone

Age: Danian (1080ft-1800ft)

Definition: The top of this zone is defined by the last appearance datum of *Monocolpites marginatus* at (1080ft) and the base of this zone is define by the last appearance datum of *Echitriporites trianguliformis* at (1800ft). Events within this zone includes the occurrence of species such as Species *Retitricolporites irregularis, Triplanosporites spp., Dictyophyllidites harrisii, Gleischenidites spp., Mauriitidites crassibaculatus, Proxapertites operculatus, Retitricolpites spp., Longerpatites vaneendenburgi, Longapertites microfoveolatus, Longapertites microfoveolatus, Verrucatosporites usmensis, Retidiporites magdalenensis, Monosulcites spp., Psilatricolporites spp., Mantonisporites spp., Dictyophyllidits spp.,* and *Anacolosidites spp.*

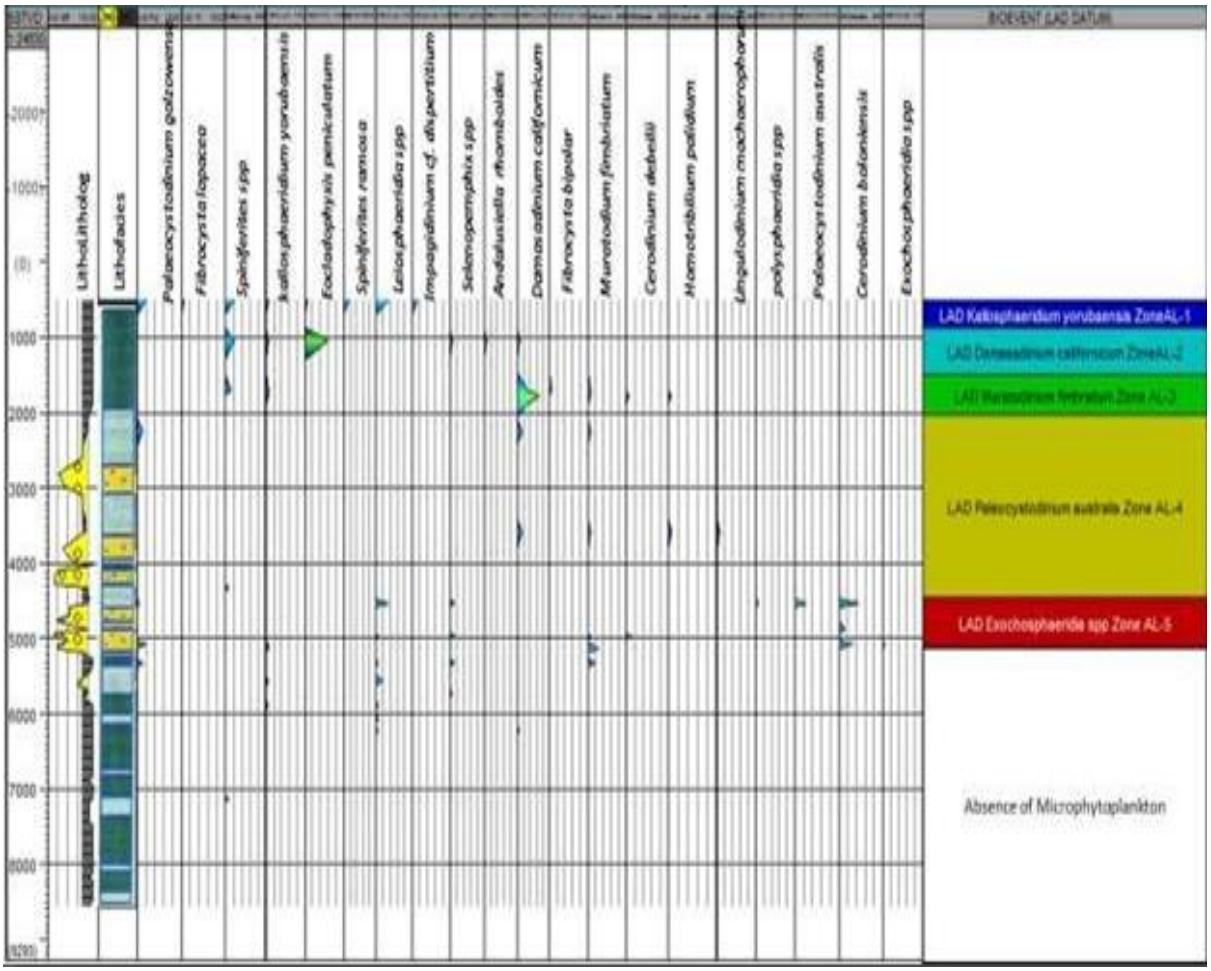


Figure 5: Dinocysts Biozonation for Alo-1 Well

The *Echitriporites trianguliformis* Assemblage Zone

Age: Danian (1800ft-1920ft)

Definition: The top of this zone is defined by the last appearance datum of *Echitriporites trianguliformis* at (1800ft) and the base is defined by the last appearance *Spinizonocolpites baculatus* at (1920ft). Events within this zone are the occurrence of species *Echiperiporites estalae, Psilamonocolpites spp., Tricolpollenites spp., Elaeis guineenses, Ephedripites costaliferous, Leitrioletes spp. Momipites africanus,* and *Striatricolpites catatumbus.*

The *Spinizonocolpites baculatus* Assemblage Zone

Age: Danian (1920ft-4360ft)

Definition: The top of this zone is defined by the last appearance datum of *Spinizonocolpites baculatus* at (1920ft) and the base this defined by the last appearance of *Constructipollenites ineffectus* at (4360ft). Events within this zone include the occurrence of *psilatricolporites transversalis, Retimonocolpites spp., Cretacaeiporites scrabatus, Concavissimisporites spp.* and Praedapollis *africanus.*

The *Constructipollenites ineffectus* Assemblage Zone
Age: Maastrichtian (4360ft-5350ft)
Definition: The top of this zone is defined by the last appearance datum of *Constructipollenites ineffectus* at (4360ft) and the base is defined by the last appearance datum of *Syncolporites marginatus* at (5350ft). Events within the zone include the occurrence of *Polypodaceiosporites spp., Rugulatisporites caperatus, Psilatricolpites spp., Buttinia andreevi, Taxodiaceaepollinites hiatus, Cingulatisporites ornatus, Aquipollenites minimus and Proxapertites tertiaria*. The presence of *Buttinia andreevi, Cingulatisporites ornatus* and *Constructipollenites ineffectus* has helped in delineating a Late Maastrichtian age for this interval.

The *Syncolporites marginatus Assemblage* Zone
Age: Maastrichtian (5350ft-5770ft)
Definition: The top of this zone is defined by the last appearance datum of Syncolporites marginatus (5350ft) and the base is defined by the last appearance datum of *Proteacidites longispinosus* (5770ft). The zone is also marked by the last appearance datum of *Zlivisporis blanensis, Cyathidites australis, Ephedripites ambonoides* and *Steevesipollenites orbiculatus.*

The *Proteacidites longispinosus* Assemblage Zone
Age: Maastrichtian (5770ft-6100ft)
Definition: The top of this zone is defined by the last appearance datum of *Proteacidites longispinosus* at (5770ft) and the base is defined by the last appearance datum of *Baculatisporites spp.* at (6100ft). The zone is also marked by the last appearance datum of *Syndemicolpites typicus,* the first appearance datum and acme occurrence of *Constructipollenites ineffectus.*

The *Baculatisporites spp.* Assemblage Zone
Age: Maastrichtian (6100ft-7060ft)
Definition: The top of this zone is defined by the last appearance datum of *Baculatisporites spp.*, at (6100ft) *and* the base is defined by the first appearance datum of *Buttinia andreevi* at (7060ft). The first appearance datum of *Monocolpites marginatus* occurs within this zone, a regular occurrence of *Verrucatosporites usmensis* also marks this zone.
The *Deltoidospora spp.* Assemblage Zone
Age: Maastrichtian (7060ft-7400ft)
Definition: The top of this zone is defined by the first appearance datum of *Buttinia andreevi* at (7060ft) and the first appearance datum of *Deltoidospora spp.* at (7400ft). The first appearance datum of *Verrucatosporites usmensis* and *Cyathidites australis* occurs within this zone.

The *Retidiporites magdalenensis* Assemblage Zone
Age: Maastrichtian (7400ft-8200ft)
Definition: The top of this zone is defined by the first appearance datum of *Deltoidospora spp.* at (7400ft) *and* the base is defined by the first appearance datum of *Retidiporites magdalenensis* at (8200ft). The zone is marked by a consistent occurrence of *Laevigatosporites spp.* and *Echiperiporites estalae.* The last appearance datum of *Afropolis jardinus* occurs within this zone.
The *Afropolis jardinus* Assemblage Zone
Age: Maastrichtian (8200ft-8600ft)
Definition: The top of this zone is defined by the first appearance datum of *Retidiporites magdalenensis* at (8200ft) *and the base is marked by the first appearance datum of Afropolis jardinus. Other events within this zone include; the first appearance datum of Monoporites annulatus* and *Monosulcites spp.*

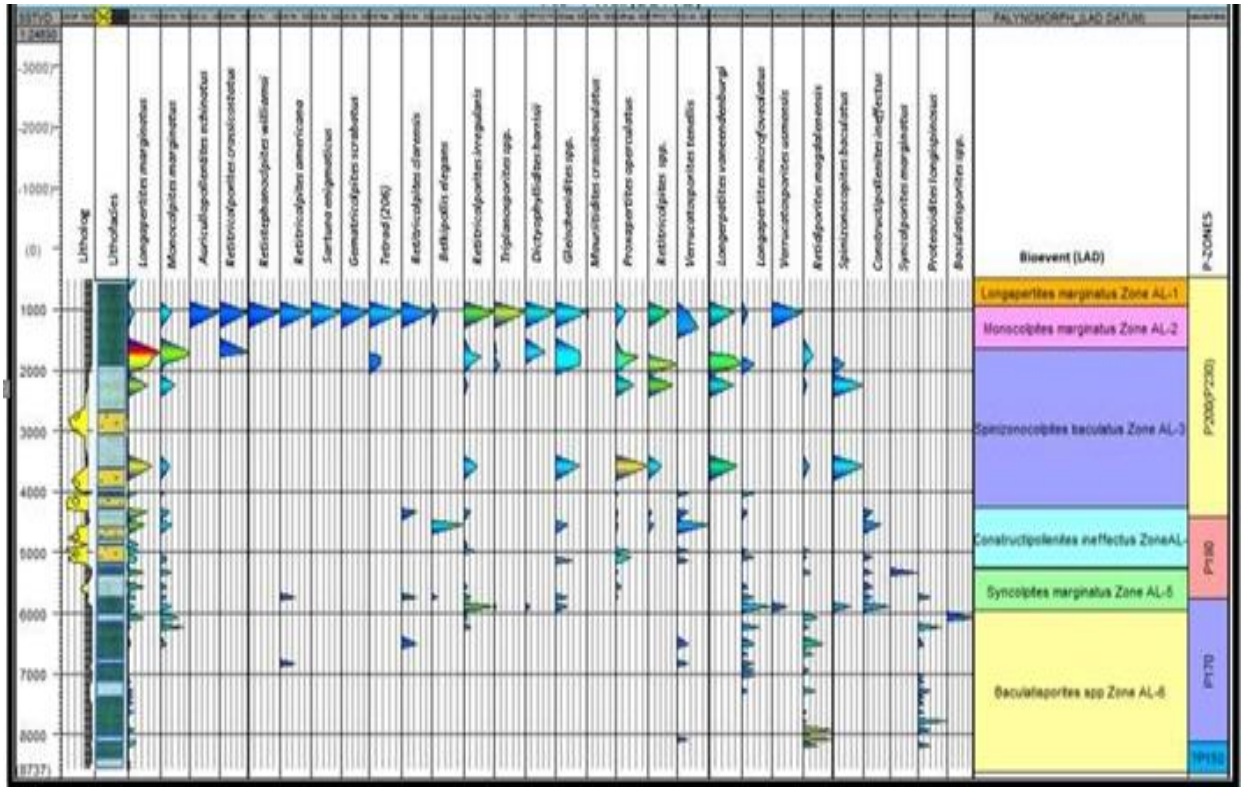


Figure 6: Miospore Biozonation for Alo-1 Well

Paleoenvironmental Reconstruction

The Paleoenvironment of deposition of the sedimentary succession penetrated by the well was established based on the palynomorph abundance pattern with depth.

Shelf Environment

***Reference Section:* 540ft-5340ft**

A shelf environment was assigned to the interval 540ft-5340ft based on the occurrence of both abundance of miospores and microphytoplankton (Gonyaulacacean and Peridiniacean dinocysts). Although the miospore abundance dominates over the microphytoplankton abundance, the regular occurrence of the dinocyst is indicative of marine influence, this too is supported by the near regular occurrence of foram test lining in this interval. The energy of the environment is inferred to be high because of the regular occurrence of both Gonyaulacacean and Peridiniacean dinocysts.

The paleoenvironment between 5340ft-8600ft is undiagnostic. There was a general decrease in palynomorph abundance with depth. The dinocysts became scarce with depth, but a few miospores were seen. The general decrease in abundance has been attributed to over maturity of the sediments, this is supported by the very dark colour of the few palynomorphs recovered. Though there were miospores, a terrestrial environment will not be fitting for this interval because the lithologic type is mainly shale.

Sequence Stratigraphy

Sequence stratigraphy is the analysis of cyclic sedimentation patterns that are present in stratigraphic successions, as they develop in responds to variations in sediment supply and space available for sediment to accumulate [7]. For this research, palynomorph abundance pattern has been applied in establishing sequence stratigraphic events in the well section (fig. 7). The essence was to identify maximum flooding surfaces (MFS) and sequence boundaries (SB). Peak abundance of microphytoplankton (dinocysts) was useful in delineating horizons in the Danian. The Niger Delta Chronostratigraphic chart (after Haq, *et. al.*, [8]) was used as a basis for marking out the key horizons. Two maximum flooding surfaces were delineated, the ages were 61.1 Ma and 64.6 Ma respectively and one sequence boundary 63.0 Ma was delineated in the Danian. The first

maximum surface occurs within Lithozone-25 at depth of 1080ft, the sequence boundary within Lithozone-23 at depth of 3120ft and the second maximum flooding surface occurs within Lithozone- 22 at depth of 3600ft. Both maximum flooding surfaces are marked by peak abundance of microphytoplankton.

Three Maximum flooding surfaces were established. These surfaces were not established based on the abundance pattern of microphytoplankton, the reason being that there was deficiency in dinocysts distribution within the Maastrichtian. The probable cause as was previously mentioned could be high temperatures as burial of sediments progressed, this may have led to destruction of the forms present in the sediments. The surfaces within the Maastrichtian were delineated using Hardenbol [9] Global Sea Level Chart. Based on this, three maximum flooding surfaces and two sequence boundaries were delineated and their respective ages are 67.9 Ma (occurs at the base of Lithozone-17 at depth 4570ft), 69.8Ma (occurs within Lithozone-14 at depth of 5350ft) and 73.5Ma (occurs within Lithozone-6 at depth of 7060ft) respectively, the associated sequence boundaries are 65.0Ma and 68.0Ma respectively. The corresponding Pzones inferred for the surfaces were also marked out. The Danian corresponds to P200 (540ft-4360ft); three P-zones were established for the Maastrichtian of the well, P190 (4360ft-5770ft), P170 (5770ft-8100ft) and P150 (8100ft-8600ft).

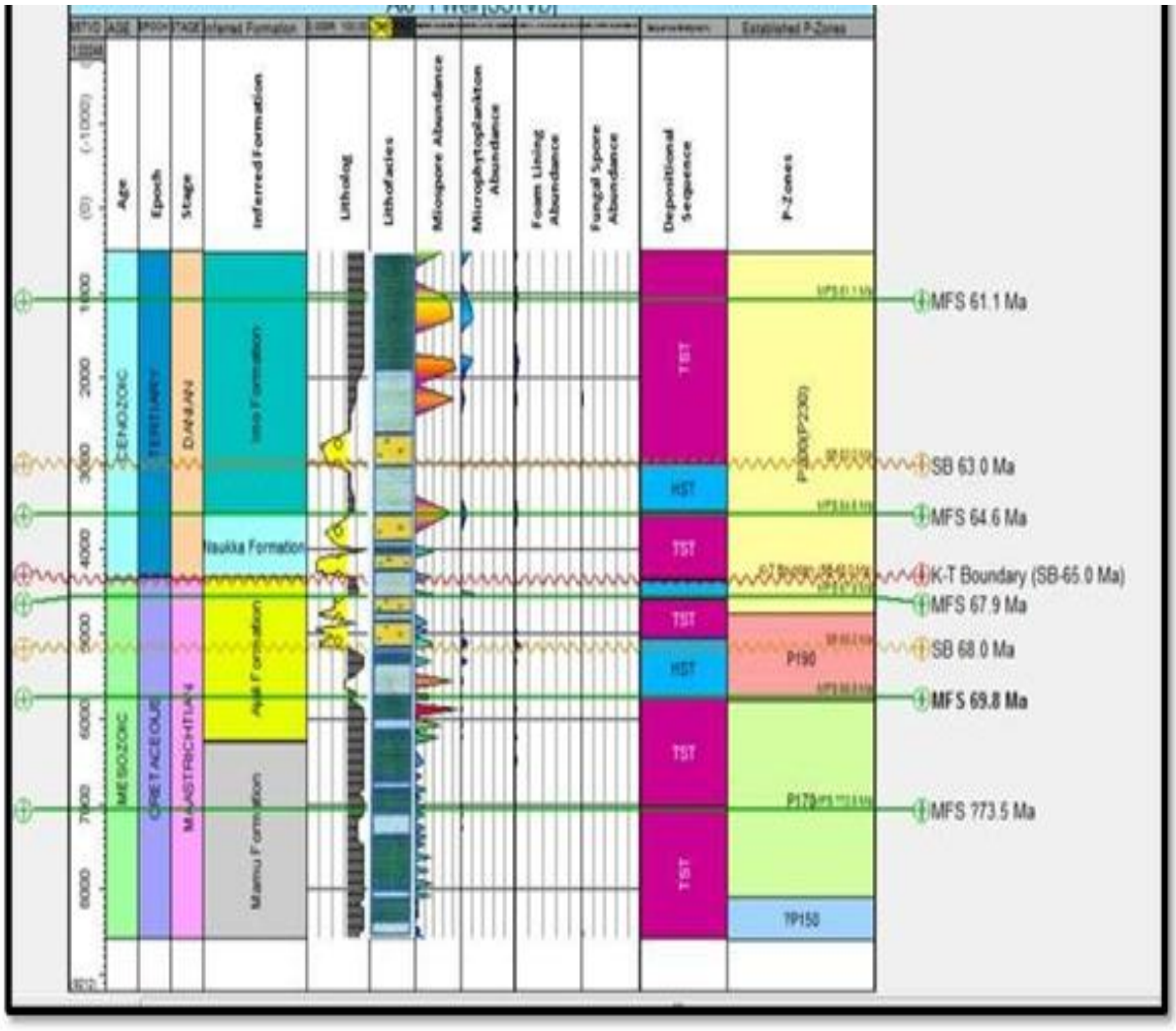


Figure 7: Sequence Stratigraphic Model for Alo-1 Well

Conclusion

Biozonation and sequences stratigraphic of Maastrichtian to Danian sedimentary succession in Alo-1 well, Anambra basin was done by carrying out a detailed Palynological study of the various formations penetrated by drill using biostratigraphically significant palynomorphs species. The assemblage consisted of miospores, dinocysts and minor occurrence of foram test linings and fungal spores. The age of the well section was

Maastrichtian to Danian. The Danian age was delineated for successions between 540ft-4360ft and the formation inferred to be Imo formation, while the Maastrichtian age was between 4360ft- 8600ft and the formations inferred are: Nsukka Formation-Ajali-Mamu.

Two maximum flooding surfaces (MFS) (61.1 Ma and 64.6 Ma are their respective age) and one sequence boundary (63.0Ma) was delineated in the Danian succession. Three maximum flooding surfaces (MFS) and two sequence boundaries (SB) were delineated in the Maastrichtian successions and their respective ages. The maximum flooding surfaces are 67.9 Ma (Present at the base of Lithozone-17), 69.8Ma (Present in Lithozone-14) and 73.5Ma (Present within Lithozone-6) and sequence boundaries 65.0Ma and 68.0Ma. The maximum flooding surfaces delineated are events that are traceable on seismic and as such can be used to define tops and base (seals) for potential reservoirs modeling.

Acknowledgement

The authors are grateful to Integrated Data Services Limited - Nigerian National Petroleum Corporation IDSL-NNPC for providing ditch cutting samples used for these findings. Special thanks to the National Petroleum Investment Management Services (NAPIMS) for their assistance.

Reference

[1]. Lucas, F. & Ishiekwene, E. (2010). Miospore (Pollen and Spore) Biozonation Model for Late Cretaceous – Tertiary Succession of Gbekebo-l Well, Benin Flank, Anambra Basin, Nigeria. *World J. of Appl. Sci. and Technol*., 2(2):303-308.

[2]. Agagu, O., Fayose, E. & Petters, S. (1985). Stratigraphy and Sedimentation in the Senonian Anambra Basin of Eastern Nigeria. *Journal of Mining and Geology*, 22(1): 26-36.

[3]. Lucas, F. & Ebahili, E. (2017). Lithofacies, Palynology and Paleoenvironmental Study of Campanian to Late Maastrichtian Deposits of Ogbabu-1 well Anambra Basin, South Eastern Nigeria. *Journal of Applied Science and Environmental Management*, 21(1):137-153.

[4]. Green, O. (2001). A Manual of Practical Laboratory and Field Techniques in Palaeobiology. Dordrecht, Kluwer Academic Publishers, 538p.

[5]. Wood, G., Gabriel, A. & Lawson, J. (1996). Palynological techniques – processing and microscopy. *In*: Jansonius, J. and McGregor, D. C. (eds.) Palynology: principles and applications, *American Association of Stratigraphic Palynologists Foundation*, 1: 29-50.

[6]. Van Hoeken-Klinkenberg, P. (1966). Maastrichtian Paleocene and Eocene pollen and spores from Nigeria. Leidse geologische Mededelingen, 38:37- 48.

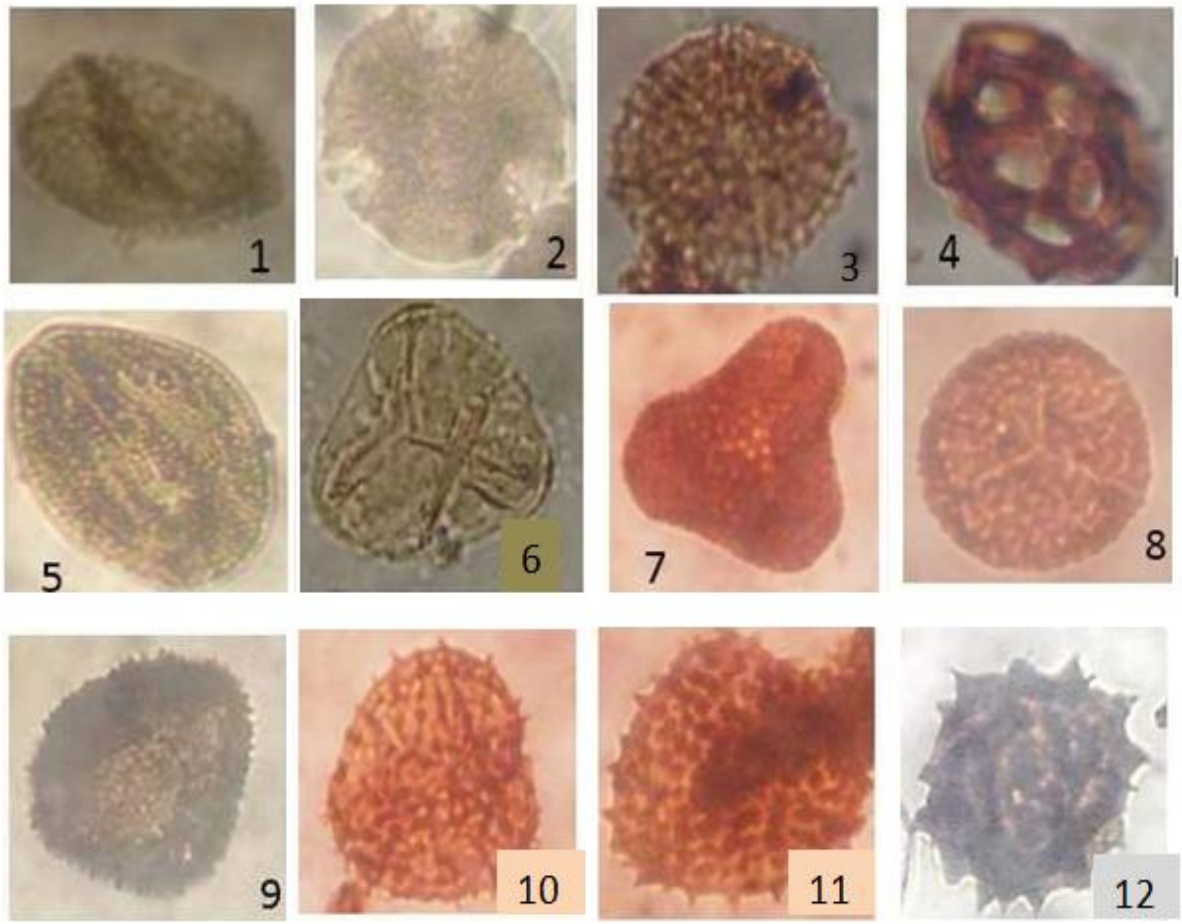
[7]. Posamentier, H. & Allen, G. (1999). Variability of the Sequence Stratigraphic Model: Effects of Local Basin Factors. Sedimentary Geology, 86: 91-109.

[8]. Haq, B. U., Hardenbol, J. & Vail, P. R. (1988). Mesozoic and Cenozoic Chronostratigraphy and Cycles of Sea Level Change. *In*: Sea Level Changes. An Integrated Approach (Eds Wilgus, C. K., Hastings, B. S., Kendall, C. G. St. C., Posamentier, H. W., Ross, C. A. and Van Wagoner, J. C.). Special Publication 42, Society of Economic Paleontologists and Mineralogists, Tulsa, OK, 71-108.

[9]. Hardenbol, J., Thierry, J., Farley, M., Jacquin, T., De Graciansky, P. & Vail, P. (1998). Mesozoic and Cenozoic sequence Chronostratigraphic framework of European Basins In: Mesozoic and Cenozoic Sequence Stratigraphy of European Basins (Eds De Graciansky, P. C., Hardenbol, J., Jacquin, T. and Vail, P. R.). Special Publication 60, SEPM (Society for Sedimentary Geology), Tulsa, OK, 3–13.

Appendix

Plate 1 (Miospores)



1. Afropollis jardinus

2. Anacolocidites spp.

3. Constructipollenites ineffectus

4. Buttinia andreevi

5. Belkispolis elegans

6. Dictyophyllidits harrisii

7. Concavissimisporites punctatus

8. Rugilatisporites caperatus

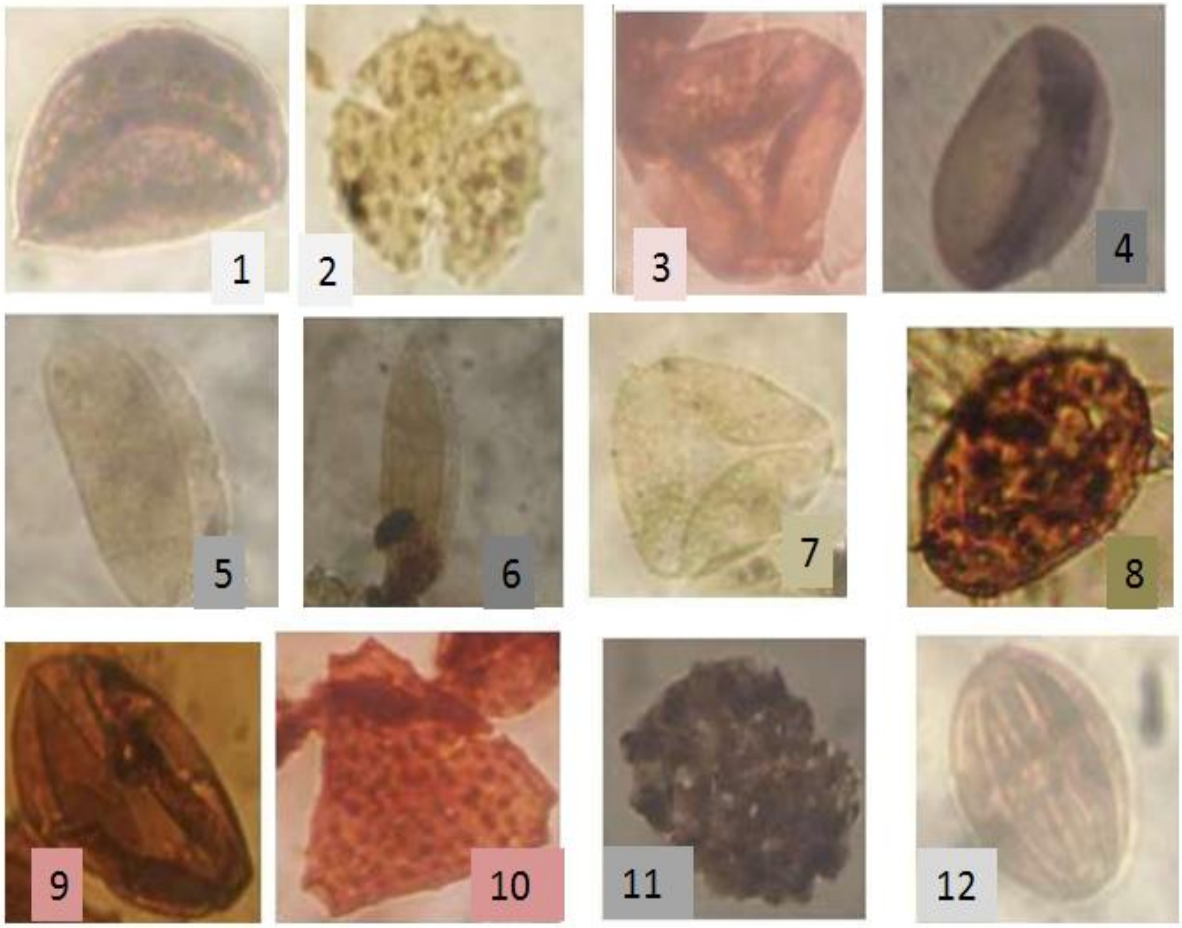
9. Cingulatisporites ornatus.

10. Echiperiporites estalae

11. Echitriporites trianguliformis

12. Echitricolporites spinosus (All magnification at X400)

Plate 2 (Miospores)



1. Ephedripites amobionides

2. Gematricolpites scabratus

3. Kyrtomisporis spp.

4. Laevigatosporites spp.

5. Longapertites marginatus

6. Longapertites microfoveolatus

7. Longapertites vaneendeburgi

8. Momipites africanus

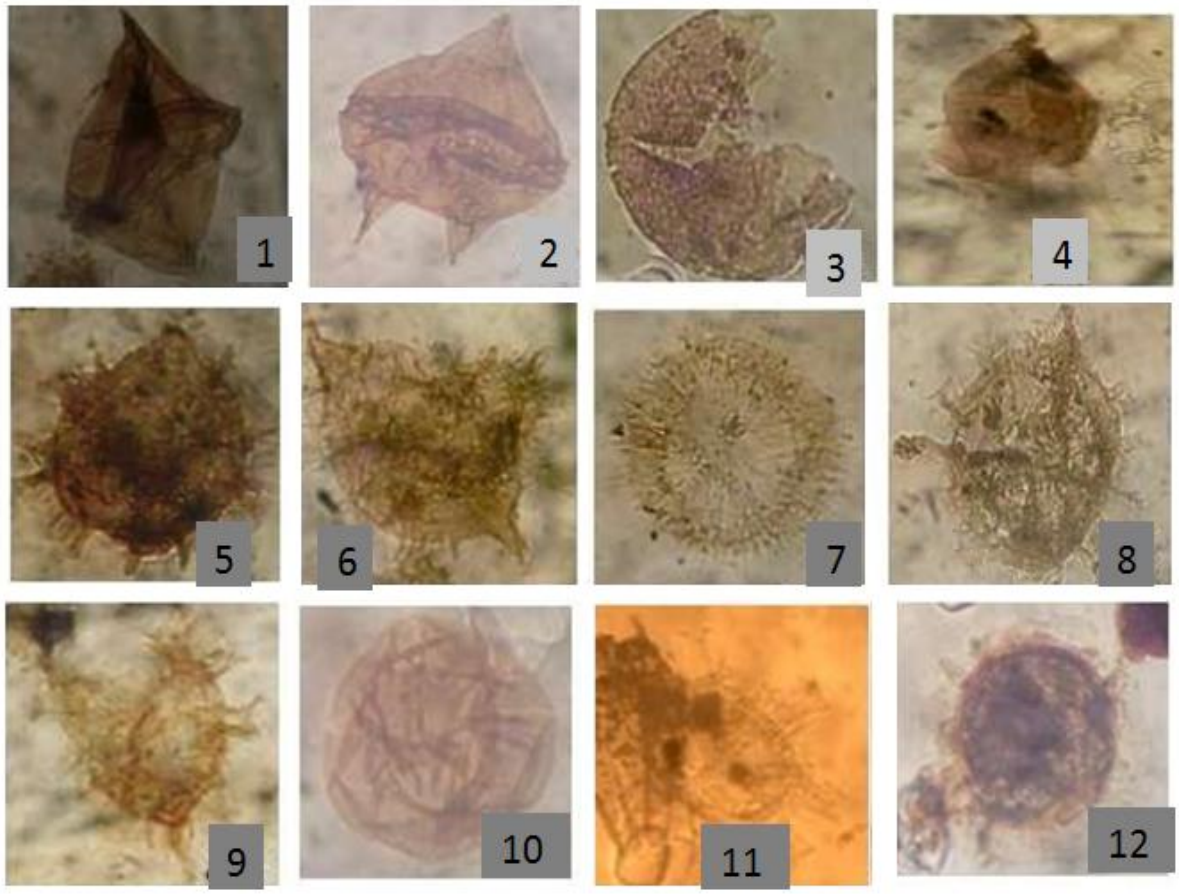
9. Monoculpites marginatus

10. Mauriitidites crassibaculatus

11. Proteacidites longispinosus

12. Proxapertites cursus (All magnification at X400)

Plate 3 (Dinocysts)



1. Andalusiella rhomboids

2.Cerodinium boloniensis

3. kallosphaeridium yorubaensis

4. Cerodinium diebelii

5. Damasadinium californicum

6. Damasadinium californicum

7. Euclydophyxis peniculatum

8. Fibrocysta lapacea

9. Fibrocysta bipolar

10. Leiosphaeridia spp.

11. Homotribilium pallidium

12. Muratodinium fimbriatum (All magnification at X400)