Scientia Africana, Vol. 23 (No. 4), October, 2024. Pp 317-326
© Faculty of Science, University of Port Harcourt, Printed in Nigeria *ISSN 1118 – 1931*

PALYNOLOGICAL AND PALEOENVIRONMENTAL ANALYSES OF THE MIOCENE SEDIMENTS OF GAP-1 WELL IN THE ONSHORE NIGER DELTA BASIN.

Alege, T.S.[1*] and Joseph, G.E.[1]
[1*] Department of Geology, Federal University Lokoja, Kogi State, Nigeria
*Corresponding author: tope.alege@fulokoja.edu.ng

Received: 26-09-2024
Accepted: 30-10-2024

https://dx.doi.org/10.4314/sa.v23i4.27

Journal Homepage: http://www.scientia-african.uniportjournal.info
Publisher: *Faculty of Science, University of Port Harcourt.*

ABSTRACT

A comprehensive palynological investigation has been carried out for Gap-1 well penetrating the Agbada Formation in the Niger Delta Basin. The identification of shaly-sandstone, shale, mudstone, and clayey-sandstone lithofacies units and the delineation of four (4) informal palynological biozones (GI, GII, GIII, and GIV), correlating with the P670, P680, and P720Niger Delta pollen zonations, suggested the Early to Middle Miocene age for the investigated Gap-1 well in the Agbada Formation. The interpretation for the common to the relatively abundant occurrence of land-derived palynomorphs such as Verrucatosporites sp., Laevigatosporites sp, Zonocostites ramonae, Sapotaceae, as well as the occurrence of dinoflagellate cysts, Pediastrum sp, amongst others, as a fluvial-dominated delta to shallow marine environment within a humid climate is confirmed.

INTRODUCTION

The Niger Delta, a prolific hydrocarbon region in West Africa, has been the subject of extensive geological research due to its complex sedimentary architecture and economic significance (Nton & Ogungbemi, 2011; Alege et al., 2020a; Alege, 2022; Odinaka et al., 2024). Palynostratigraphy has emerged as a vital tool in studying the stratigraphy and paleoenvironmental conditions of different world basins by offering insights into the age, depositional environments, and potential hydrocarbon reservoirs in sedimentary sequences. Numerous studies have investigated the palynostratigraphy and paleoenvironmental evolution of the Niger Delta, with works such as that of Evamy et al. (1978) and Jan du Chêne et al. (1978), laying the foundation for understanding the biostratigraphy and stratigraphic frameworks in the delta. These foundational studies established zonal schemes based on palynomorph assemblages, aiding in correlating sedimentary layers across the delta. Similarly, other researchers, such as Alege et al. (2020b) and Alege et al. (2023a), also conducted palynological analyses of the Campanian-MaastrichtianMamu Formation of the Anambra basin to identify its paleoenvironment during the Late Cretaceous period. Aigbadon et al. (2023) employed the palynological, petrological and geochemical attributes of sediments of the Southern Bida Basin to interpret its provenance and paleoenvironment of deposition.

Subsequent research expanded on these early works, with notable contributions by Petters (1995), who examined the paleoenvironmental changes in the Niger Delta using micropaleontological data, and Oloto (1989), who emphasized the role of palynology in dating sedimentary sequences and reconstructing past environments. Furthermore, Osokpor and Oboh-Ikuenobe (2008) provided detailed palynofloral analyses, contributing to understanding the delta's stratigraphic history. However, despite these advancements, gaps remain in the detailed palynostratigraphic zonation and paleoenvironmental interpretation of specific wells, particularly in underexplored onshore areas.

The GAP-1 well, located in the onshore Niger Delta, presented an opportunity to address these research gaps. Previous works have focused mainly on offshore or regional stratigraphic interpretations, leaving the palynostratigraphy of specific onshore wells, such as GAP-1, less understood. Detailed palynostratigraphic and paleoenvironmental analyses of sediments from the GAP-1 well could enhance the biostratigraphic resolution for this region and provide a more refined understanding of the depositional environments that characterised the onshore Niger Delta during different geological periods.

This study aimed at filling the gap by conducting a palynostratigraphic and paleoenvironmental analyses of sediments from the GAP-1 well with the objectives of analysing palynomorph assemblages and identifying age-diagnostic taxa. This research refined the biostratigraphic framework and reconstructed the paleoenvironmental conditions of deposition of these sediments. The findings contributed to a better understanding of the onshore Niger Delta's stratigraphic architecture and its implications for hydrocarbon exploration and environmental changes over geological time.

General Geology of the Area

The Niger Delta Basinis located on the continental margin of West Africa. It covers an area of approximately 75,000 square kilometres, extending from the Gulf of Guinea to onshore Nigeria (Weber & Daukoru, 1975). The delta developed during the Late Cretaceous to Tertiary periods as a result of the interplay between the tectonic activity associated with the opening of the South Atlantic Ocean and the enormous sediment supply from the Niger River system (Burke, 1972).

The geology of the basin is characterised by a thick sedimentary sequence exceeding 12,000 meters in some areas, consisting of three primary lithostratigraphic units: the Akata Formation, the Agbada Formation, and the Benin Formation (Short &Stauble, 1967). These units reflect a progressive transition from deep marine to coastal and fluvial environments (Figure 1)

The Akata Formation is the deepest unit, consisting of marine shales, silts, and clays. It was formed in deep marine environments and is the primary source of hydrocarbons in the Niger Delta. It ranges in age from Paleocene to Recent. Above the Akata Formation is the Agbada Formation, consisting of alternating sandstones and shales, representing deltaic environments. This formation contains the primary hydrocarbon reservoirs, with sandstone beds serving as reservoir rocks and shale units acting as seals (Stacher, 1995). The Agbada Formation developed during the Eocene to Recent. The Benin Formation is the shallowest and youngest, consisting of continental sands and gravels deposited in a fluvial environment. It is Miocene to Recent in age and is mainly non-hydrocarbon-bearing but is important for groundwater aquifers (Doust&Omatsola, 1990; Reijers, 2011).

The Niger Delta Basin is influenced tectonically by growth faulting and rollover anticlines, which are very significant as hydrocarbon traps (Doust & Omatsola, 1990; Alege, 2017b; Rotimi et al., 2022; Odinaka et al., 2024). The tectonic and sedimentary evolution of the delta, combined with the vast organic-rich sediments deposited in its deep marine environments, have made the basin one of the most prolific petroleum provinces in the world.

Scientia Africana, Vol. 23 (No. 4), October, 2024. Pp 317-326
© Faculty of Science, University of Port Harcourt, Printed in Nigeria *ISSN 1118 – 1931*

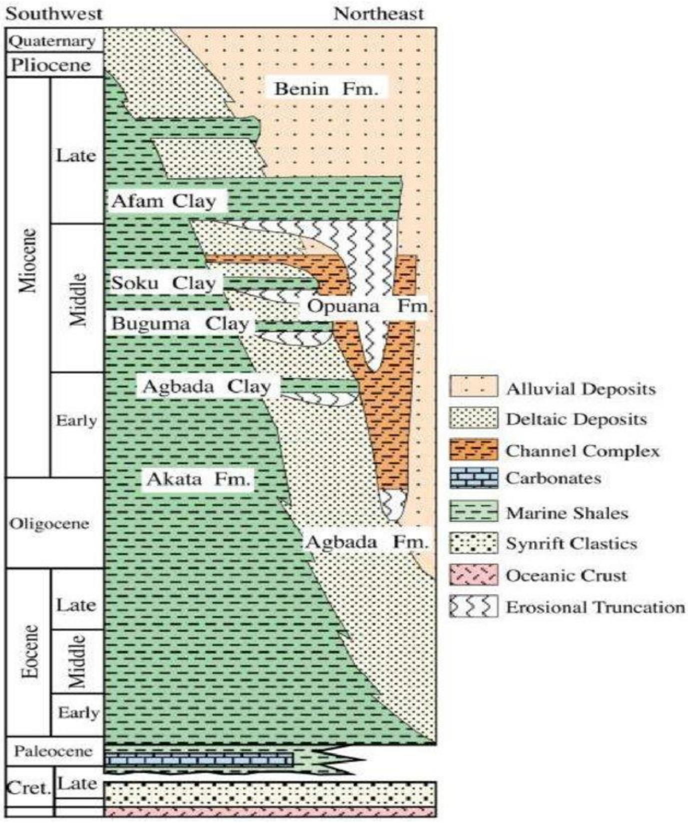

Figure 1. The stratigraphic column shows the three lithostratigraphic formations of the Niger Delta (Lawrence et al., 2002).

MATERIALS AND METHODS

Ninety (90) ditch-cutting samples of the GAP-1 well ranging from 3520 to 6190ft and composited at 30ft were processed and analysed for their palynomorphs contents.

Careful physical examination identified the dominant and minor lithologies, textures, colours, and other accessory mineral components, enabling a detailed lithologic description of the samples (Alege et al., 2015; Idakwo et al., 2013; Alege, 2022; Aigbadon et al., 2023).

A palynological processing method for the maceration of samples modified from Traverse (2007) was applied. This involved crushing samples into fragments, weighing 25 g of each of the samples and alternate usage of inorganic reagents such as dilute Hydrochloric acid (Hcl), concentrated Hydrofluoric acid (HF) and Nitric acid (HNO_3) to macerate the sediments. These reagents removed carbonate and silicate minerals and helped concentrate the palynomorphs. The acidic reaction was neutralised using potassium hydroxide (KOH) and distilled water. Subsequently, the palynomorph-rich residue was mounted on labelled glass slides using a Norland mounting medium for microscopic analysis. Photomicrographs of the palynomorphs were taken using a camera, and the Strataburg 2.0 software was used in the statistical analysis plot. The results were used to decipher the age and possible paleoenvironment of deposition of the well succession.

RESULTS AND DISCUSSION

Lithofacies

The lithofacies units of Gap-1 have been identified in the ditch-cutting samples by examining the physical and textural characteristics of the sediments (Billman, 1992; Alege, 2017b; Adamu et al., 2018a; Alege et al., 2020a; Oretade and Ali, 2021; Alege et al., 2024; Aigbadon et al., 2024). Four lithofacies units were identified in the study:

the shaly sandstone, shale, mudstone, and clayey sandstone units.

Shaly-sandstone facies

These facies represented about 60% of the constituent of the entire Gap-1 well. The facies comprise 85-90% sandstone and 10% shale constituent. The sandstones are mainly fine to medium-grained and sometimes coarse-grained, yellow to brown, and moderately sorted. The minor shale constituents were grey and less fissile. Thesefacies units were well represented at the following depths: 3520-3550 ft, 3760-3880 ft, 4030- 4150 ft, 4600-4630 ft, 5230- 5440 ft and 5860- 6190ft.

Shale facies

The Shale facies represent about 15% of the entire well-depth interval. They are dark grey, soft to moderately hard, and non-fissile. They occurred at depth intervals of 3910-4000ft, 4180-4330ft, 4480- 4950ft, and 4720- 4750ft.

Mudstone facies

The mudstone facies is represented in Gap-1 well by a mixture of shale (30%), clay (40%), and fine to medium-grained sandstone (30%) constituents at depth intervals of 3550 - 3760ft, 4330 - 4390ft, 4720 - 4750ft, 4950 - 5050ft, 5140 - 5230ft, and 5740- 5860ft. The colours range from brown to grey. This facies represents about 20% of the entire well.

Clayey-sandstone facies

The clayey sandstone facies consist of about 10 - 15% constituent of clay to 85 - 90% sandstone occurring at depth intervals of 5050 - 5140ft and 5440 - 5680ft. The sandstones are brownish, fine to medium-grained and well-sorted.

These facies suggest the fluvial-dominated deltaic facies to shallow marine facies of the transitional paralic sequence of the Agbada formation and are interpreted to be from the fluvial-dominated delta to shallow marine environment (Chukwu, 1991; Reijers, 2011; Nton&Ogungbemi, 2011; Alege, 2017a; Alege et al., 2020a; Alege, 2022).

Palynomorph distribution

Palynomorph analysis was carried out on ninety (90) ditch-cutting samples of the GAP-1 well, ranging from 3520 to 6190 feet. A total of sixty-eight (68) palynomorphs species consisting of forty-seven (47) species of pollens, twelve (12) species of spores, six (6) dinoflagellate spores, diatom frustules, fungal spores and *Pediastrum* were recovered from the well with the percentage proportions of 69.1% (pollens), 17.6% (spores), 8.82% (dinoflagellate cysts), 2.0% (diatom frustules), 2.0% (fungal spores) and 2.0% (freshwater algae, *Pediastrum* sp.) respectively.

The studied interval (3520 to 6190 ft) was characterized by poor to moderately abundant and diverse palynomorphs, which were dominated by terrestrial species such as *Laevigatosporites* sp., *Zonocostites ramonae, Acrostichum aureum, Psilatricolporit escrassus, Retitricolporites irregularis, Verrucatosporites sp., Sapotaceae* and *Striatricolporites catatumbus*. Low to common records of fungal spores and freshwater algae *Botryococcus braunii* also characterised the studied section. Sparse occurrence of dinoflagellate cysts such as *Lingulodinium machaerophorum, Spiniferites sp.* and *Operculodiniumc entrocarpum* were also identified (Figure 2).

Scientia Africana, Vol. 23 (No. 4), October, 2024. Pp 317-326
© Faculty of Science, University of Port Harcourt, Printed in Nigeria **ISSN 1118 – 1931**

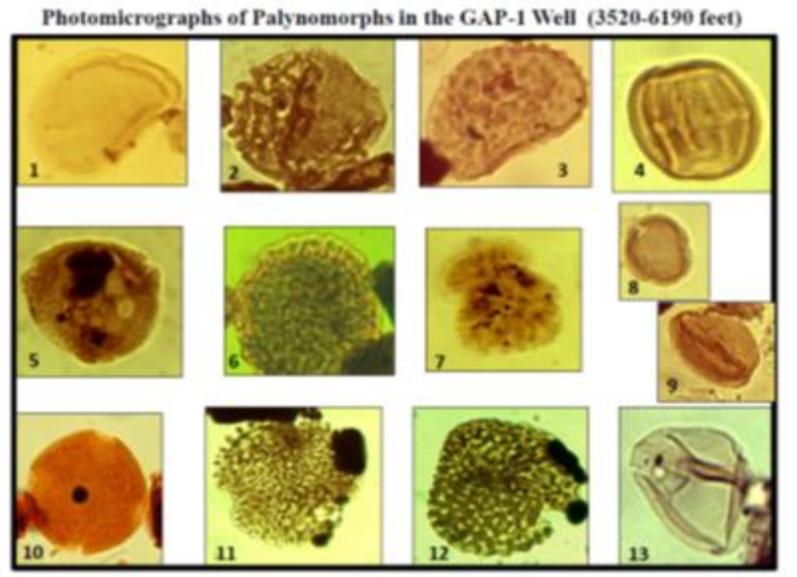

Figure 2: Photomicrographs of some palynomorph species from GAP-1 well.

(1).*Laevigatosporites* sp. (3520 ft) (2). *Peregrinipollisnigericus* (4480 ft) (3). *Verrucatosporites* sp. (4060 ft) (4). *Sapotaceae* (4450 ft) (5). *Retibrevitricolporitesobodoensis* (5020 ft) (6). *Spirosyncolpitesbrauni* (6070 ft) (7) *Botryococcusbraunii* (4510 ft) (8). *Zonocostitesramonae* (4030 ft) (9). *Striatricolporitescatatumbus* (4000 ft) (10). *Pachydermitesdiederixi* (6160 ft) (11). *Retitricolporitesirregularis* (3820 ft) (12). *Crassoretitriletesvanraadshoveni* (4030 ft) (13). *Monoporitesannulatus* (5350 ft) **(mag. X400)**

Palynostratigraphy

Stratigraphic significant species (marker species) and diagnostic palynoflora associations were identified and used to define the ages of the sedimentary successions penetrated by GAP-1. Figure 3 presents the stratigraphic chart of the palynomorphs.

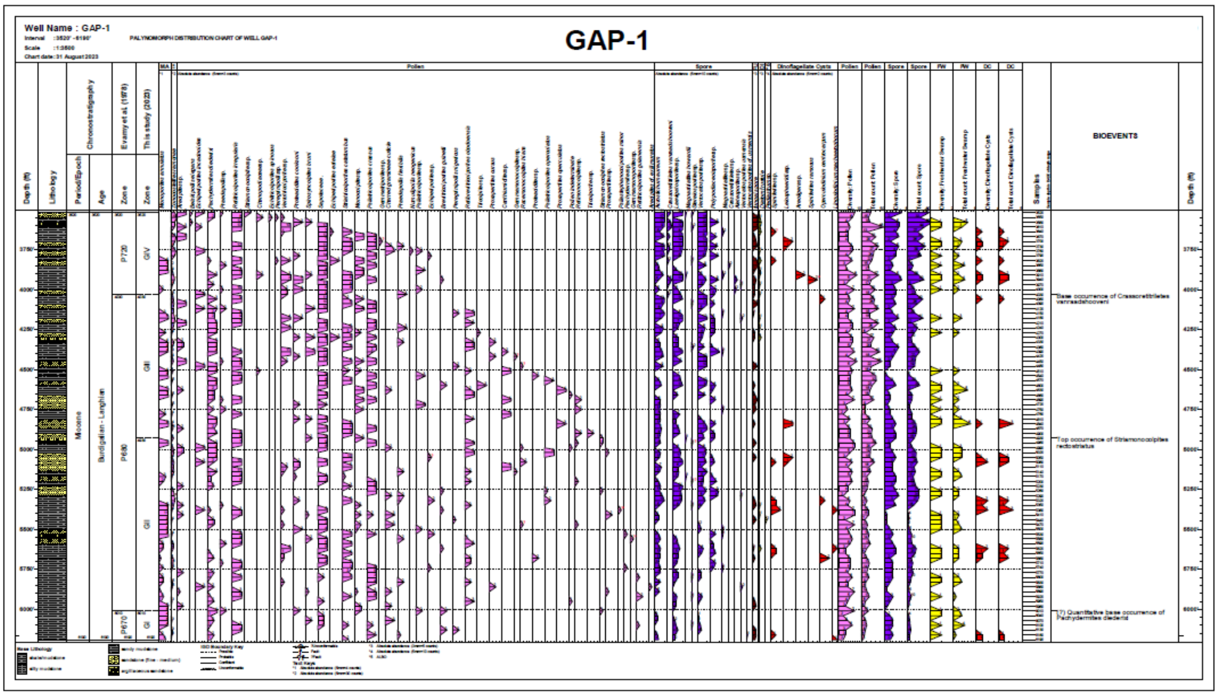

Figure 3. Stratigraphic distribution of palynomorphs in GAP-1 well

Palynostratigraphic zonation

Four (4) informal biozones, namely GI, GII, GIII, and GIV, were established based on the association of recovered marker species and palynomorphs (Figure 3). These zones correlate with the P670, P680, and P720 subzones of Evamy*etal*. (1978). Thus, the Early to Middle Miocene age is interpreted for the studied interval. Detailed results of the palynological zone are presented in Figure.

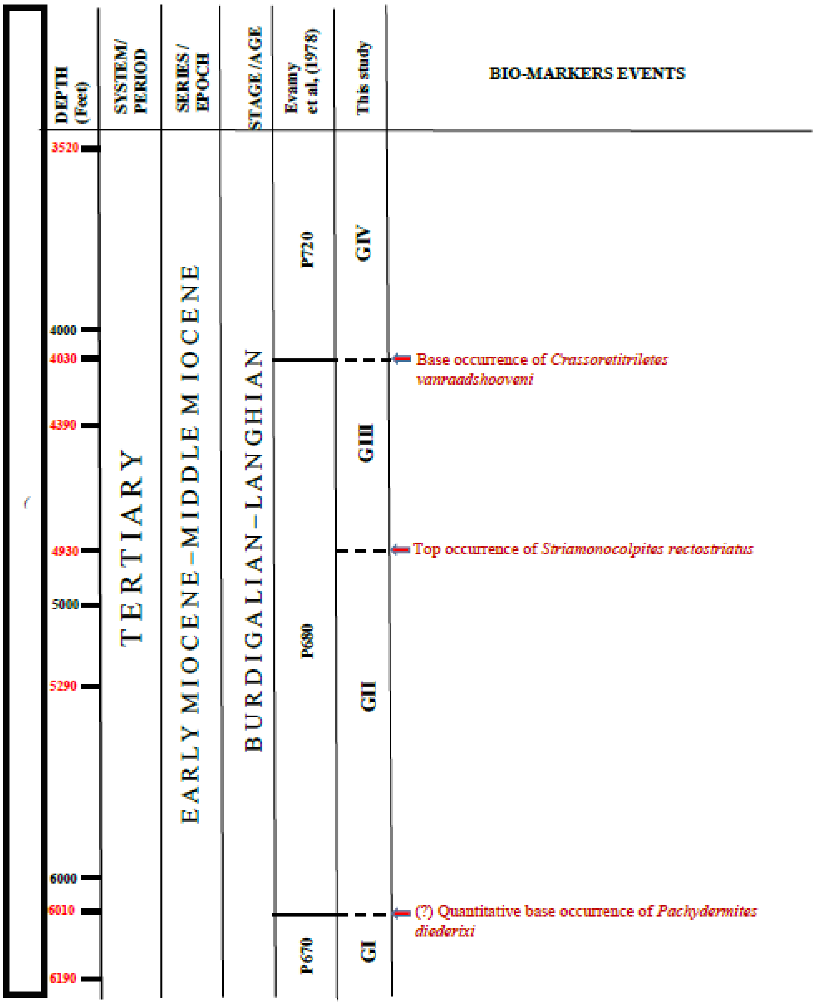

Figure 4. Summary of the palynological zones identified in the GAP-1 Well (3520-6190 feet)

Zone GIV

Depth: 3520 - 4030 feet

Age: Middle Miocene (Langhian)

The top of this zone coincides with the first sample analysed and, as such, is stratigraphically higher than the first sample at 3520 feet. The base is defined by the base occurrence of *Crassoretitriletes vanraadshoveni* at 4030 feet. This interval is further characterised by the common occurrence of *Proteacidites cooksonii*, *Magnastriatite showardi*, *Pachydermit esdiederixi*, the rare presence of *Belskipolliselegans* and abundant *Zonocostites ramonae* (Figure 4).

In addition, rare occurrences of dinoflagellate cysts such as *Spiniferites*sp. and *Operculodinium centrocarpum* were identified. This interval correlates with the P720 subzones of Evamy *et al*. (1978).

Zone GIII

Depth: 4030 – 4930 feet

Scientia Africanica, Vol. 23 (No. 4), October, 2024. Pp 317-326
© Faculty of Science, University of Port Harcourt, Printed in Nigeria **ISSN 1118 – 1931**

Age Middle Miocene (Langhian) – Early Miocene (Burdigalian)

The top occurrence of Striamonocolpites defines the base of this zone *rectostriatus* at 4930 feet. The top is defined by the base occurrence of *Crassoretitriletes vanraadshoveni* at 4030 feet. Additional palynoflora events characterising this interval include *Retibrevitricolporites obodoensis, Pachydermites diederixi, Retitricolporites irregularis* and *Sapotaceae*. A few fungal spores and diatom frustules were also identified (Figure 4&5). This interval correlates with the P680 subzone of Evamy et al. (1978).

Zone GII

Depth: 4930 - 6010 feet

Age: Early Miocene (Burdigalian) – Middle Miocene (Langhian)

The base of this zone is defined by the (?) quantitative base occurrence of *Pachydermites diederixi*at 6010 feet. In comparison, the top is defined by the top occurrence of *Striamonocolpites rectostriatus* at 4930 feet. The common occurrence of *Zonocostites ramonae*, *Pachydermites diederixi*, and *Acrostichum aureum* with low records of *Retibrevitricolporites obodoensis* also characterised this interval (Figures 4 and 5). Sparse *Lingulodinium machaerophorum, Leoisphaeridia* sp. And *Operculodinium centrocarpum* were also identified. This zone relates to the P680subzone of Evamy *et al*. (1978).

Zone GI

Depth: 6010 - 6019 feet

Age: Early Miocene (Burdigalian)

The base of this zone coincides with the last sample analysed, while the top is defined by the (?) quantitative base occurrence of *Pachydermites diederixi* at 6010 ft (Figures 4 and 5). Additional palynoflora events include common *Monoporites annulatus, Acrostichum aureum Verrucatosporites* sp., *Sapotaceae* and *Striatricolporites catatumbus*. This zone correlates with the P670 subzone of Evamy et al. (1978).

Paleoenvironment

The paleoenvironmental analysis was based on the different species of palynomorphs within the study (Figures 3 and 4). The relative abundance of land-derived palynomorphs such as *Verrucatosporites*sp., *Laevigatosporites*sp., *Acrostichumaureum, Zonocostitesramonae, Sapotaceae*, *Striatricolporites catatumbus* and *Pachydermites diederixi* amongst others, were interpreted to be predominantly fluvio-deltaic to brackish swamp water environment of deposition within a humid climate (Reijers et al., 1997; Idakwo et al., 2013; Ogbahon, 2019; Aigbadon et al., 2022; Alege et al., 2023).

The presence of dinoflagellate cysts: *Operculodinium centrocarpum* (4060ft, 5290ft and 5710ft) and *Spiniferites sp*. (3640ft, 3700ft) with moderate records of pollen, spores and *Botryococ cusbraunii* indicate a shallow marine environment with frequent freshwater incursions (Wrenn & Kokinos, 1986; Bolaji et al., 2020). Similarly, the lone occurrence of *Pediastrum*sp (5440ft) and freshwater algae suggests a progradational marginal marine environment (Tahoun et al., 2017; Aigbadon et al., 2023). Diatom frustules in the study also indicate a shallow marine deposition environment (Henchiri, 2007).

Thus, the occurrences of terrestrial palynomorphs and freshwater algae, along with dinoflagellate cysts and diatom frustules, give credence to a fluvial-dominated deltaic environment to a shallow marine environment of deposition within a wet to humid climate (Garzon et al., 2012; Adamu et al., 2018b; Ogbahon, 2019; Alege et al., 2020a).

CONCLUSION

The investigation of palynomorphs recovered from ninety (90) ditch cuttings obtained from Gap-1 well has aided in interpreting the palynostratigraphy and paleoenvironment in the onshore Niger Delta basin. Four lithofacies units were identified in the study: the shaly sandstone, shale, mudstone, and clayey sandstone units. These facies suggested the fluvial-dominated deltaic facies to shallow marine facies of the transitional paralic sequence of the Agbada formation. They were interpreted to be from the fluvial-dominated delta to shallow marine environment.

Four (4) informal biozones, namely GI, GII, GIII, and GIV, were established based on the association of recovered marker species and palynomorphs. These zones correlated with the P670, P680, and P720 subzones of Evamy*etal*. (1978). Thus, the Early to Middle Miocene age are interpreted for the studied interval. The paleoenvironmental analysis was based on the different species of palynomorphs within the study. The common occurrence of land-derived palynomorphs such as *Verrucatosporites* sp., *Laevigatosporites* sp, *Zonocostites ramonae, Sapotaceae, Striatricolporites catatumbus* and *Pachydermites diederixi* amongst others, are interpreted to be predominantly fluvial-deltaic to brackish swamp water environment of deposition within a humid climate.

Thus, the occurrences of terrestrial palynomorphs and freshwater algae (*Pediastrum* sp,) along with dinoflagellate cysts (*Operculodinium centrocarpum, Spiniferites* sp.*)* and diatom frustules, give credence to a fluvial-dominated deltaic environment to a shallow marine environment of deposition in a humid climate in the Agbada Formation of the Niger Delta.

REFERENCES

Adamu L.M., Ayuba, R., and Alege, T.S. (2018b): Sedimentology and Depositional Environments of the Maastrichtian Mamu Formation, Northern Anambra Basin, Nigeria. *Advances in Applied Science Research,* 9(2); 53-68. Published by Pelagia Research Library.

Adamu, L.M., Rufai A., Odoma, A.N. &Alege, T.S. (2018a): Sedimentology and Depositional Environment of the Mid-Maastritchtian Ajali Sandstone in Idah and Environs, Northern Anambra Basin, Northcentral Nigeria. *IOSRJ Journal of Applied Geology and Geophysics, (IOSR-JAGG),* 6(1); 38-51.

Aigbadon GO, Ocheli A, Alege TS, David EO (2023) Petrological, palynological analysis and Geochemistry of Maastrichtian Patti Shale in some parts of the southern Bida Basin, Nigeria: Implications for provenances and hydrocarbon studies. Commun Phys Sci 9(3)

Aigbadon, G.O., Chinyem, F.I., Alege, T.S., Overare, B., Akakuru, O.C., Obasi, A.I., Akudo, E.O., Ocheli, A., Ayok, J., Jimoh, O.A., Akpunonu, E.O., Baba-Aminu, M., and Aminu, B.O. (2024). Outcrops as windows to petroleum systems: Insights from the southern Bida Basin, Nigeria. Energy Geoscience, Volume 5, Issue 3, 2024, https://doi.org/10.1016/j.engeos.2024.100294.

Alege TS (2017a) Sequence stratigraphy of Akos field in the Coastal swamp depobelt of the Niger Delta. AdvApplSci Res 8(1):16–27

AlegeTS, Adamu ML, Odoma AN (2020b). Sedimentology, lithofacies, palynofacies and sequence stratigraphy of the Campano-Maastrichtian successions within the Southern Bida Basin Nigeria. Min J Geos MJG 4(2):122–142

Alege TS, OmadaJI, Onimisi M (2020a). Lithofacies and depositional environmental interpretation of well logs within Akos field, Coastal Swamp Depobelt of Niger Delta. Petrol Tech Develop J 10(1):14–26.

Alege TS, OmadaJI, Onimisi M (2020a). Lithofacies and depositional environmental interpretation of well logs within Akos field, Coastal Swamp Depobelt of Niger Delta. Petrol Tech Develop J 10(1):14–26

Alege TS, Omada JI, Uchendu K (2022). Field and sedimentological studies of Nataco-Banda sediments of Lokoja formation, Southern Bida Basin, Nigeria: implication

Scientia Africana, Vol. 23 (No. 4), October, 2024. Pp 317-326
© Faculty of Science, University of Port Harcourt, Printed in Nigeria ***ISSN 1118 – 1931***

for depositional environment. J Appl Sci Environ Manag 26(11):1835–1842

Alege T.S., Tella T.O., Aigbadon G.O., Omada J.I. (2023a) Sedimentary facies and palynological studies of ajali sandstones formation outcropping in Idah, Northern Anambra Basin, Nigeria. J ApplSci Environ Manag 27(6):1207–1215

Alege, E. K., Alege, T. S., Barnabas, G. Y., &Idakwo, S. O. (2015). Compositional Characteristics and Industrial Assessment of the Cretaceous Clay Deposits within Northern Anambra Basin, Nigeria.

Alege, T.S. (2022). Sequence stratigraphic evaluation of sediments domicile in day field located in the onshore central swamp depobelt of the niger delta, Nigeria. J. Appl. Sci. Environ. Manage. Vol. 26 (6) 1129-1135 June 2022

Alege, T.S. (2017b). Structural Interpretation of 3D Seismic Data of Akos Field in the Coastal Swamp Depobelt of the Niger Delta.

Alege, T.S., Tella, T.O. &Aigbadon, G.O. (2024). Lithofacies, bio-sequence stratigraphy and paleoenvironment of the Cretaceous-Neogene at the BG-1 well, offshore Eastern Dahomey Basin, Nigeria: implications for future exploration and development efforts. *Carbonates Evaporites* 39, 49 (2024). https://doi.org/10.1007/s13146-024-00953-6

Alege, T.S., Tella, T.O., and Aigbadon, G.O. (2023). Textural and Provenance Studies of Ajali Sandstones Formation Outcropping in Idah, Northern Anambra Basin, Nigeria. African Journal of Engineering and Environment Research Vol.5(1) 2023

BillmanH.G. (1992) Offshore stratigraphy and paleontology of the Dahomey (Benin) Embayment West Africa. NAPE Bull. 7(2):121–130

Bolaji, T.A., Ndukwe, O.S., and Oyebamiji, A.R. Palynological Age Control and Paleoenvironments of the Paleogene Strata in Eastern Dahomey Basin, Southwestern Nigeria. *Sci Rep* **10**, 8991 (2020). https://doi.org/10.1038/s41598-020-65462-7

ChukwuG.A. The Niger Delta Complex Basin: Stratigraphy, structure and hydrocarbon potential. Journal of Petroleum Geology. 1991; 14:211-220.

Doust, H., &Omatsola, E. (1990). Niger Delta. In J. D. Edwards & P. A. Santogrossi (Eds.), Divergent/Passive Margin Basins* (Vol. 45, pp. 201–238). American Association of Petroleum Geologists.

Evamy, B. D., Haremboure, J., Kamerling, P., Knaap, W. A., Molloy, F. A., & Rowlands, P. H. (1978). Hydrocarbon habitat of the Tertiary Niger Delta. **American Association of Petroleum Geologists Bulletin, 62(1), 1–39.

Garzon, S., Warny, S., Bart, P.J. (2012). A palynological and sequence-stratigraphic study of Santonian–Maastrichtian strata from the Upper Magdalena Valley basin in central Colombia. *Palynology* 2012; 36 (Suppl_1): 112–133. doi: https://doi.org/10.1080/01916122.2012.675147

Garzon, S., Warny, S., Bart, P.J. (2012). A palynological and sequence-stratigraphic study of Santonian–Maastrichtian strata from the Upper Magdalena Valley basin in central Colombia. *Palynology* 2012; 36 (Suppl_1): 112–133. doi: https://doi.org/10.1080/01916122.2012.675147

Henchiri, M (2007). Sedimentation, depositional environment and diagenesis of Eocene biosiliceous deposits in Gafsa basin (southern Tunisia). Journal of African Earth Sciences 49, 187 200 HoekenKlinkenberg, V (1964). Palynological investigation of some Upper Cretaceous sediments in Nigeria. Pollen Spores 6, 209–231.

Idakwo, S.O., Gideon Y.B., Alege, T.S., and Alege, E.K. (2013): Paleoclimate Reconstruction during Mamu Formations (Cretaceous) Based on Clay Mineral Distribution in Northern Anambra Basin, Nigeria. *International Journal of Science and Technology (IJST)*, 2(12): 879-885. Published by Center of Professional

Research Publications.

Jan du Chêne, R. E., Sowunmi, M. A., & Weber, R. (1978). Palynology and the Tertiary stratigraphy of Nigeria. Revista Española de Micropaleontología, 10 (3), 379–386.

Lawrence, S.R., Munday, S., Bray, R., 2002. Regional geology and geophysics of the eastern Gulf of Guinea (Niger Delta to Rio Muni). Lead. Edge 21 (11), 1112–1117.

Nton ME, OgungbemiTS (2011) Sequence stratigraphic framework of K-field in part of Western Niger Delta: RMZ- Materials and Geoenv. J ApplSci Environ Manag 58(2):163–180

Odinaka, A. C., Auduson, A., Alege, T., &Odunsanwo, Y. (2024). Formation Evaluation Using Integrated Petrophysical Data Analysis of Maboro Field Niger Delta Sedimentary Basin, Nigeria. *Communication in Physical Sciences, 11*(3).

Ogbahon, OA (2019). Palynological Study of OSE 1 Well in Offshore Niger Delta Basin: Implications for Age, Paleoclimate and Depositional Paleoenvironment. Inter. J. Geosci. 10, 860–883.

Oloto, I. N. (1989). Biostratigraphic zonation based on palynological data from the Niger Delta. Nigerian Journal of Science, pp. 23, 45–56.

Oretade, B. S. and Ali, C. A (2021). Calcareous nannofloras in Western Lobe Offshore, Niger Delta: Eutrophication and climate change implications. Malaysian Journal of Society and Space, 17 issue 4 (274- 287) https://core.ac.uk/download/511435979.pdf

Osokpor, J., &Oboh-Ikuenobe, F. E. (2008). Palynofacies analysis of Tertiary sediments in wells from the Niger Delta. Geological Society of America Special Paper 437, 249–262.

Petters, S. W. (1995). Foraminiferalbiofacies in the Nigerian delta: paleoenvironmental and stratigraphic significance. Journal of Foraminiferal Research, 25 (2), 116–130.

ReijersTJA, Petters SW, Nwajide CS. The Niger Delta Basin, In: Selley RC, editor, African Basins-Sedimentary Basin of the World 3: Amsterdam. Elsevier Science. 1997;151-172.

ReijersTJA. Stratigraphy and sedimentology of the Niger Delta. Geologost. 2011;17:133-162

Rotimi, O.J., Chukwuka, S., Oyeyemi, K.D., Ogunkunle, T., Akande, A.M., Ihekona, B., Iyamah, O., & Alege, T. S. (2022). Reconstructing Deposition Environment Using Energy Regime Assessment of Stacked Sequences from Gamma Ray Log and 3D Seismic Data.

Short KC, StaubleAJ. Outline of geology of Niger Delta. American Association of Petroleum Geologists Bulletin. 1967;51:761-779.

Tahoun, S.S., Deaf, A.S., and Mansour,A. (2017). Palynological, palaeoenvironmental and sequence stratigraphical analyses of a Turonian-Coniacian sequence, BeniSuef Basin, Eastern Desert, Egypt: Implication of Pediastrum rhythmic signature, Marine and Petroleum Geology, Volume 88, 2017, Pp 871-887. https://doi.org/10.1016/j.marpetgeo.2017.09.026.

Weber, K.J., Daukoru, E., 1975. Petroleum geology of the Niger Delta. Proc. World Petrl. Cong. 9, 209–221.

Wrenn, J. H. and Kokinos, J. P., 1986. Preliminary comments on Miocene through Pleistocene dinoflagellate cysts from De Soto Canyon, Gulf of Mexico, Amer. Assoc. Strat. Palynologists Contribution Series, 17: 169 - 225.