



Palynostratigraphy, Age Dating and Paleoenvironment of Deposition of ETA Zuma Coal Mine, Ankpa, Anambra Basin, North Central Nigeria

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ABSTRACT

This study focuses on the petrography and palynological analyses of the Upper Cretaceous sedimentary facies in Ankpa, North Central Nigeria. The primary aim was to unravel the organic composition, age and the prevailed paleoenvironmental conditions of the sediments. The methodology employed towards achieving these was the application of palynological analysis on 20 samples composed of coal and claystone, recovered from the coal mine. The samples were subjected to series of laboratory procedures such as decarbonisation with dilute HCl, sample digestion with hydrofluoric acid, sieving of the samples with 10 μ mesh, oxidation, heavy liquid separation, rinsing with ethanol, and mounting of the macerals on glass slides. Subsequently, the organic residues were microscopically analyzed using an OPTIKA G-150 microscope, facilitating the identification and counting of pollen, spores, dinoflagellates, and algae. In establishing the age and paleoenvironment of deposition of the sediments, marker species and stratigraphically significant forms were considered. The stratigraphic interval 0.05 to 23.8 m is composed of claystone at the upper part with dominant underlying coal beds. The palynostratigraphy of the coal measure was defined based on recovery of marker palynomorphs which belongs to *Spinizonocolpites baculatus* Assemblage Zone, characterized by the co-occurrences of *Constructipollenites ineffectus*, *Auriculiidites* sp., *Proxapertites operculatus*, *Longapertites microfoveolatus*, *Retidiporites magdalenensis*, *Syncolporites marginatus*, *Cingulatisporites ornatus*, *Buttinea andreevi*, *Proteacidites* sp., and *Inaperturopollenites* sp., all indicative of Late Maastrichtian age. The co-occurrence of terrestrially derived miospores and marine peridinacean form of dinoflagellates such as *Andalusiella polymorpha senegalium* sp., and *Oligosphaeridium* sp. are indicative of fluviomarine setting. However, evidence of sea level fluctuation was noticed whereby the coal interval of about 12.4 m which is rich in pollen, spores, dinoflagellates, and algae suggest a shift in coastline further landward compared to the overlying claystone. The ETA Zuma coal is characteristically similar to other coal deposits such as Mamu Coal Measure, dated late Maastrichtian on the basis of similarity in palynomorph assemblage.

Keywords: Coal, Palynomorph, Paleoenvironment, Dinoflagellate, Fluviomarine, Late Maastrichtian.

INTRODUCTION

Temperature, time, depositional environment and pressure play important role in transformation of organic matter constituents of sedimentary rocks. This is often studied under the microscope, following necessary Organic petrographic procedures, as palynomorphs, organic matter, macerals (vitrinites, liptinites and inertinites), palynofacies or kerogens in sedimentary rocks (Ayinla *et al.*, 2017a; 2023). Advance in Organic petrography has made it more useful with the development of fluorescence mode to compliment the reflected and transmitted light microscopy in describing organic matters. Even more and better descriptions of organic matter in coal, shales, mudstones, oil shales, limestones, sandstones and petroleum source-rocks have been possible in recent time (Ayinla *et al.*, 2017b; Pickel *et al.*, 2017).

In Palynology, the focus is mainly microorganisms and microscopic fragments of mega-organisms that are composed of acid-resistant organic material that

can be found in sediments, sedimentary rocks (e.g. Anambra Basin), and even some metasedimentary rocks. Palynomorphs which are the microscopic, acid-resistant organic remains and debris produced by a wide variety plants, animals, and Protista cover a number of geological ages, hence, are useful in age determination (Ayinla *et al.*, 2013; Ola-Buraimo and Ehinola, 2022; Ayinla *et al.*, 2023). This scientific approach studies present-day and fossil palynomorphs (paleopalynology), such as pollen, spores, orbicules, dinocysts, acritarchs, chitinozoans and scolecodonts, together with particulate organic matter (POM) and kerogen found in sedimentary rocks and sediments. It is on record that Palynology does

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not include diatoms, foraminiferans or other organisms with siliceous or calcareous tests (Peters *et al.*, 2005).

Although, this actually involves interdisciplinary science especially Geology and Biological Science, with emphasis on Botany in particular, other fields do employ it. In Biostratigraphy, a branch of paleontology and paleobotany, it involves fossil palynomorphs from the Precambrian to the Holocene for their usefulness in the relative dating and correlation of sedimentary strata (Peters *et al.*, 2005; Ayinla *et al.*, 2023). Palynology is also used to date and understand the evolution of many kinds of plants and animals (Ola-Buraimo *et al.* 2015).

The study area is located in Kogi State, Ankpa Local Government Area, and it is bordered by the Longitudes E07°41'0" to E07°43'0" and the Latitudes N07°28'0" to E07°30'00". Its western flank is covered by the lower coal measure/false bedded sandstones. The Mamu Formation's Lower Coal Measure is made up of alternating sandstones, carbonaceous shales, and coal. A sub-basin produced by the Santonian tectonic pulse gave rise to the Anambra Basin by the fault containing a lithostratigraphic component similar to those of the Cenozoic Niger Delta (Nwajide and Reijers, 1996). These authors and Obi (2000) studied the depositional model of the outcrops along Isele Azagba Onitsha-Akwa areas of the northern Niger Delta and Anambra Basins. The analysis and interpretation of the data sets allowed the reconstruction of sedimentary facies parameters, diagenetic histories, dominant control, and sequence stratigraphic concepts for the Anambra Basin and Niger Delta. Ola-Buraimo and Ehinola (2022) worked on reconstruction of the stratigraphy of the Anambra Basin using palynomorphs to suggest existence of about 8 transgressive cycles with 5 major unconformities within the Basin.

Recent work by Ayinla *et al.* (2023) used organic petrography characterization of sedimentary facies in the Zuma mine to determine the organic matter quantity, quality, and thermal maturity of the potential source rock in the area. Ayinla *et al.* (2023) and this study rely on palynological tool to make necessary inferences. Therefore, the main focus of this study is to determine the Palynostratigraphy and paleoenvironment of the Mamu Formation exposed at the Okobo coal mine in Kogi State by determining the age and environment of the exposed formation at ETA Zuma coal mine.

Geological Setting of the Study Area

Anambra Basin, a roughly triangular basin, is located in the southeastern part of Nigeria (Fig. 1).

The basin is bounded from the west by the Okitipupa Ridge, south by the Niger Delta Basin, and at the northwest it directly overlies the Basement Complex and interfingers with the Bida Basin. The basin is delimited in the north by the Basement Complex, the Middle Benue Trough and the Abakaliki Anticlinorium (Obaje, 2009). Akande and Erdtmann, 1998; Obaje 2009 considered the basin as the or part of the Lower Benue Trough, a Northeast – Southwest (NE-SW) trending, folded, aborted rift basin that runs obliquely across Nigeria. Hence its origin was linked to the tectonic processes that accompanied the separation of the African and South American plates in the Early Cretaceous (Burke *et al.*, 1970; Murat, 1972). The rift model had been supported by evidence garnered by structural, geomorphic, stratigraphic and paleontologic studies (Reyment, 1965; Burke *et al.*, 1970; Benkhelil, 1989; Guiraud and Bellion, 1995). The evolution of the basin represents the third cycle in the evolution of the trough and its associated basins when the Abakaliki Trough was uplifted to form the Abakaliki Anticlinorium whilst the Anambra Platform was downwarped to form the Anambra Basin (Murat, 1972; Weber and Daukoru, 1975) resulting in the westward displacement of the trough's depositional axis.

The basin is generally considered a sedimentary succession that directly overlies the facies of the Lower Benue Trough and consists of Campanian to Early Paleocene lithofacies. A great deal of work had been done to elucidate the age, paleoenvironment, paleogeography, sedimentary tectonics, origin of the deposits, the litho- and biostratigraphy and hydrocarbon (or fossil fuel) potentials of the basin (Reyment, 1965; Murat, 1972; Salami, 1983; Agagu *et al.*, 1985; Akande *et al.*, 1992; Nwajide and Reijers, 1996; Akande *et al.*, 2007; Akinyemi *et al.*, 2013; 2014; Ola-Buraimo and Ehinola, 2022), Deposition of sediments in Anambra Basin commenced during the Campanian, with Nkporo and Enugu shales and Owelli Sandstone which are regarded as the Nkporo Group, constituting the basal beds of the Campanian period (Reyment, 1965). During the Campanian was a period, there was a short period of marine transgression and regression in the basin resulting in shallow-sea which later became shallower due to subsidence, thereby resulting in a regressive phase during the Maastrichtian which deposited the flood plain sediments and deltaic foresets of Mamu Formation that was regarded as the Lower Coal Measures. Mamu Formation is overlain by the Ajali Sandstone, Nsukka and Imo formations and Ameki Group in that order. The detailed stratigraphic description of these formations is available in several publications (e.g. Agagu *et al.*, 1985; Reijers, 1996).

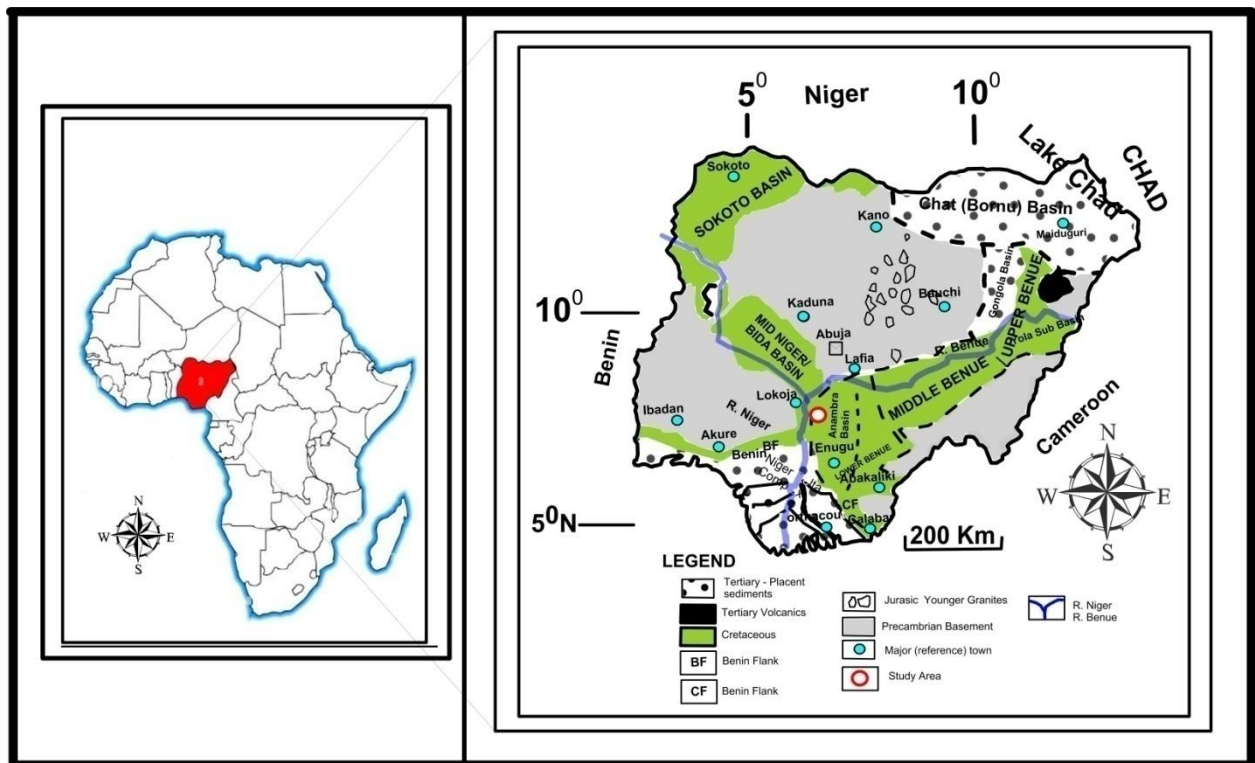


Figure 1: Geologic map of Nigeria showing the location of the Study area within the Anambra basin (Modified after Obaje, 2009).

The stratigraphic sequence of the Anambra Basin has been discussed extensively by several workers including Agagu *et al.* (1985), Ladipo (1986), Murat (1972), Nton and Bankole (2013), Ola-Buraimo and Akaegbobi (2013), and Reyment (1965). Though, sedimentation in the Anambra Basin was based on the long-standing assumption that it started and ranged from late Santonian to Eocene, but research work of Ola-Buraimo and Akaegbobi (2012) on Ogwashi–Asaba Formation has shown that the youngest formation in Anambra Basin, Ogwashi/Asaba Formation was dated Late Miocene to Pliocene age based on the occurrence of stratigraphic age diagnostic palynomorphs (miospores and dinoflagellates). It has also been advanced that the oldest sediment in the basin like the other known parts is Asu-River Group, dated as Albian to Early Cenomanian through the use of pollen and spores (Ola-Buraimo and Akaegbobi, 2013).

The Asu-River Group has varied lithologic unit, dark grey to black coloured shale, variously ferruginized, deposited in environment varying from continental through marginal marine to open marine systems (Ola-Buraimo and Akaegbobi, 2013). This is overlain by Eze-Aku Formation, composed of predominantly dark shale, dated late Cenomanian to Turonian (Ola-Buraimo, 2013a). Awgu Shale dated Coniacian (Ola-Buraimo, 2013) overlies the Eze-Aku Formation and marked the end of the first phase of sedimentation in the Anambra Basin before the

commencement of tectonic event in the Santonian. The dislocation of the depocenter into the Anambra platform resulted into the deposition of the Nkporo Shale (Nwajide, 1990). The Nkporo Group comprises of Nkporo Shale, Owelli Sandstone, and Enugu Shale dated late Campanian (Obi, 2000, Reyment, 1965). However, study based on palynology has dated the Asata/Nkporo Shale to be Campanian–Earliest Maastrichtian age (Ola-Buraimo and Akaegbobi, 2013).

The Nkporo Shale is overlain by Mamu Formation deposited during Early Maastrichtian (Kogbe, 1989, Obi, 2000). It is composed of siltstone, shale, coal seams and sandstone (Kogbe, 1989, Nton and Bankole, 2013). The age dating of Mamu Formation has been further refined and recently dated to range from early to middle Maastrichtian based on pollen and spores recovered (Ogala *et al.*, 2009). The Ajali Sandstone broadly dated Maastrichtian age overlies the Mamu Formation (Nwajide, 1990, Reyment, 1965). The sandstone is unconsolidated, coarse to fine grained, poorly cemented, with little mudstone and siltstone (Kogbe, 1989).

The Ajali Sandstone is overlain by Nsukka Formation dated Maastrichtian–Danian. This is also known as Upper Coal Measures (Obi, 2000; Reyment, 1965). The Imo Shale (Paleocene) overlies the Nsukka Formation (Nwajide, 1990) while it is successively overlain by Ameki Group, dated Eocene (Obi, 2000); Ogwashi-Asaba Formation consists of dark grey shale and sandy shale,

characterized by evidence of sediment reworking and dated Late Miocene–Pliocene (Ola-Buraimo

and Akaegbobi, 2012). The detailed stratigraphy of the basin is given in Figure 2.

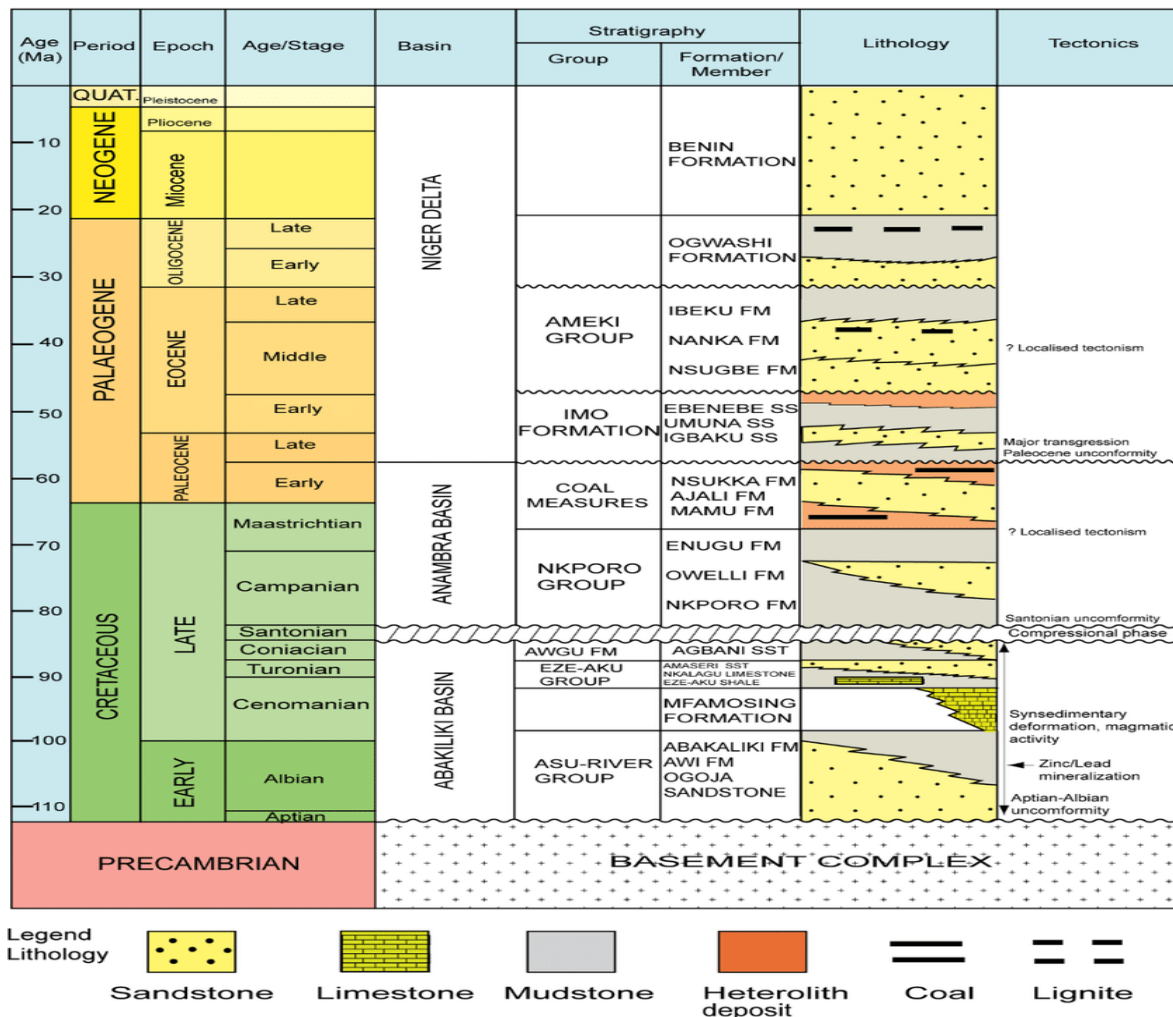


Figure 2: Stratigraphic Succession in the Anambra Basin and Outcropping Niger Delta (after Ekwenye and Nichols, 2016).

METHODOLOGY

Twenty samples comprising of claystone/shale and coal recovered from ETA Zuma Coal Mine were subjected to laboratory palynological sample preparation. The samples were initially decarbonised with dilute hydrochloric acid. This was followed by samples digestion with hydrofluoric acid. After the digestion, the samples were sieved with 10 µm mesh, allowing for concentration of the organic matter and removal of clay size particles that might obscure the clarity under the microscope and clear photomicrographs. Other sample processing includes maceral separation through heavy liquid separation using

zinc bromide. This stage was followed by oxidation of the organic matter using nitric acid. The separated organic maceral was rinsed with ethanol, before mounting on the glass slides for microscopic analysis and photography of the preserved forms.

RESULTS AND DISCUSSION

The results (Figs. 3 and 4) of this study reveal that the basal to middle part of the ETA Zuma Coal Mine (12.5-23.8 m) is composed of moderately rich palynomorph abundance and diversity. Evidence from the upper section of the interval shows paucity of recorded pollen and spores.

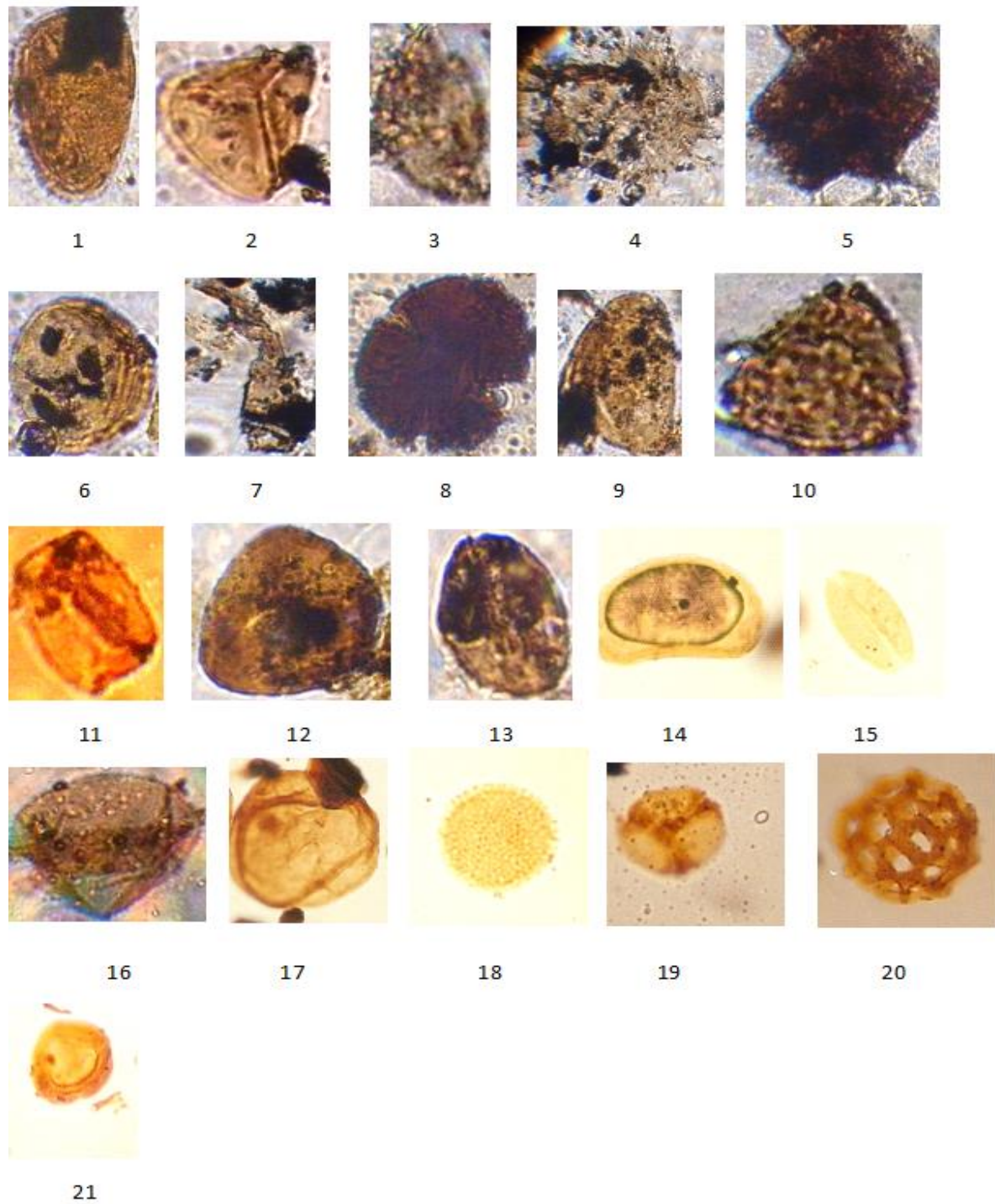


Figure 3: Photomicrograph of some of the identified palynomorphs from the studied samples (Magnification x 800)

- 1 *Longapertitesmicrofoveolatus*
- 2 *Cyathidites* sp.
- 3 *Auriculiidites* sp.
- 4 *Oligosphaeridium* sp.
- 5 *Senegalinium* sp.
- 6 *Proxapertitesoperculatus*
- 7 *Odontochina* sp.
- 8 *Stephanocolpites* sp.
- 9 *Longapertitesmarginatus*

- 10 *Proteacidites* sp.
- 11 *Retidiporitesmagdalenensis*
- 12 *Foveotriletesmargaritae*
- 13 *Monocolpitesmarginatus*
- 14 *Verrucatosporites* sp.
- 15 *Monosulcites* sp.
- 16 *Araucariacites* sp.
- 17 *Inaperturopollenites* sp.
- 18 *Constructipollenitesineffectus*

- 19 *Syncolporitesmarginatus*
 20 *Buttineaandreevi*
 21 *Cingulatisporitesornatus*

The palynomorph age dating and paleoenvironment of deposition deduction (Fig. 4) was based on composition of pollen, spores and dinoflagellates retrieved from the samples. These assemblages were compared with documented works of earlier workers on sedimentary basins having similar assemblages in Nigeria sediments and Coal Measures such as Ute Coal and Mamu Coal deposits in Dahomey Embayment and Anambra Basin respectively and sedimentary basins in other parts of the world.

Notable researchers include Germeraadet *et al.* (1968), Evamyet *al.* (1978), Lawal and Moullade (1986), Ogalaet *al.* (2009), Ola-Buraimo and Adeleye (2010), Ola-Buraimo (2020), Ola-Buraimo and Ehinola (2022) and Ayinla *et al.* (2023).

Palynozonation (Fig. 4)

Interval: 0.5-23.8 m

Zone: *Spinizonocolpitesbaculatus* Assemblage Zone

Age: Late Maastrichtian

Characteristics: The lower segment of the ETA Zuma coal mine stratigraphic section is a claystone, characterized by moderate abundance and diversity of palynomorphs. The lower section of the interval lies between 18.9-21.8 m. The basal claystone is composed of marker palynofoms such as *Longapertitesmarginatus*, *Cingulatisporitesornatus*, *Foveotrilitesmargaritae*, and *Retidiporitesmagdalenensis*. Pollen with new appearance in the interval are *Stephanocolpitesp.*, *Foveomonocolpitesbauchensis*, *Tricolpitesp.*, *Stephanoporitesp.*, *Proteaciditesdehaani*, and *Verrucatosporitesusmensis*.

The appearance of the marker forms in the interval is similar to miospores retrieved from the Mamu Coal in Anambra Basin, dated Late Maastrichtian (Ogala *et al.*, 2009). It is also in tandem with pollen and spores' assemblage in Ute Coal deposit in Dahomey Embayment, dated Late Maastrichtian (Ola-Buraimo and Adeleye, 2010).

The lower interval is also composed of appreciable quantitative occurrence of dinoflagellates cysts, rare occurrence of *Senegalinium* sp., continuous occurrence of *Phelodiniumbolonienae*, rare occurrences of *Batiacasphaera* sp., *Oligosphaeridium complex*, *Spiniferites* sp., and *Canningia* sp. The preponderance of peridinaceans indicate marginal marine paleoenvironment of deposition of the claystone (Ogala *et al.*, 2009; Ola-Buraimo and Adeleye, 2010; Ola-Buraimo, 2020;

Ola-Buraimo and Ehinola, 2021; Ola-Buraimo *et al.*, 2023).

Overlying the basal claystone is the Coal intercalated by adjacent claystone beds. The coal interval ranges between 6.5-18.9 m of about 12.4 m thick. The coal interval is moderately rich in pollen, spores and dinoflagellates compared with the overlying section. The apparent quantitative of pollen, spores, dinoflagellates, and algae in the interval compared with the overlying section could suggest a drastic shift in coast line further landward from its previous position.

The interval is marked by the appearances of *Constructipollenitesineffectus*, *Auriculiiditesp.*, *Proxapertitesoperculatus*, *Monocolpitesp.*, *Monocolpitesmarginatus*, *Longapertitesmicrofoveolatus*, *Syncolporites* sp., continuous regular occurrence of *Araucariacites* sp., and *Retidiporitesmagdalenensis*. Other miospores include *Syncolporites marginatus*, *Moosulcitesp.*, *Cingulatisporitesornatus*, *Butinea andeevi*, *Proteaciditesp.*, *Inaperturopollitesp.*, and *Longapertites* sp. The composition of the pollen and spores of the coal beds are similar in part with some other pollen assemblages described by Van Hoeken-Klinkenberg (1964), Jardine and Magloire (1965), Lawal and Moullade (1986), Edet and Nyong (1994), SalardCheboldaeff (1991), Ogala *et al.* (2009) and Ola-Buraimo and Adeleye (2010). In particular, the ETA Zuma Coal is correlatable with the Mamu Coal Measure Seam dated Late Maastrichtian (Ogala *et al.*, 2009) and for the Mamu Formation in Anambra Basin, southeastern Nigeria (Ola-Buraimo, 2020). Therefore, the coal interval was conveniently dated Late Maastrichtian. The paleoenvironment of deposition is marginal marine based on the occurrence of dinoflagellate cysts which belong to peridinacean group; indicative of marginal marine environment (Ola-Buraimo, 2020; Ola-Buraimo and Ehinola, 2022).

The upper part of the stratigraphic interval (0.5-6.5 m) is composed of claystone. The interval is characterized by paucity of miospores. This feature is strongly associated with the topmost part of Late Maastrichtian age sediments. Such paucity in miospores occurrence was reported in the work of Lawal and Moullade (1986) and in the research study of Nzam-1 well in Anambra Basin (Ola-Buraimo, 2020). The upper section of the studied stratigraphic interval is dated Late Maastrichtian age. The paleoenvironment of deposition of the sediment was possibly fluviomarine due to preponderance of terrestrially derived forms and the influx of rare dinoflagellate cysts.

- Akinyemi, S. A., Adebayo, O. F., Ojo, O. A., Fadipe, O. A. and Gitari, W. M. (2013). "Mineralogy and Geochemical Appraisal of Paleo-Redox Indicators in Maastrichtian Outcrop Shales of Mamu Formation, Anambra Basin, Nigeria", *Journal of Natural Sciences Research*, 3(10), 48-64.
- Ayinla, H.A., Abdullah, W.H., Makeen, Y.M., Abubakar, M.B., Jauro, A., Sarki Yandoka, B.M., Mustapha, K.A. and Zainal Abidin, N. S. (2017a). Source rock characteristics, depositional setting and hydrocarbon generation potential of Cretaceous coals and organic rich mudstones from Gombe Formation, Gongola Sub-basin, Northern Benue Trough, NE Nigeria. *International Journal of Coal Geology*, 173, 212-226.
- Ayinla, H.A., Abdullah, W.H., Makeen, Y.M., Abubakar, M.B., Jauro, A., Sarki Yandoka, B.M. and Zainal Abidin, N.S. (2017b). Petrographic and geochemical characterization of the Upper Cretaceous coal and mudstones of Gombe Formation, Gongola Sub-basin, Northern Benue Trough Nigeria: Implication for organic matter preservation, paleodepositional environment and tectonic settings. *International Journal of Coal Geology*, 180, 67-82.
- Ayinla, H.A., Musa A. O., Ola-Buraimo, A. O., Isaac, S. P., Emmanuel, D. and Aminu, B.M., Francis, J. A. (2023). Hydrocarbon Generation Potential of the ETA Zuma Coal Mines, Anambra Basin, Nigeria: Insight from Organic Petrography. *Communication in Physical Sciences*, 10(2), 244-260
- Ayinla, H.A., Ola-Buraimo, A.O., Adeigbe, O.C., Bankole, S.A. and Adebowale, M. (2013). Palynostratigraphy and high resolution paleoenvironmental reconstruction of part of Kemar-1 well, Bornu Basin, Northeastern Nigeria. *Journal of Research in Environmental Science and Toxicology*, 2, 53-63.
- Benkhelil, J. (1989). The origin and evolution of the Cretaceous Benue Trough, Nigeria. *Journal of African Earth Sciences*, 8, 251-282.
- Burke, K.C., Dessauvage, T. F. and Whiteman, A. J. (1970). "Geologic History of the Benue Valley and Adjacent Areas," In: Dessauvage, T. F. J. and Whiteman, A. J. Eds., *African Geology*, Ibadan University Press, Ibadan, 187-205.
- Edet, J.J. and Nyong, E.E. (1994). Palynostratigraphy of Nkporo shale exposures (Late Campanian- Maastrichtian) on the Calabar Flank, SE Nigeria. *Review of Palaeobotany and Palynology*, 80, 131-147.
- Ekwenye, O.C. and Nichols, G. (2016). Depositional facies and ichnology of a tidally influenced coastal plain deposit: the Ogwashi Formation, Niger Delta Basin. *Arabian Journal of Geosciences*, 9(18), 700.
- Evamy D.D., Heremboe, J., Kemeling P., Knaap W.A., Morlly F.A. and Rowlands, P.H. (1978). Hydrocarbon habitat of Tertiary Niger Delta. *American Association of Petroleum Geologists Bulletin*, 62, 1-39.
- Germaraad, J. H., Hopping, C.A. and Muller, J. (1968). Palynology of Tertiary sediments from tropical areas. *Review of Palaeobotany and Palynology*, 6, 189-348.
- Graham and Trotman, London, pp. 349.
- Guiraud, R. and Bellion, Y. (1995). Late Carboniferous to recent, geodynamic evolution of the West Gondwanian, cratonic, Tethyan margins. In *The Tethys Ocean* (101-124). Boston, MA, Springer US.
- Jardine, S. and Magloire, L. (1965). Palynologie et stratigraphie du Cretace des Bassins du Senegal et du Cote d'Ivoire. *Mem. Bur. Rech. Geology Min., botaniques. Review of Palaeobotany and Palynology*, 32, 187-245.
- Kogbe, C.A. (1989). Geology of Nigeria. *Rockview (Nigeria) Limited*. pp. 325-333
- Ladipo, K. O. (1986). Tidal shelf depositional model for the Ajali sandstone, Anambra Basin, Southeastern Nigeria. *Journal of African Earth sciences* 5(2), 177-185
- Lawal, O. and Moullade, M. (1986). Palynological biostratigraphy of the Cretaceous sediments in the upper Benue Basin, N.E. Nigeria. *Revue micropaleontologie*, 29(1), 61-83.
- Murat, R.C. (1972). Stratigraphy and paleogeography of the Cretaceous and Lower Tertiary in Southern Nigeria. *African Geology*, 1(1), 251-266.
- Nton, M. E. and Bankole, S. A. (2013). Sedimentological characteristics, provenance and hydrocarbon Potential of post Santonian sediments in Anambra Basin, southeastern Nigeria. *RMZ-Materials and Geo-environment Journal*, 60(1), 47-66.
- Nwajide C.S., (1990). Cretaceous sedimentation and Paleogeography of the Central Benue Trough. In: C.S. Ofoegbu (Edition). *The Benue Trough, Structure and Evolution. International Monography series, Braunschweig*. 19-38.

- Nwajide, C.S. and Reijers T.J.A. (1996). Sequence Architecture in Outcrops. Examples from the Anambra Basin, Nigeria. *NAPE Bulletin.*, 11(01), 23-32.
- Obaje, N.G. (2009). Geology and Mineral Resources of Nigeria. *Springer-Verlag Berlin Heidelberg*. www.Spinger.com. (120), 221
- Obi, G. C. (2000). Depositional Model for the Campanian-Maastrichtian succession Anambra basin, Southeastern Nigeria. *PhD Thesis, University of Nigeria Nsukka, Nigeria*.
- Ogala, J.E., Ola-Buraimo, A.O. and Akaegbobi, I. M. (2009). Palynological investigation of the Middle- Upper Maastrichtian Mamu Coal facies in Anambra Basin, Nigeria. *World Applied Sciences Journal* 7(12), 1566-1575.
- Ola-Buraimo A. O., Oladimeji, R.G. and Badamosi, B. (2023). Geochemical and Petrographic Studies: Implication on the Mineralogical Maturity, Sedimentation Processes and Paleoenvironment of Deposition of Jodu Sandstone, Gwandu Formation, Sokoto Basin, Northwestern Nigeria. *International Journal of Innovative Environmental Studies Research*, 11(1), 1-11.
- Ola-Buraimo A.O. (2013a). Palynological stratigraphy of the Upper Cenomanian-Turonian Eze-Aku Formation in Anambra Basin, southeastern Nigeria. *Journal of Biological and Chemical Research*, 30(10), 54-67.
- Ola-Buraimo A.O. and Ehinola, O.A. (2022). Sequence stratigraphy and sea level changes in relation to Evolution of Anambra Basin, Southeastern Nigeria. *Savanna Journal of Basic and Applied Sciences*, 3(2), 124-138.
- Ola-Buraimo, A. O. and Akaegbobi, I. M. (2012). Neogene dinoflagellate cyst assemblages of the Late Miocene-Pliocene Ogwashi-Asaba sediment in Umuna-1 Well, Anambra Basin, southeastern Nigeria. *Journal of Petroleum and Gas Exploration Research*, 2(6), 115-124
- Ola-Buraimo, A. O. and Akaegbobi, I. M. (2013). Palynological and paleoenvironmental investigation of the Campanian Asata/Nkporo Shale in the Anambra Basin, southeastern Nigeria. *British Journal of Applied Science and Technology*, 3(4), 898-915.
- Ola-Buraimo, A.O. (2020). Palynozonation Chronostratigraphy of deposition of the Albian to Pliocene Sediments of the Nzam-1, Umuna-1, and Akukwa-2 wells Anambra Basin, Southwestern Nigeria. *University of Ibadan PhD thesis*, 182p.
- Ola-Buraimo, A.O. and Adeleye, M. (2010). Palynological characterization of the Late Maastrichtian Ute Coal measure deposit, Southwestern Nigeria. *Science Focus*, 15(2), 276-287.
- Ola-Buraimo, A.O., Adebayo, O.F. and Umaru, S. (2015). Palynological characterization of the organic richness, kerogen type and thermal maturity of Kemar-1 well, northeastern Nigeria. *Journal of Biological and Chemical Research*, 32(2), 720-732.
- Peters, K.E., Walters, C.C. and Moldowan, J.M. (2005). The Biomarker Guide: Biomarkers and Isotopes in Petroleum Exploration and Earth History. second ed. *Cambridge University Press, Cambridge*. 1132.
- Pickel, W., Kus, J., Flores, D., Kalaitzidis, S., Christanis, K., Cardott, B.J., Misz-Kennan, M., Rodrigues, S., Hentschel, A., Hamor-Vido, M. and Crosdale, P.I.C.C.P. (2017). Classification of liptinite-ICCP System 1994. *International Journal of Coal Geology*, 169, 40-61.
- Reyment, R.A. (1965). Aspects of the Geology of Nigeria. Nigeria: *University of Ibadan Press*. 133.
- Salami, M.B. (1983). "Some Late Cretaceous and Early Tertiary pteridophytic spores from the northern Nigeria sedimentary basin". *Revue de micropaleontologie*, 15, 257-272.
- Salard-Cheboldaeff, M. (1991). Intertropical African palynologiquespalyostratigraphy from Cretaceous to Late Quaternary times. *Journal of African Earth Sciences*, 11(1/2), 1-24.
- Van Hoeken-Klinkenberg, P.M.J. (1964). Palynological investigation of some Upper Cretaceous sediments in Nigeria. *Pollen Spores*, 6(1), 209-231.
- Weber, K. and Daukoru, E. (1975). Petroleum geological aspects of the Niger Delta. *Journal of Mining and Geology*, 12(1/2), 1-32.