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Examination and Classification of Biostratigraphy of Paleoenvironmental Interpretation and Hydrocarbon Prospects in Northern Anambra Basin, Eastern Nigeria

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ABSTRACT: Biostratigraphy uses fossils to establish relative ages of rock and correlate successions of sedimentary rocks within and between depositional basins. Hence, this study examined and classified biostratigraphy of paleoenvironmental interpretation and hydrocarbon prospects in Northern Anambra Basin, Eastern Nigeria using appropriate standard methods. Data obtained point to a continental environment form of deposition for this area of the basin. The *Eucommiidites* sp., *Nyssapollenites triangulus, Tricolporopollenites subtilis, Rotverrusporites granularis, Execipollenites cf.*, made up the first zonewhile*Psilatricolporitesprolatus, Florentinia laciniata seghiris, Cingularisporites ornatus, Cicatricosisporites cf. orbiculatus, Lycopodiacidites asperatus, Mycrhystridium* sp, *Longapertites discordis,. Leptolepidites major, Retitriporites* sp., *and Triporites* sp. were the palynoflora of the second assemblage zone while the third assemblage zone were made up of *Cleistopshaeridium cf. Echitriporites trianguliformis, Stephanocolporate zonorate* and some megaspores. The observable barren zones were barren in marine fossils (foraminifera and dinoflagellates), but rich in seed cuticles and megaspores, which are important markers of continental deposition. The three biostratigraphic assemblage zones identified differed from those found in the deeper and more fossiliferous southern Onitsha sub-marine basement feature and the Benin flank regions of the larger Anambra Basin.

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The palaeoecologic and paleoclimatic studies, as well as the interpretation of Cretaceous pollen and spore assemblages, frequently rely on the overall makeup of the flora. The Ankpa sub-Basin (northern Anambra Basin), a sub-basin of the Anambra Basin, is of critical importance as one of the physiographically subdivided three of Ladipo, 1988. The shallow and smaller Ankpa sub-basin (this research region) is separated from the deeper and larger southern Onitsha sub-marine basement feature, while the Nsukka High and the sub-basin's south-western extension form the third arm, the Benin flank. The basin is a triangular-shaped embayment covering around 30,000 square kilometers (Ofodile, 2002). The objective of this study was to examine and classify the biostratigraphy of paleoenvironmental interpretation and hydrocarbon prospects in Northern Anambra Basin, Eastern Nigeria.

MATERIALS AND METHODS

Description of Study Area: The Anambra Basin runs from area just south of the junction of the rivers Niger and Benue to Auchi, Okene, Agbor, and Asaba, west of the river to Anyigba, Idah, and Nsukka. East of the river, Onitsha and Awka (Nwajide and Reijers, 1996). The Udi, Idah, and Kabba escarpments to the east,

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north, and northwest, respectively, define the basin's surface area. (Fig.1).

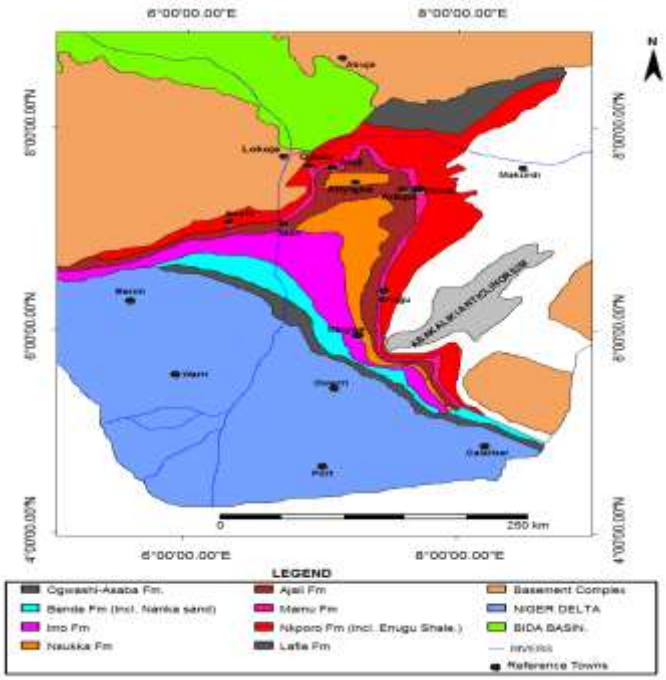

Fig 1. Generalised geological map of Anambra Basin(Odoma*et al*., 2023; Aigbadon *et al*., 2023)

The sedimentary successions in parts of the northern Anambra Basinwere analyzed for their biostratigraphic contents. The northern Anambra Basin is a part of the straddled section which is adjacent to the Mid-Niger Basin (Odoma, 2015). The Ajali and Mamu Formations are the exposed mappable sections observable in this part of the basin. Much work has been done in trying to unravel the sedimentary successions found in the Anambra Basin and to some extent the northern part of the basin. Some of the work has been in attempting to unravel the biostratigraphy with hydrocarbon prospects in the Benue Trough and the Anambra Basin (Obaje *et al.*, 1999), where biostratigraphy and sequence stratigraphy approaches were used to determine the ages and interpret the paleoenvironments for different sections of the successions in each of the basins. Other researchers, including Onuigbo *et al.* (2012), studied the palynology, palaeoenvironments, and sequence stratigraphy of the Anambra Basin's Campanian-Maastrichtian deposit. They produced a report on the deposition environment and developed a sequence stratigraphic model for the exposed Campanian-Maastrichtian sedimentary sequences in the Anambra Basin. Chiaghanam *et a*l. (2012) investigated the sequence stratigraphy and palynology of late Campanian to Maastrichtian strata.They were able to carry out detailed sedimentological, palynological, and sequence stratigraphic interpretations for the late Campanian-Maastrichtian sedimentary rocks of Nkporo Shale, Mamu Formation, and Nsukka Formation in that part of the basin due to their work focusing primarily on the areas around Okigwe and other adjoining environs. A full outcrop examination of the rocks was also conducted in order to establish sedimentological characteristics, sequence stratigraphic record, and palynological record of the area, with the goal of presenting a more detailed and comprehensive age determination and paleoenvironments of that location. Odunze and Obi (2013) investigated the sedimentology and sequence stratigraphy of the Anambra Basin's Nkporo Group (Campanian-Maastrichtian). The Nkporo Group sedimentologic and sequence stratigraphic interpretation offered a foundation for a basin-wide framework for anticipating possible source, seal, and reservoir rocks in the Anambra Basin. According to the findings of their study's lithofacies and biostratigraphic data, the Nkporo Group contains three major facies associations (fluvial-deltaic facies, estuarine central basin/shallow shelf facies, and estuarine channel fill facies) that determine reservoir containers, flow units, and seals. The information they supplied was important in the geological modeling of reservoirs in the Anambra Basin's Late Cretaceous Paleocene succession.The emphasis of this work is on identifying the implications for interpreting the paleoenvironment by investigating the

biostratigraphic contents (biozonation) of the strata found in this area of the basin, with specific regard to the fossils contents apparent within them. For this work, the shale units of the Mamu Formation exposed near Ojodu on the Anyigba - Itobe - Lokoja route (Figs.2a, and b) were investigated and analyzed.

Fig. 2. Massive bed of the shale unit of Mamu Formation exposed at Ojodu. Latitude N07^0 24$^{'}$ 53$^{''}$and Longitude E006^0 55$^{'}$26$^{''}$

*Regional stratigraphic setting:*From the point of view of the broader Lower Benue Trough, the geological context of the Anambra Basin can be regarded holistically. The basin is located in the southernmost section of the Benue Trough, one of several Cretaceous rift basins in central West Africa. The Anambra Basin's tectonic development may be traced back to the late Jurassic, when asthenosphere convection currents precipitated the breakup of the Gondwana Supercontinent. After the African and South American plates separated, the Benue Trough became an aulacogen, a failed arm of an RRR Tripple Junction (Burke 1972; Olade 1975).The Benue Trough is part of a much larger West and Central African rift system that opened up a large sinistral wrench complex (Emery et al 1975; Whiteman, 1982; Genik 1993). Murat (1972) reconstructs the southern part of the Benue Trough as longitudinally faulted, with the eastern side subsiding preferentially to form the Abakaliki depression. During the Albian-Santonian filling of the Abakaliki-Benue region of the Benue Trough, the proto-Anambra Basin was a platform that became only lightly sediment-draped (Nwajide and Reijers, 1997). The Benue Trough experienced spasmodic basin subsidence (Ojo, 1990). This is assumed to be the real time of the Anambra Basin's formation; a process that began in the Coniacian and culminated during the Santonian thermal tectonic event (Nwajide, 2005). The Anambra Basin was formed by post-deformational sedimentation in the Lower Benue Trough. The Campanian-Maastrichtian marine and paralic shales of the Enugu and Nkporo Formations began the sedimentation in the Anambra Basin. The occurrence of Afrobolivina afra in this basal sedimentary level, which was formed following the Santonian folding and inversion in southern Nigeria, indicates a late Campanian age (Reyment, 1965). This formation is overlain by the Mamu Formation's coal measures and contains sandstone, shale mudstone, sandy-shale, and coal seams in various layers. The Ajali and Owelli fluviodeltaic sandstones lie on the Mamu Formation and are its lateral equivalents in most locations. During the Palaeocene, the Nsukka Formation and the Imo Shale represent the beginning of another incursion in the Anambra Basin. Obaje (2009) defines the Eocene Nanka Sands as a return to regressive circumstances. The marine shales of the Imo and Nsukka Formations were deposited in the Palaeocene and were overlain by the Eocene tidal Nanka Sandstone.

*Sampling and Evaluation:*Twenty-five samples of the Mamu Formation shale unit were collected from various places in the northern Anambra Basin and tested for fossil content. The Mamu Formation was presumably heavily concentrated because it is the only exposed formation or portion in this region of the basin with a high fossil abundance. To eliminate the carbonates, five grams of each crushed sample were treated with 10% HCl before being neutralized with distilled water. The silicates were then dissolved with hydrochloric acid, which was then neutralized with distilled water. The acid-insoluble residue was sieved ultrasonically (mesh size 10m). Glycerin jelly was used to mount the organic residue on slides. At the Federal Institute for Geosciences and Natural Resources in Hannover, Germany, photo documentation of potentially interesting palynomorphs was made using a microscope; Leitz DM RB; microscope camera and software: Leica EC3 with Leica Application Suite.

RESULTS AND DISCUSSION

The palynomorphs are presented in Figures 3a and 3b. They are majorly pollens and serves as basis for correlation between strata in studied outcrop. These palynomorphs mentioned in Fig. 3a and 3b are good indicators for deducing environment of deposition in the study outcrop section (Fig. 4).For the straddled area of the northern Anambra Basin, three separates geographic palynofloras assemblage zones were discovered. An upper section palynoflora composed of pollen derived primarily from the Mediterranean Sea, most likely due to sea incursion during the Cretaceous period, a central or Saharan palynoflora composed of pollen derived from desert plants, and a southern (Tropical-Equatorial) palynoflora composed of pollen

derived from tropical plants but including some allochthonous pollen from West Africa's drier interior.The first assembly zone includes *Eucommiidites* sp., *Nyssapollenitestriangulus, Tricolporopollen itessubtilis, Rotverrusporites granularis, Execipollenites cf.,* and *Psilatricolporites prolatus, Florentinia laciniata seghiris. Longapertites discordis, Cingularisporites ornatus*, *Cicatricosisporites cf. orbiculatus, Lycopodiacidites asperatus, Mycrhystridium* sp. The second assemblage zone is made up of *Leptolepidites major, Retitriporites sp.*, and *Triporites* sp., while the third assemblage zone is made up of *Cleistopshaeridium cf. Echitriporites trianguliformis, Stephanocolporate zonorate*, and megaspores.

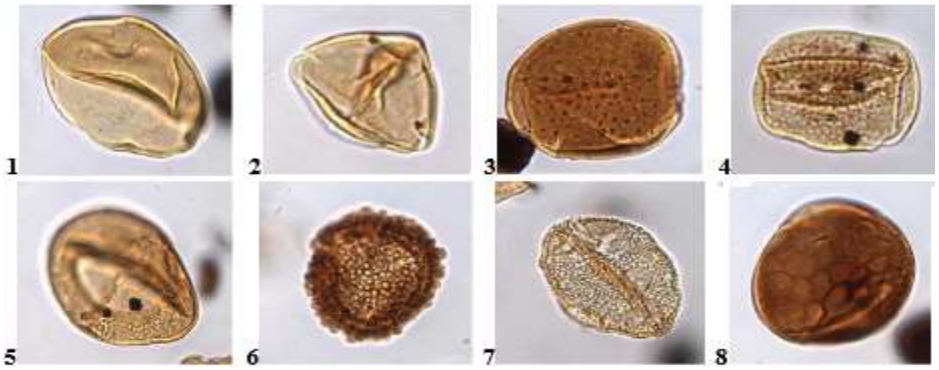

Fig.3a: Paaalynomorphs of the first assemblage zone

Fig3b. Palynomorphs from the second assemblage zone

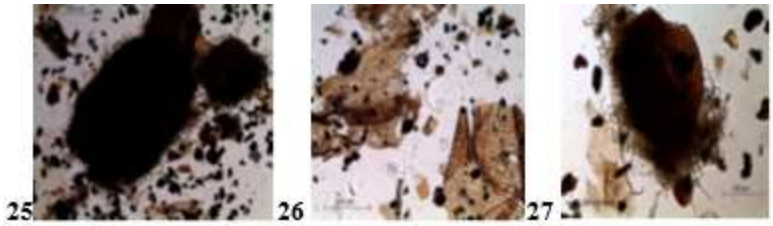

Fig.3c. Palynomorphs from the third assemblage zone

1, 4. *Eucommiidites* sp.; 2. *Nyssapollenites triangulus;* 3.8, *Execipollenites cf.*; 5. *Tricolporopollenites subtilis;* 6. *Rotverrusporitesgranularis;* 7. *Psilatricolporitesprolatus;* 9. *Verracutitrieletes* sp; 10. *Spiniferits cf.;* 11. *Ericipites* sp. 12. *Florentinia laciniata seghiris;*13, 14. *Cingularisporitesornatus;* 15. *Cicatricosisporites cf. orbiculatus;* 16.*Lycopodiacidites asperatus;* 17. *Mycrhystridium* sp; 18. *Longapertites discordis;* 19.*Leptolepidites major;*20. *Retitriporites* sp.*;* 21. *Triporites* sp; 22. *Cleistopshaeridium cf.;*23. *Echitriporites ttrianguliformis;* 24. *Stephanocolporate zonorate;* 25 – 27. *Megaspores*

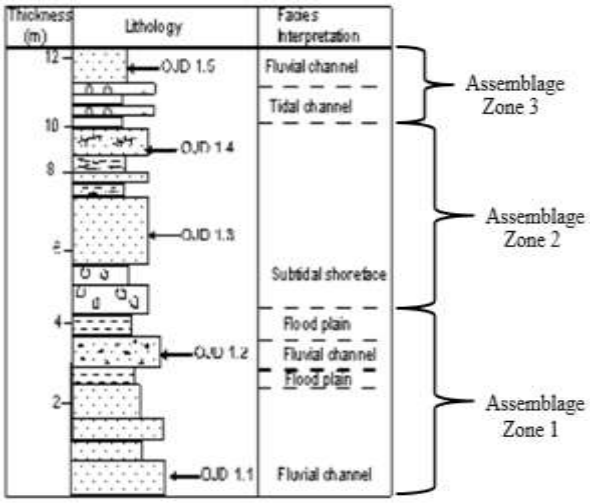

Fig. 4: Lithologic section of the straddled area and the biozones

The biostratigraphy of the examined outcrop in some sections of the region of the northern Anambra Basin is therefore based on the fossil assemblages recovered during laboratory investigation of the samples therein (palynomorphs, megaspores, dinoflagellates, and seed cutticles).Some palynomorphs, such as *Eucommiiditessp. Nyssapoll enitestriangulus Tricolporopoll enitessubtili, Execipollenites cf.,Psilatricolporit esprolatus, Florentinia laciniata seghiris.Cingularis poritesornatus Cicatricosisporites cf. orbiculatus, Lycopodiacidi tesasperatus, Mycrhystridium*sp. *Retitriporites*sp, *Triporites*sp. *Cleistopshaeridium cf., Echitriporitestrianguliformis, Stephanocol poratezonorate*, and host of others and the Campanian-Maastrichtian palynofloras and other fossils observed hereare overwhelmingly dominated by terrestrially derived palynomorphs (Plates nos. 1 - 27). Taking into account the palaeobiogeographic point of view the study area was part of the tropical African – South American as pointed out by Herngreen and Chlonova, 1981, in the Mid-Cretaceous and the Senonian (Late Cretaceous), respectively. It has certain general traits with these provinces, such as the abundance of Late Cretaceous monocolpate, palm-like pollen (*Arecipites*). Other research studies in dry areas of Egypt and Sudan indicated the existence of several of the palynomorphs species seen in this study area, which has been linked to continental habitats. While studying on the southern half of the Anambra Basin, Ladipo *et al*., 1992, discovered ichnofossils such as Skolithos and Ophiomorpha. These are parts of the characteristics structure of the formation across the entire basin and suggestive of tidal shallow marine depositional environment, however, in this part of the basin, less of the ichnofossils (*Skolithos* and *Ophiormopha*) were found and in association with high number of seed cuticles and megaspores tends to show continental environment of deposition. The Ajali Sandstone overlies the Mamu Formation and is diachronous from south to north (Middle upper Maastrichtian), with significant thickness variation ranging from less than 300m to over 1000m in the basins center (Ladipo *et al.,* 2001). This area of the basin, on the other hand, has thicknesses varying from 50m to around 300m. Most of the basin's depositional characteristics are consistent, with texturally mature sand facies composed of mature quartz arenite intercalated with Kaolinite layers. Cross-bedding associated with reactivation surfaces, mud drapes, tidal bundles, backflow ripples, channel-cut and fills, and lateral accretion surfaces are dominant sedimentary structures. Though the palynomorphs assemblage cannot be used as the only yardstick for measuring the prospectively of hydrocarbon of a formation or a basin, from this study carried out using the palynomorphs assemblages encountered, the prospect for its availability is still moderate.

Conclusions: Palynomorph distributions are known to be tightly tied to both source vegetation and atmospheric and oceanic transport mechanisms, and distribution patterns in bottom sediments and aerosols are often complimentary. The palynomorph assemblages discovered, as well as the megaspores of this straddled layer, all suggest to a continental deposition environment for this location. There may have been significant arid and semiarid zones of non-deposition and possibly seasonally dry periods throughout the Cretaceous. Some of the characteristics of the local palynofloras observed are most likely due to its inner continental location.

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