



Palynomorphs Content and Paleodepositional Environments of Mamu Formation in Okpekpe-1, Imiegba-1 and Imiegba-2, Benin Flank of Anambra Basin, Nigeria

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ABSTRACT: Twenty surface samples were taken from road cuttings along Okpekpe and Imiegba areas located in Benin Flank of Anambra Basin, Nigeria with an aim to establish the biozones, age and paleodepositional environments of the Mamu Formation. Using palynological laboratory standard procedures, the shale surface samples collected from the Mamu Formation in the study area were prepared and analyzed. The recovered marker pollens, spores and dinoflagellate cysts from the study area are *Milforadia jardinei*, *Milforadia* sp., *Longapertites marginatus*, *Longapertites* sp., *Retidiporites* sp., *Monocolpites marginatus*, *Cyathidites minor*, *Cyathidites* spp., *Cingulatisporites ornatus*, *Distaverrusporites simplex*, *Laevigatosporites* spp., *Foveotriletes margaritae*, *Subtilisphaera* sp., *Andalusiella* sp., *Paleocystodinium australinum* and microforaminiferal wall linings. Four biozones were erected for the shale intervals in the study area, namely: *Longapertites* sp., *Monocolpites marginatus*, *Cyathidites minor*, and *Paleocystodinium australinum* biozone, respectively, dated to Upper Maastrichtian to Early Paleocene age, which are lateral equivalents to *Spinizonocolpites baculatus* biozone of the Upper Benue Trough. The presence of the dinoflagellates cysts such as *Paleocystodinium australinum*, *Subtilisphaera* sp. and *Andalusiella* sp., microforaminiferal wall linings, pollens and spores established that the shales were deposited in nearshore to shallow marine environments. The presence of *Cingulatisporites ornatus* and *Distaverrusporites simplex* are indicative of marine regression that was followed by fluvial continental influence in anoxic bottom conditions that in turn favored the formation of coal seams in shales in the study area. The paucity of palynomorphs in the study area is inferred to have occurred because of the dry climatic condition that prevailed during the Upper Maastrichtian to Early Paleocene.

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Depositional systems of sediments are of essential value because they provide groundwork for predicting reservoir facies and potential petroleum source. The paleodepositional environment offers a basis for predicting comprehensive sedimentary characteristics, sand body geometry, and architecture of petroleum reservoirs. Formation outcrops are dependable analogs to subsurface lithofacies, and therefore, they are useful in studying facies distribution, reservoir characterization, and geohistory (Boggs, 2006;

Tetyukhina *et al.*, 2014). Palynomorphs are organic-walled microfossils with sizes that range from 5µm to 500µm, and they are generally composed of chitin, pseudochitin, sporopollenin and dinosporin. Examples of palynomorphs include acritarchs, plant spores, pollen grains, chitinozoans, dinoflagellates cysts, green and blue algae, fungi bodies, scolecodonts (jaws, and associated parts of polychaete annelid worms, and scleroprotein teeth), arthropod organs (such as insect mouth parts) and microforaminiferal wall linings

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(Traverse, 2007; Batten, 1996). Palynomorphs are preserved in unoxidized, fine-grained, mainly dark-colored (gray to black) sediments such as shales, mudstones, siltstones, micritic limestones, cherts and coals. Palynomorphs are ubiquitous in diverse sedimentary environments in rocks that are made up of clay or silt-sized particles. They are very resistant to oxidation and chemically stable but they are readily destroyed by metamorphism and igneous processes. Consequently, palynomorphs are absent in metamorphic and igneous rocks. Palynomorphs are very important in the field of palynology and they are useful for the following: botany, archaeology, pedology, medicine, limnology, forensic crime investigation, melissopalynology, paleogeography, paleoclimatology, biostratigraphy, paleoenvironmental interpretation, source rock maturity studies, petroleum exploration and production, and green energy development in terms of carbon sequestration (Faegri *et al.*, 1989; Batten, 1996). The objective of this paper was, therefore, to evaluate the palynomorphs content and paleodepositional environments of Mamu Formation in Okpekpe-1, Imiegba-1 and Imiegba-2, Benin Flank of Anambra Basin, Nigeria. Anambra Basin is one of southern Nigerian sedimentary basins, while Mamu Formation is one of the constituent lithostratigraphic units in the Anambra Basin (Obaje and Ahmed, 2022).

MATERIALS AND METHODS

Description of the Study Area: The study area lies within latitudes N07°11.4'57" and N07°12'30" and longitudes E006° 26.8'33" and E006°27'33" with elevations of 150m - 205m above sea level (Figure 1). The study area is located on the trunk 'A' road cuts connecting Okpekpe and Imiegba to Auchi. The samples were collected from the exposed shale outcrops of the Mamu Formation in the study area which is located in the Benin Flank (western part) of the Anambra Basin in Nigeria. Several works has been carried out on the stratigraphy, age, paleoenvironment, paleogeography, sedimentary tectonics and origin of the Anambra Basin, and its component formations in the eastern flank (Simpson, 1954; Petters, 1978; Agagu *et al.*, 1985; Arua, 1980; Ladipo, 1988; Ogala *et al.*, 2009; Ojo *et al.*, 2009; Onuigbo *et al.*, 2012; Sorannadi-Ononiwu *et al.*, 2012; Odunze and Obi, 2013; Lucas and Ebahili, 2017; Kovona *et al.*, 2020; Izuazu-Gerry and Onuigbo, 2022; Adamu *et al.*, 2022). However, very few publications are available on the biostratigraphy and lithostratigraphy of the western flank of the Anambra Basin (Chiaghanam *et al.*, 2013; Ejeh, 2016; Jayeola *et al.*, 2016; Igbinigie *et al.*, 2017; Obaje, 2019; Obaje and Ahmed, 2022.); thus the need for this study.

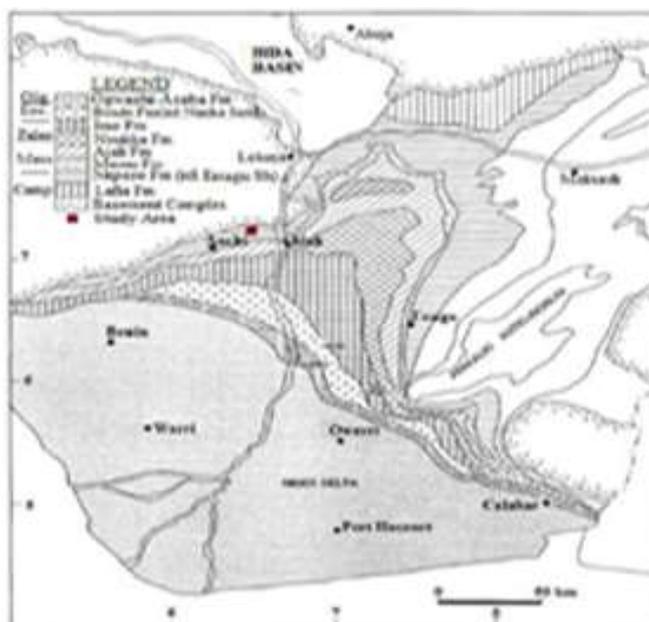


Fig 1: Geological Map Anambra Basin showing Study Area (after Nwajide and Reijers, 1996)

Regional Geology and Stratigraphy of Anambra Basin: Anambra Basin originated from the Benue Trough, which was formed by rifting of the central West African basement that began in the Cretaceous

period. The Benue Trough is an aulacogen, a failed arm of the triple rift valley system. Initially the Benue Trough was filled with sediments deposited by rivers and lakes. During the Late, Early to Middle

OBAJE, S. O; AKINYELE, O; AHMED, R; ALLI, B; ADEFEMISOYE, A

Cretaceous, it subsided and then filled with ocean water. Large quantities of sediments accumulated in the bottom of the southern Abakiliki Rift in anoxic conditions (Nwajide, 2013). In the Upper Cretaceous, the Benue Trough probably formed the main link between the Gulf of Guinea and the Tethys Ocean (predecessor of the Mediterranean Sea) through the Chad and Iullemmeden Basins. After this period, the basin rose above sea level, and extensive coal forming swamps developed, especially in the Anambra Basin. The westward displacement of massive sediments in the Lower Benue Trough led to the formation of the Anambra Basin (Burke *et al.*, 1972; Nwajide, 2013; Obaje, 2013). Stratigraphically, the oldest formation in Anambra Basin is the Late Campanian Nkporo Shales, which is the lateral equivalent of the Enugu Formation, and overlies the Santonian Agwu Formation of the Lower Benue Trough. Nkporo Shale was formed from the first marine transgression into the Anambra Basin. (Obaje and Ahmed, 2022; Nwajide, 2013). Nkporo Shale is overlaid by the highly fossiliferous Campanian–Maastrichtian carbonaceous shale rich Mamu Formation. Overlying the Mamu Formation is the Upper Maastrichtian aged Ajali Formation, which marked the marine regressive phase of the Anambra Basin. Ajali Formation is made up of white fine- to coarse-grained friable sandstones with lots of sedimentary structures and ichnofossils with evidence of fluvial-deltaic influence. Maastrichtian–Paleocene (Danian) aged Nsukka Formation lies unconformably on the Ajali Formation. Nsukka Formation is composed mainly of shales with very rich coal seams. Nsukka Formation marked another phase of the Post-Santonian marine transgression in the Anambra Basin. Above the Nsukka Formation is the Paleocene aged Imo Formation, which is the equivalent of the subsurface Akata Formation in the Niger Delta area of Nigeria (Ogala *et al.*, 2009).



OBAJE, S. O; AKINYELE, O; AHMED, R; ALLI, B; ADEFEMISOYE, A

Fig 2: Photographs of Lithostratigraphic Sections in the Study Area The Imo Formation is mostly made of up shales deposited under littoral-neritic environment and it is the lateral equivalents of Ebenebe, Mamuna and Agbabu Sandstones, respectively (Obaje and Ahmed, 2022). Mamu Formation in Okpekpe-1, Imiegba-1 and Imiegba-2 is a constituent lithostratigraphic unit in the Anambra Basin. The lithology of the Mamu Formation exposures in Okpekpe-1, Imiegba-1 and Imiegba-2 consist predominantly of dark carbonaceous shale, ferruginized shale with intercalation of siltstone, sandstone, siltstone and mudstone (Figures 2 and 3). Ferruginized shale occurs at the base at depths of > 11.0m. The sandstones are medium- to coarse-grained, while the siltstones and mudstones are thinly laminated. The Mamu Formation in the study area sits unconformably on the ferruginized Lokoja-Basange Formation which is the lateral equivalent of Nkporo Shale and Enugu Formation in the eastern part of the Anambra Basin. The Lokoja-Basange Formation lies unconformably on the Igarra Schist Basement Complex (Alli, 2021).

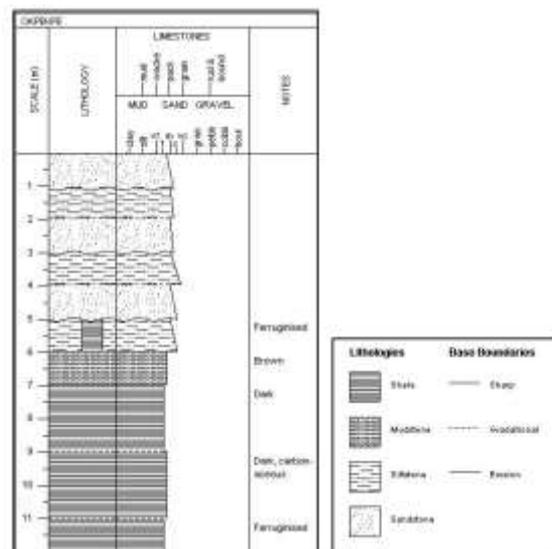


Fig 3: Lithology log of the Study Area (after Obaje and Ahmed, 2022)

Laboratory Samples Preparation: The surface exposures of the Mamu Formation were geologically mapped and logged in the study area. Twenty clean outcrop samples were collected, labeled and transmitted in waterproof bags to the laboratory for preparation and analysis in line with the procedures of Faegri *et al.* (1989). 10 grams of each sample was crushed and then treated with 10% dilute hydrochloric acid to remove carbonates and after decalcification and acid neutralization, average of 9.90 grams residues remained and then 40% hydrofluoric acid was applied to the samples in a fume chamber to eradicate silica

and silicates from each sample. After complete neutrality of the acid, the residues were weighed and average of 2.54 grams was recorded. Thereafter, samples were bleached using sodium hypochlorite and hydrogen peroxide procedure and 65 mesh residues retained were weighed and average of 1.05 grams (10.50%) remained and the organic matter residues recovered via heavy mineral separation were mounted on glass slides by means of Canada balsam for microscopic identification of the palynomorphs.

RESULT AND DISCUSSION

Palynomorphs distribution in the study area and photomicrographs of marker species are given in Figures 4 - 7. Twenty surface samples from Okpekpe-1 (also abbreviated to 'Oke-1') and Imiegba-1 and Imiegba-2 (nicknamed as Eba-1 and Eba-2, respectively) were painstakingly prepared and analyzed for their palynomorphs content. The recovered pollens are *Monocolpites marginatus*, *Milfordia jardinei*, *Milfordia* sp., *Retidiporites* sp., *Retimonocolpites* sp. and *Longapertites marginatus*, *Longapertites* sp., while the spores are *Cyathidites minor*, *Cyathidites* sp., *Cingulatisporites ornatus*,

Laevigatosporites sp., *Foveotriletes margaritae*, *Distaverrusporites simplex*, *Acrostichum* sp. and *Verrucatosporites* sp. On the other hand, the recovered dinoflagellates cysts are *Subtilisphaera* sp., *Paleocystodinium australinum*, *Andalusiella* sp., *Leiosphaeridia* sp., *Odontochitina* sp. and *Spinidinium* sp. and lastly, microforaminiferal wall linings. In Oke-1, the assessed depths are 3.84m to 9.92m. At depths of 6.08m and 8.06m, pollens abundance and diversity were noticed, while spores abundance and diversity were observed at depths of 4.96m and 6.08m. On the other hand, the abundance and diversity of dinoflagellates cysts were recorded at the depths of 4.96m and 8.06m. However, at depth < 4.34m, palynomorphs were not recovered. In Eba-1, the studied depths are 16.02m to 27.22m. Pollens abundance and diversity were noted at depths of 22.24m – 24.57 m and 27.22m. Spores abundance and diversity were noticed at depths of 20.50m, 23.66m and 25.56m, while dinoflagellates cysts abundance and diversity were recorded at depths of 17.53m, 20.50m, 22.24m, 23.66m -25.66m and 27.22m. Nevertheless, at depth < 17.22m, palynomorphs were not recovered. In Eba-2, the assessed depths are 0.0m to 21.7m.

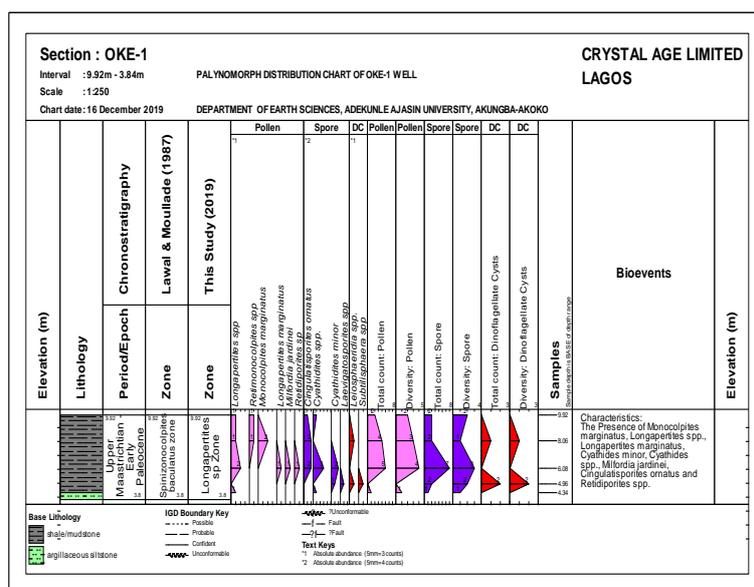


Fig 4: Palynomorphs Distribution Chart of Okpekpe-1

Pollens abundance and diversity were observed at depths of 8.20m, 10.60m, 12.90m and 21.70m. On the other hand, Spores abundance and diversity were detected at depths of 8.20m and 10.60m, while dinoflagellates cysts abundance and diversity were noted at depths of 8.20m, 12.90m and 21.70m. However, at depth < 6.30m no palynomorphs was recovered. The characteristic marker palynomorphs present in Okpekpe-1 are *Monocolpites marginatus*,

Longapertites marginatus, *Longapertites* sp., *Cyathidites minor*, *Cyathidites* sp., *Milfordia jardinei*, *Cingulatisporites ornatus* and *Retidiporites* sp. (Figure 4). *Longapertites* sp. biozone was erected for the interval and dated to Upper Maastrichtian to Early Paleocene which is a lateral equivalent of *Spinizonocolpites baculatus* zone of Upper Benue Trough (Lawal and Moullade, 1987).

OBAJE, S. O; AKINYELE, O; AHMED, R; ALLI, B; ADEFEMISOYE, A

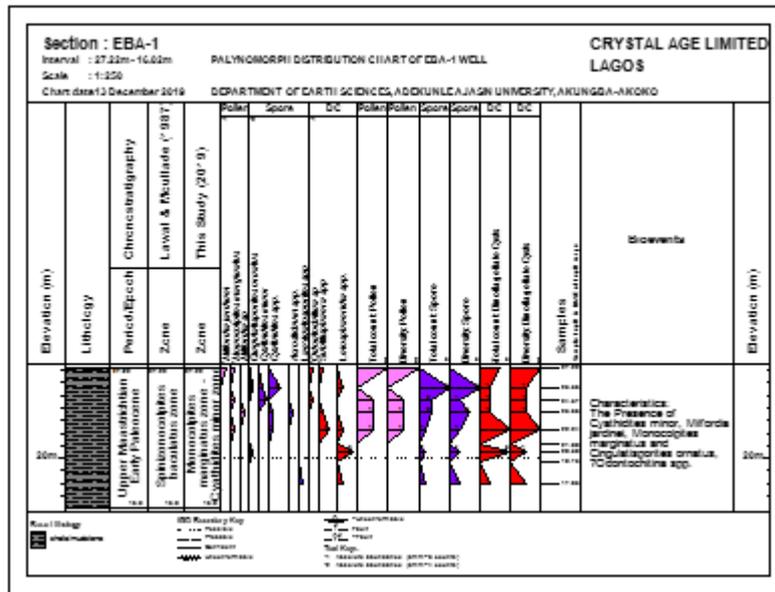


Fig 5: Palynomorphs Distribution Chart of Imiegba-1

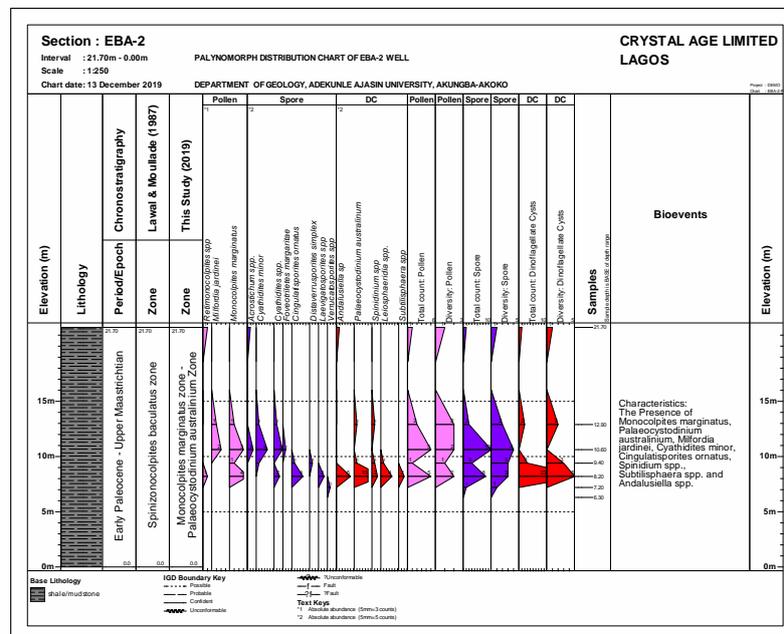


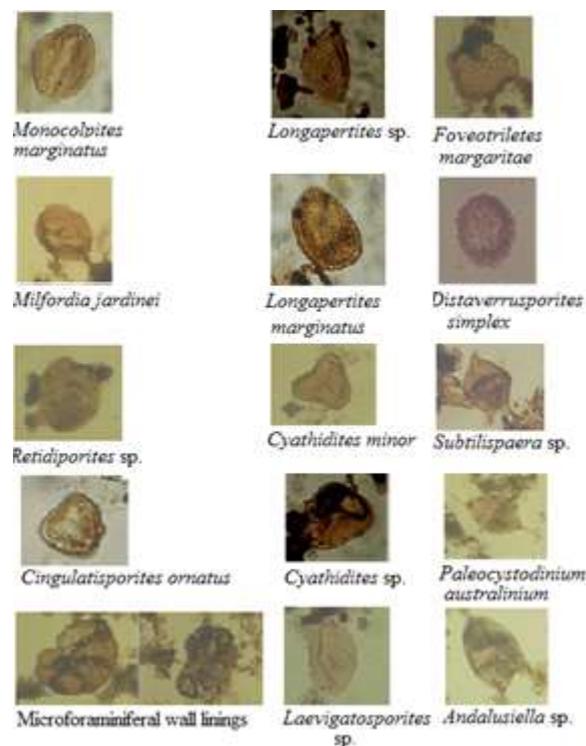
Fig 6: Palynomorphs Distribution Chart of Imiegba-2

The presence of the dinoflagellate cysts, microforaminiferal wall linings are indicative of marine depositional environment for the shale in Okpekpe-1 section in the study area; however, the presence of *Longapertites marginatus* and *Cingulatisporites ornatus* are indicative of marine regression followed by fluvial influence. The poor quantities of the pollens and spores point to dry continental climatic condition that took place during the Upper Maastrichtian to Early Paleocene in Okpekpe-1.

The characteristic marker palynomorphs present in Imiegba-1 are *Cyathidites minor*, *Milfordia jardinei*, *Monocolpites marginatus* and *Cingulatisporites ornatus* (Figure 5). Two biozones, namely: *Monocolpites marginatus* and *Cyathidites minor* biozone, respectively, were erected for the intervals and dated to Upper Maastrichtian to Early Paleocene which is a lateral equivalent of *Spinizonocolpites baculatus* zone of Upper Benue Trough (Lawal and Moullade, 1987). The presence of dinoflagellate cysts and microforaminiferal wall linings also indicated marine depositional environment

OBAJE, S. O; AKINYELE, O; AHMED, R; ALLI, B; ADEFEMISOYE, A

for the shale in Imiegba-1 section in the study area. The presence of *Cingulatisporites ornatus* is indicative of marine regression that followed after the marine transgression in Imiegba-1.



(All magnifications at x800)

Fig 7: Photomicrographs of Marker Palynomorphs from the Study Area

The characteristic marker palynomorphs present in Imiegba-2 are *Monocolpites marginatus*, *Cyathidites minor*, *Milfordia jardinei*, *Cingulatisporites ornatus*, *Paleocystodinium australinium*, *Subtilisphaera* sp. and *Andalusiella* sp. (Figure 6). Two biozones, namely: *Monocolpites marginatus* and *Paleocystodinium australinium* biozone, respectively, were erected for the intervals and dated to Upper Maastrichtian to Early Paleocene which is a lateral equivalent of *Spinizonocolpites baculatus* zone of Upper Benue Trough (Lawal and Moullade, 1987). The presence of the dinoflagellate cysts such as *Paleocystodinium australinium*, *Subtilisphaera* sp. and *Andalusiella* sp., microforaminiferal wall linings and other pollens and spores established that the shales were deposited in nearshore to shallow marine environment with fluvial continental influence that made allowance for the formation of coal seams in Imiegba-2 section of the study area.

Conclusion: Three surface exposed sections, namely: Okpeke-1, Imiegba-1 and Imiegba-2 were studied in

the study area. Four biozones were erected for the shale intervals in the study area, namely: Okpeke-1: *Longapertites* sp. biozone; Imiegba-1: *Monocolpites marginatus* and *Cyathidites minor* biozone, respectively, and Imiegba-2: *Monocolpites marginatus* and *Paleocystodinium australinium* biozones. The associated palynomorphs are *Milfordia jardinei*, *Milfordia* sp., *Longapertites marginatus*, *Longapertites* sp., *Retidiporites* sp., *Monocolpites marginatus*, *Cyathidites minor*, *Cyathidites* spp., *Cingulatisporites ornatus*, *Distaverrusporites simplex*, *Laevigatosporites* spp., *Foveotriletes margaritae*, *Subtilisphaera* sp., *Andalusiella* sp., *Paleocystodinium australinium* and microforaminiferal wall linings. The four biozones were dated to Upper Maastrichtian to Early Paleocene and they are lateral equivalent of *Spinizonocolpites baculatus* zone of Upper Benue Trough. The presence of the dinoflagellate cysts such as *Paleocystodinium australinium*, *Subtilisphaera* sp. and *Andalusiella* sp., microforaminiferal wall linings, pollens and spores established that the shales were deposited in nearshore to shallow marine environment. The presence of *Cingulatisporites ornatus*, *Cingulatisporites ornatus* and *Distaverrusporites simplex* are indicative of marine regression that was followed by fluvial continental influence in anoxic bottom conditions that favored the formation of coal seams in the shales in the study area. The paucity of palynomorphs in the study area is inferred to have occurred because of the dry climatic condition that prevailed during the Upper Maastrichtian to Paleocene.

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