



Paleoenvironmental Analysis of Imo Shale Outcrops, using Miospores, from Parts of Ini Local Government Area, Southeastern Nigeria

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Abstract

This study investigates the paleoenvironmental characteristics of Imo Shale outcrops in parts of Ini, Southeastern Nigeria, through a systematic palynological analysis of miospores. The objectives were to identify and interpret the recovered palynomorph assemblages, classify the vegetation types, and infer the climatic conditions and depositional settings during sedimentation. Thirteen (13) shale samples from three (3) locations were analyzed, yielding a total of 1,854 palynomorphs from 65 genera. These include five (5) spore types, 25 pollen types, and 24 marine indicators. The presence of index species such as *Proxapertites cursus*, *P. operculatus*, *Mauritidites crassiexinous*, *Retistephanocolpites williamsi*, and dinocysts like *Lejeunecysta* and *Apectodinium* suggest a Paleocene to Eocene age. This interpretation is further supported by the occurrence of *Selenopemphix nephrois*, *Apectodinium parvum*, *Spiniferites hyalospinosus*, and *Lejeunecysta fallax*. The palynomorph assemblages indicate a mix of coastal, nearshore, and terrestrial vegetation, pointing to a deltaic or estuarine paleoenvironment. These findings enhance understanding of the paleoenvironmental evolution of the Imo Formation and have implications for hydrocarbon exploration and geological history in Southeastern Nigeria.

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1.0 Introduction

The study of paleoenvironmental conditions is crucial for understanding the geological history and evolution of Earth's climate and ecosystems. One valuable method for reconstructing past environments is through the analysis of miospores, which are microscopic spores and pollen grains produced by terrestrial plants (Ehinola *et al.*, 2012). These microfossils are often well-preserved in sedimentary rocks and provide significant insights into past vegetative landscapes, climate conditions, and depositional environments (Adeleye *et al.*, 2015). Imo Shale, is located in southeastern Nigeria and is a notable geological formation of Paleocene age within the Niger Delta Basin. It comprises predominantly of Shales with interbedded sandstone and exhibits rich fossil content, including miospores (Nwajide *et al.*, 1995). These outcrops present an excellent opportunity to investigate the paleoenvironmental conditions of the region during the Paleocene epoch. This research aims to conduct a detailed paleoenvironmental analysis of Imo Shale outcrops through the examination of miospore from three selected locations; Ikporom, Ananamong, and Ibam Edet, all in Ini Local Government Area.

Understanding the paleoenvironment of the Imo Shale is significant for several reasons. First, it provides insights into the historical climatic and ecological conditions that prevailed in West Africa during the Paleocene. Second, it aids in reconstructing the paleoecological framework necessary for petroleum exploration, as the Niger Delta is a major hydrocarbon province. Third, the findings can offer comparative data for similar geological formations worldwide, thereby contributing to the global paleoclimatic and paleoecological research.

The exploration of past environments through paleoenvironmental analysis is fundamental to understanding Earth's geological history and the dynamics of climate and ecosystems (Ruddiman *et al.*, 2001). In the southeastern region of

Nigeria lies the Ini Local Government Area, an area of significant geological interest hosting outcrops of the Imo Shale Formation. These outcrops provide a unique opportunity for paleoenvironmental investigation, particularly through the examination of miospores, spores and pollen grains that are preserved within the sedimentary rocks (Adeleye *et al.*, 2015). The Imo Shale Formation, dating back to the Paleocene epoch, is renowned for its rich fossil content and holds crucial clues to the environmental conditions prevailing during its deposition (Nwajide, 2013).

This research focuses on the paleoenvironmental analysis of the Imo Shale outcrops in Ini Local Government Area, Southeastern Nigeria, utilizing miospores as proxies for past vegetation and climatic conditions. The objectives are twofold: to reconstruct the paleoenvironmental context of the region during the Paleocene epoch and to contribute to the broader understanding of geological and paleoecological processes in West Africa. Furthermore, the study will infer the vegetation types that existed during the deposition of Imo Shale, reconstruct the vegetation landscape of the Paleocene epoch, and analyze the sedimentological context and depositional environments. Finally, findings from this study will be compared with similar paleoenvironmental studies from the Niger Delta Basin to enhance the understanding of regional paleoecological evolution. By integrating palynological and sedimentological approaches, this study will contribute to a deeper understanding of the environmental conditions that prevailed during the Paleocene and provide valuable data for reconstructing past climates and ecosystems in southeastern Nigeria.

2.0 Materials and Methods

2.1 Location of the Study Area

Ini Local Government Area is situated in the southern part of Nigeria, within Akwa Ibom State. It shares boundaries with the former Ikono

Local Government Area and Abia State (Figure 1). Ini Local Government area is located between latitudes $5^{\circ}20'$ and $5^{\circ}31'N$ and longitudes $7^{\circ}38'$ and $7^{\circ}53'E$. The area is classified as a lowland region, with an elevation of less than 200 metres above sea level. The region experiences a tropical climate with two distinct seasons: a rainy season from April to October and a dry season from November to March. Annual rainfall can reach up to 2,000 mm, with temperatures ranging from $26^{\circ}C$ to $28^{\circ}C$. The vegetation is primarily tropical rainforest, with a mix of dry land and freshwater

swamp forests. This local government area is rich in natural resources, including limestone, clay, gravel, fine sand, crude oil, and iron ore. The region is also known for its agricultural produce, such as rice, palm products, cassava, cocoa, and bananas. Additionally, its forests provide valuable resources such as timber and firewood. The area is home to a diverse range of wildlife, including several species of mammals such as the roan antelope, red river hog, king genet, and African civet. The region's forests also support a variety of bird species and other wildlife.

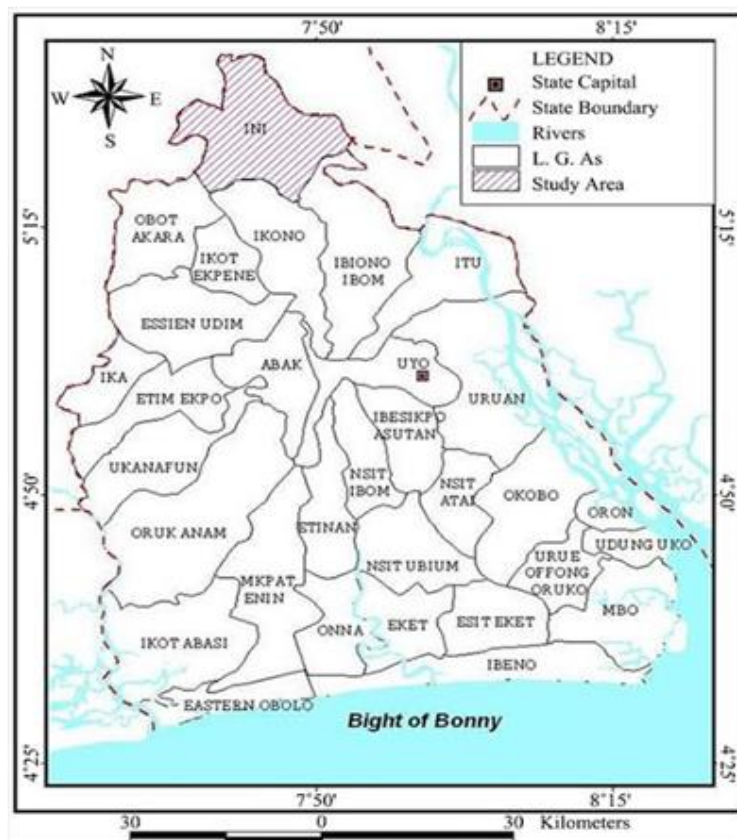


Figure 1: Map of the Study Area (Source: Office of the Surveyor General Akwa Ibom State, 2023)

2.2 Geology of the Study Area

Ini Local Government Area is characterized by sedimentary rocks of the Niger Delta Basin (Kogbe, 1989). The basin is bounded by the Precambrian Basement Complex to the north and the Atlantic Ocean to the south (Edet and Okereke, 1997). The sedimentary sequence in the area can be divided into three main lithostratigraphic units, which are; Benin Formation (Miocene – Pliocene): a sequence of

unconsolidated to semi –consolidated sands, clays and silts: Agbada Formation (Eocene – Miocene): a sequence of sand stones, silt stones and clay stones. Which underlies the Benin Formation; Akata Formation (Paleocene – Eocene): a sequence of shales, siltstones, and sandstones, which is the oldest unit in Ini area. (Nwajide, 2013).

The area is characterized by a complex network of faults, folds, and fractures (Nwajide, 2013).

Ini area is known for its rich mineral resources, including petroleum, natural gas, and limestone (Adeyomo, 2007; Adegoke, 2012; Famuboni,

2004). The sample collection sites, shown in Figure 2, were selected based on outcrops that reflect the subsurface geology.

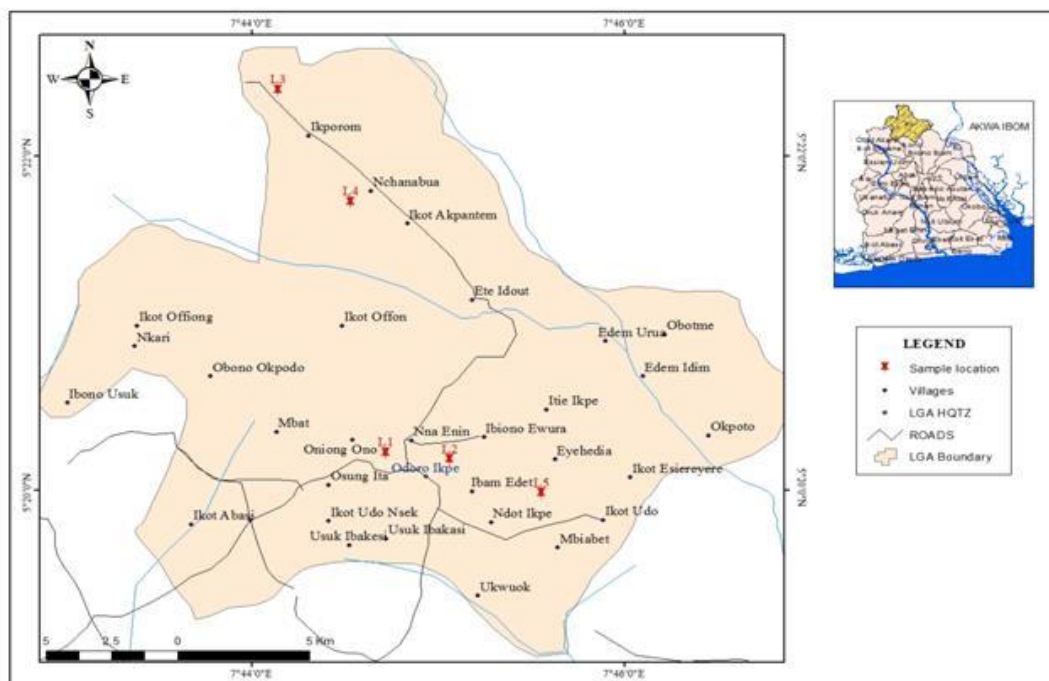


Figure 2: Map of the study area showing sample collection points

2.3 Materials Used

The following equipment were used for samples collection such as; Camera, Global positioning system (GPS), geologic hammer, clinometer, magnifier, sample bags, masking tape, colour maker, water proof, and 6ft tape. Zinc bromide or sodium polytungstate (SPT) as heavy liquids, Beakers or centrifuge tubes, Centrifuge (optional, but helpful for better separation), Stirring rod or magnetic stirrer, Fine mesh sieve (to remove large debris), Filter paper or nylon mesh, Microscope slides, Fine mesh sieve (10–20 μm mesh size), Sieving apparatus (manual or mechanical shaker), Ultrasonic bath (optional), Water or dispersing agent (e.g., weak solution of sodium hexametaphosphate), Beakers, Microscope slides and Filter paper.

2.4 Methods

2.4.1 Sample Collection Methods

Representative samples from three outcropped exposures from different locations were collected during the field exercise and labelled

Ikporom, Ananamong and Ibam Edet, as indicated in

Figure 2. The coordinates for the studied locations are; Ikporom with Coordinates N: $05^{\circ}30.091'$ E: $007^{\circ}41.310'$ and the Elevation is 110m. Ananamong with Coordinates N: $05^{\circ}27.831'$ E: $007^{\circ}44.363'$ and Elevation is 104m. Ibam Edet with Coordinates N: $05^{\circ}20.704'$ E: $007^{\circ}45.971'$ and Elevation 70m in Ini local Government Area of Akwa Ibom State, Southern Nigeria.

The sampling area was slightly weathered but adequate care was taken to trench and obtain unweather samples for use in the study. The retrieved samples were stored in a well labeled sample bags and taken to the Department of Geology, Akwa Ibom State University for chemical analysis.

The region experiences a tropical climate with two distinct seasons: a rainy season from April to October and a dry season from November to March. Annual rainfall can reach up to 2,000 mm, with temperatures ranging from 26°C to 28°C . The vegetation is primarily tropical

rainforest, with a mix of dry land and freshwater swamp forests.

This local government area is rich in natural resources, including limestone, clay, gravel, fine sand, crude oil, and iron ore. The region is also known for its agricultural produce, such as rice, palm products, cassava, cocoa, and bananas. Additionally, its forests provide valuable resources such as timber and firewood. The area is home to a diverse range of wildlife, including several species of mammals such as the roan antelope, red river hog, king genet, and African civet. The region's forests also support a variety of bird species and other wildlife. Representative samples from five outcropped exposures from different locations were collected during the field exercise and labelled Ikporom, Ananamong & Ibam Edet (Figure 2). The coordinates for the studied locations are Ikporom with coordinates N: 05°30.091' E: 007°41.310, and the elevation is 110 m. L. Ananamong, with coordinates N: 05°27.831' E: 007°44.363' and elevation 104 m, and Ibam Edet, with coordinates N: 05°20.704' E: 007°45.971' and elevation 70 m, are in the Ini local government area of Akwa Ibom State, Southern Nigeria. The sampling area was slightly weathered, but adequate care was taken to trench and obtain unweathered samples for use in the study. The retrieved samples were stored in well labelled sample bags and taken to the Department of Geology, Akwa Ibom State University, for laboratory analysis.

2.4.2 Sample Analysis Procedures

The methods employed for sample preparation in this research was the density separation and mechanical sieving methods. The method involve separation of palynomorphs (organic matter) from mineral components in a sediment sample based on their differing densities, according to method by Doherty (1980). The samples obtained were dried in the Oven at below 40° C before processing to avoid damaging the organic matter. The samples were

crushed with a mortar and pestle to gently break apart the sediment into finer particles, with carefulness not to grind to too fine, as this may damage fragile palynomorphs (Wood *et al.*, 1996). The crushed samples were sieved to the particle size range of between 150 - 250 µm according to the Method of Traverse (2007). Heavy liquid separation of palynomorphs was carried out with zinc bromide (ZnBr₂) and sodium polytungstate (SPT), diluted with water to a density of 2.0–2.2 g/cm³ according to the method reported elsewhere (Wood *et al.*, 1996).

Density measurement of the palynomorphs was by the use a hydrometer or a density meter ensuring that the liquid is at the correct density for separation, according to Method of Traverse (2007). The crushed sample was added to Heavy Liquid and lace a small amount of the sieved sediment (1–2 g) into a beaker or centrifuge tube. The suspension was stirred with magnetic stirrer to mix the sediment with the heavy, ensuring that all particles are suspended. The suspension was allowed to Settle and let the mixture sit for several minutes (5 – 10 minutes). After settling, the organic material (palynomorphs) float to the top of the heavy liquid, while denser mineral grains settled to the bottom. Recovery of organic fraction was achieved by decanting using a pipette to remove the upper fraction, which contains the lighter organic material. Organic fraction was transferred to a new container and rinse with distilled water several times to remove the heavy liquid. This was achieved by gently swirling the mixture and decanting the liquid through a filter paper or a fine nylon (10–20 µm) to collect the organic material, including palynomorphs and rinsing the residue on the filter with water to ensure that all heavy liquid has been removed. The final residue (containing palynomorphs) was transferred onto microscope slides for examination at 40 x using light transmitted Microscope (AMSCOPE). Microscope was used to identify and count the recovered palynomorphs.

2.4.3 Mechanical Sieving

The purpose of the mechanical sieving method was to physically separate palynomorphs from mineral grains based on size without the use of chemical reagents. This method ensured the preservation of delicate organic materials while effectively isolating them from larger sediment particles. The procedure involved a systematic approach, including sample preparation, disaggregation, sieving, and recovery of the organic fraction. Each step was carefully performed to prevent damage to the palynomorphs and maintain the integrity of the sediment sample for further analysis. The unit operations of mechanical sieving were done under the following sequence:

Initial Sample Preparation

To ensure optimal separation of palynomorphs, the sediment sample was first subjected to preliminary preparation. The sample was gently dried in an oven at a low temperature to prevent thermal degradation of organic matter. Once dried, the sediment was carefully crushed using a mortar and pestle. The crushing process was controlled to avoid excessive grinding, which could damage fragile palynomorphs.

Disaggregation of Sediment

To facilitate the separation of palynomorphs from mineral grains, the sediment was mixed with water or a weak dispersing agent such as sodium hexametaphosphate. This helped in breaking down aggregates and preventing particle adhesion. Mild agitation was applied to enhance the dispersion process. In cases where additional disaggregation was required, the sample was subjected to ultrasonication for a few minutes, ensuring the complete separation of palynomorphs from the mineral matrix.

Sieving the Sample

The disaggregated sample was sieved to isolate the palynomorph fraction based on particle size. A fine sieve (10–20 μm) was selected for this purpose. Wet sieving was conducted under a gentle stream of running water to prevent

damage to delicate palynomorphs. Larger mineral grains were washed away, while the finer organic material remained on the sieve. The sieving process was continued until only the organic residue was retained on the sieve surface.

Recovery of Organic Material

The organic material collected on the sieve was carefully transferred into a clean container using a small brush or spatula. To remove any remaining mineral impurities, the residue was further washed with distilled water. The washed organic fraction was then filtered using filter paper or a fine mesh to eliminate excess water and concentrate the palynomorphs. The final residue was allowed to dry naturally or at a low temperature, ensuring that the integrity of the organic material was preserved.

Slide Preparation

For microscopic analysis, the dried organic residue was mounted onto microscope slides. Depending on the analytical requirements, the material was embedded in a suitable mounting medium such as glycerin jelly or Canada balsam. If necessary, staining with dyes such as safranin was performed to enhance contrast and improve palynomorph visibility under the microscope.

Microscopic Examination

The prepared slides were examined under a microscope to identify, count, and analyze the recovered palynomorphs. The observations were recorded for further study, providing insights into the sediment's organic content and palynological composition.

Generally, the mechanical sieving method effectively isolates palynomorphs based on size without the use of strong acids, ensuring the preservation of delicate organic materials. While heavy liquid separation relies on density differences, mechanical sieving offers a chemical-free alternative for extracting palynomorphs from sediment samples. The choice of method depends on sediment characteristics and research objectives.

3.0 Results and Discussions

The examined section (Figure 3) reveals a grayish shale unit with a thickness of approximately 4 meters, characterized by a significant presence of dino indet (a diatom species). The considerable thickness of this shale unit suggests an extended period of shale deposition, indicating a stable and relatively low-energy depositional environment. Such conditions are typical of marine or marginal marine settings, where fine-grained sediments accumulate in calm waters with minimal disturbance. The palynomorph recovery for this location was notably high, supporting the interpretation of favorable conditions for organic preservation (Okosun *et al.*, 1995).

A total of five samples from this location were analyzed, yielding a substantial concentration of palynomorphs. The identified index fossils include *Proxapertites cursus*, *Proxapertites operculatus*, and *Mauritidites crassiexinous*. These species are significant biostratigraphic markers, and their occurrence within the studied sediments strongly suggests a Paleocene to Eocene age interval. This age determination aligns with previous studies on the Imo Shale, reinforcing its paleoenvironmental and chronological framework.

Further supporting this interpretation is the occurrence of dinocysts such as *Spiniferites*

hyalospinosus, *Selenopemphix nephroides*, and *Apectodinium parvum*. These dinoflagellate cysts are indicative of marine influence, reinforcing the interpretation of a predominantly marine depositional environment for the studied sediments. Additionally, the palynological analysis revealed that *Diatom sp.* (Table 1 and Figure 4) had the highest count of 2, further suggesting deposition in a marine setting (Nwajide & Reijers, 1996).

Diatoms are commonly associated with lacustrine, fluvial, deltaic, or estuarine environments, reflecting conditions where nutrient-rich waters promote their proliferation. The presence of diatoms within the Imo Shale suggests that while the primary depositional setting was marine, there may have been periodic influences from adjacent freshwater or brackish water sources. This interpretation aligns with previous findings by Stoermer *et al.* (1999) and Witkowski *et al.* (1993), who reported similar occurrences of diatoms in marginal marine and estuarine environments. The combined presence of dinocysts and diatoms supports a dynamic depositional setting with a marine influence, further refining the paleoenvironmental reconstruction of the Imo Shale Formation.

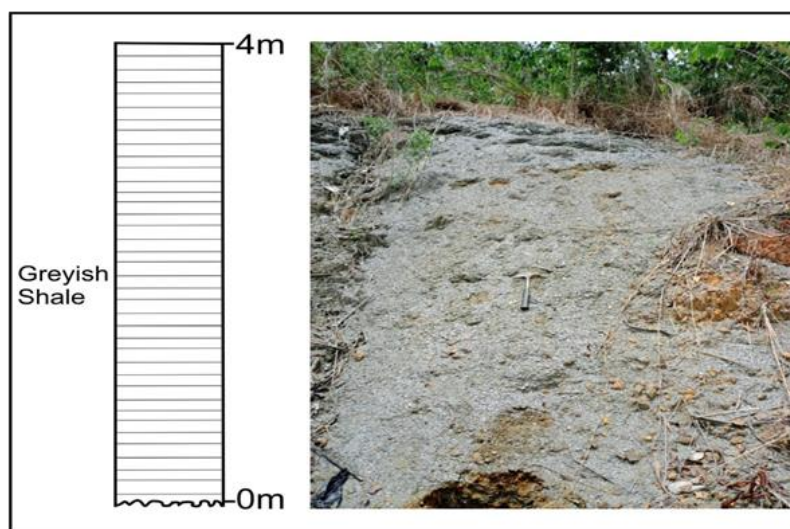
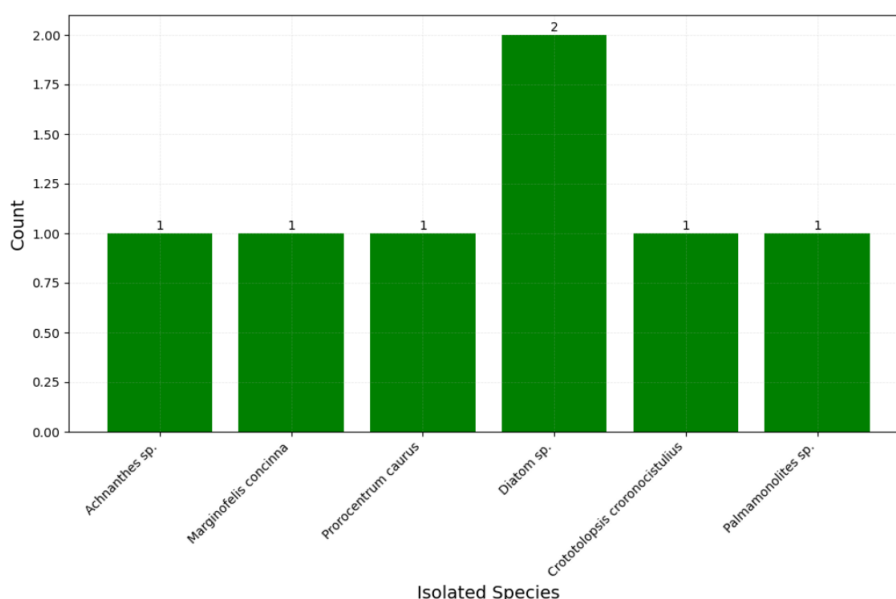


Figure 3: Lithological description of outcrops Sample at Ikorom

Table 1: Palynomorph Count at Ikorom

S/No.	TAXON NAME	COUNT
1.	Achritarch sp	1
2.	Marginipollis concinnus	1
3.	Protopertites cursus	1
4.	Diatom sp	2
5.	Crototricolpites crotonoisculptus	1
6.	Psilamonocolpites sp	1

**Figure 4:** Palynomorph Counts at Location 3, Ikorom

Palynological analysis of Sample 2 reveals significant variations in palynomorph distribution, providing insights into the paleoenvironmental conditions during the deposition of the Imo Shale. The palynomorph count chart indicates that *Mauritidites crassiexinous* had the highest count of 3, suggesting that these sediments were deposited in a marine paleoenvironment. However, *Mauritidites* is predominantly associated with land plants, typically found in humid and warm tropical to subtropical swampy or deltaic settings. This dual occurrence suggests a depositional environment influenced by both terrestrial and marine conditions, possibly a nearshore deltaic or estuarine system. These findings align with the studies of Germeraad et al. (1968) & Müller (1961), who documented *Mauritidites* as a key indicator of coastal to swampy depositional environments.

Additionally, the occurrence of *Achriostichum aureum* in Sample 2, with the highest count of 8, strongly supports a terrestrial paleoenvironment. *Achriostichum aureum* is commonly found in tropical rainforests, riverine settings, and lake-margin environments, where humid conditions promote its proliferation. The high abundance of this palynomorph suggests significant terrestrial input into the sedimentary system, possibly from adjacent floodplains or lowland swamp forests. This interpretation is consistent with the findings of Traverse (1991) and Tiwari *et al.* (1995), who identified *Achriostichum aureum* as a key indicator of fluvial or lacustrine paleoenvironmental conditions.

Furthermore, the presence of *Acritarch sp.*, with the highest count of 4, indicates deposition in a warm tropical to subtropical marine setting. Acritarchs are typically associated with marine environments and are known to signify high

primary productivity in ancient ecosystems. Their abundance suggests an open marine or shallow shelf environment, where nutrient-rich waters supported high levels of phytoplankton activity. These findings are supported by previous research conducted by Albani *et al.* (2011) and Servais *et al.* (2007), who emphasized the role of acritarchs as indicators of marine productivity and paleoclimatic conditions. The palynological data from Sample 2 suggest a complex depositional history influenced by both terrestrial and marine factors. The co-occurrence of *Mauritidites crassiexinous* and *Achriostichum aureum* points to a dynamic system with deltaic, swamp, and riverine influences, while the presence of *Acritarch sp.* supports periodic marine incursions. These findings provide strong evidence for a fluctuating paleoenvironment within the Imo Shale Formation, characterized by alternating terrestrial and shallow marine conditions. The palynological distribution in Figures 4 and 5 provides detailed data from Ikporom.

The lithology consists of a 4-meter-thick, greyish shale, with a total pollen count of 50, total spore count of 50, and total count of marine indicators also at 50. The presence of *dinocysts*, *Spiniferites hyalospinosus*, *Selenopemphix nephroides*, and *Apectodinium parvum* suggests that the age of the deposit ranges from the Paleocene to the Eocene. At Ananamong, the section consists of a 1.5-meter-thick, bluish-grey shale rich in palynomorphs, including *Mauritidites crassiexinous*, *Operculodinium sp.*, and *Selenopemphix nephroides*. Three samples were analyzed from this location, with palynomorph recovery ranging from fair to very good. The co-occurrence of *Proxapertites cursus*, *P. operculatus*, *Teracolpites reticulatus*, and *Mauritidites crassiexinous*, along with dinocysts such as *Spiniferites hyalospinosus*, *Selenopemphix nephroides*, and *Ifecysta pachyderma*, indicates that these sediments were deposited during the Paleocene to Eocene.

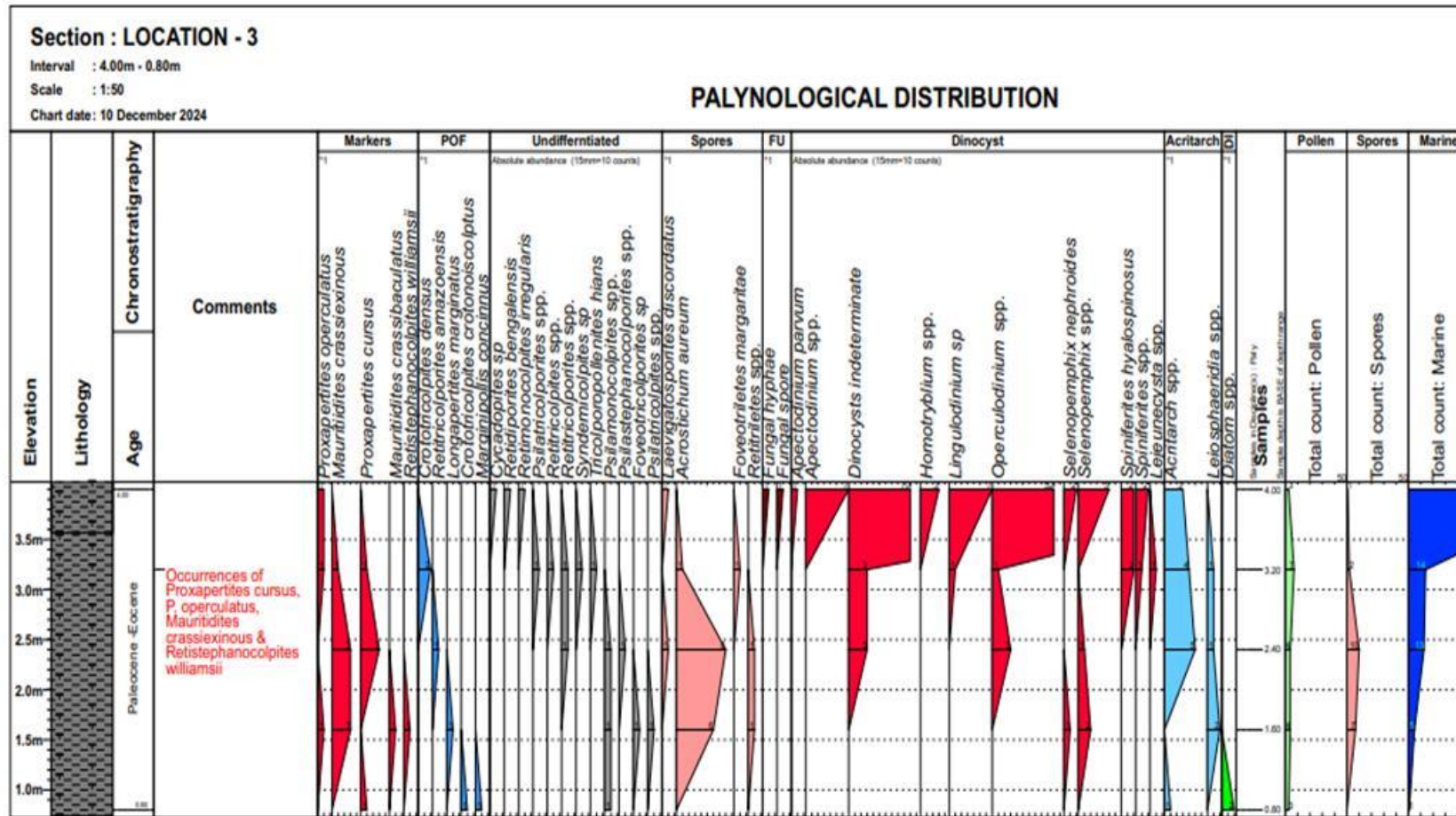


Figure 5: Summary of Chart in Location three, Ikporom

The presence of bluish grey shale in this location (Figure 6) suggests a relatively low-energy depositional environment. The bluish grey colour of the shale could be a varying degree of oxidation. The relatively thin thickness of the shale unit could be a shorter period of shale deposition or a marine depositional environment.

The summary of charts (Figures 7 and 8) and Table 2 gives detailed palynological distributions at Ananamong. *Proxapertites cursus*, *P operculatus*, *Teracolpites reticulatus*, *mauritidites crassiexinous*, with *dynocyst like Spiniferites hyalospinosus*, *Selenopemphix nephroides* and *Ifecysta*.

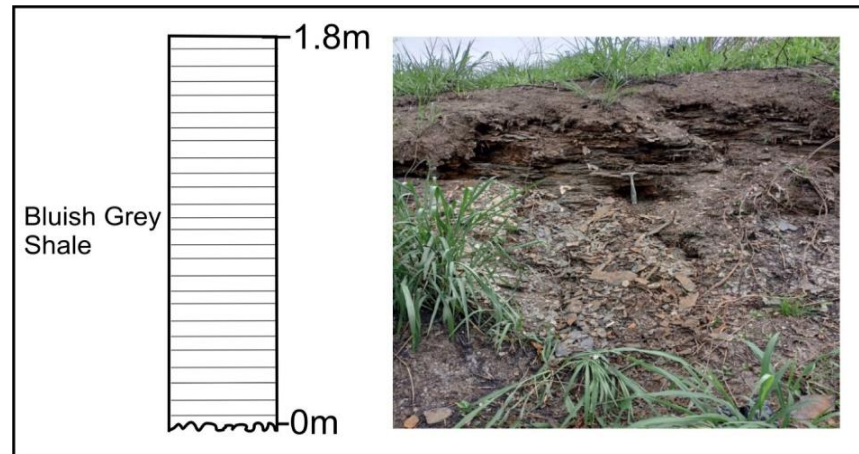


Figure 6: Lithological description of outcropped Sample at Location 4 (L4), Ananamong

Table 2: Palynomorph Count at Ananamong

S/No.	TAXON NAME	COUNT
1.	Proxapertites operculatus	5
2.	P. Cursus	5
3.	Selenopemphix nephroides	6
4.	Dino indet	9
5.	Ifecysta pachyderma	5
6.	Psilamonocolpites sp	7
7.	Operculodinium sp	9
8.	Homotryblium pallidum	7
9.	Apectodinium sp	3
10.	Selenopemphix sp	2
11.	Psilatricolporites sp	1
12.	Calamuspollenites pertusus	3
13.	Retitricolporites sp	2
14.	Teracolpites reticulatus	2
15.	Mauritidites crassiexinous	11
16.	Longapertites sp	2
17.	Achrostichum aureum	9
18.	Psilatricolporites crassus	1
19.	Adenantherites sp	2
20.	Gemmatricolpites sp	1
21.	Mauritidites crassibaculatus	2
22.	Hystiochokolpama sp	1
23.	Acritarch sp	1
24.	Laevigatosporite discordatus	5

25.	Tuberculodinium vancampae	1
26.	Homotryblum sp	5
27.	Foveotriletes margaritae	1
28.	Monocolpopollenites sphaeridites	2
29.	Adnatospheridium sp	6
30.	Longapertites marginatus	2
31.	Apectodinium parvum	3
32.	Echimonocolpites Sp	2
33.	Triporetetradites hoekeni	1
34.	Lycopodium sporites	2
35.	Retimonocolpites irregularis	2
36.	Syndemicolpites sp	1
37.	Spiniferites ambonoids	2
38.	Ephedrites ambonoids	2
39.	Cycadopites sp	1
40.	Spiniferites sp	1

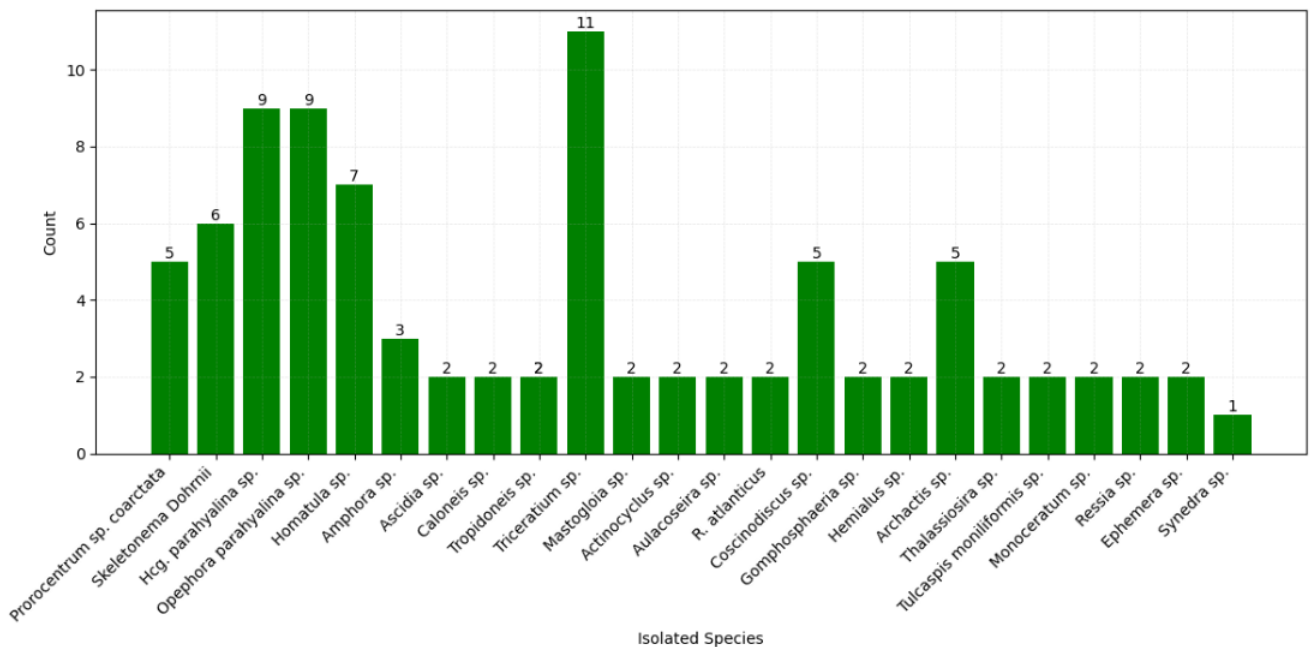


Figure 7: Palynomorph Counts at Location 4, Ananamong

The summary of chart (Fig. 8) gives a detailed palynological distribution at Ananamong. *Proxapertites cursus*, *P operculatus*, *Teracolpites reticulatus*, *mauritidites crassiexinous*, with *dynocyst* like *Spiniferites hyalospinosus*, *Selenopemphix nephroides* and

Ifecystapachydermaare mostly common in a marine environment with an influence from coastal or estuarine settings. This result corresponds with the findings of Jan du Chene (1978).

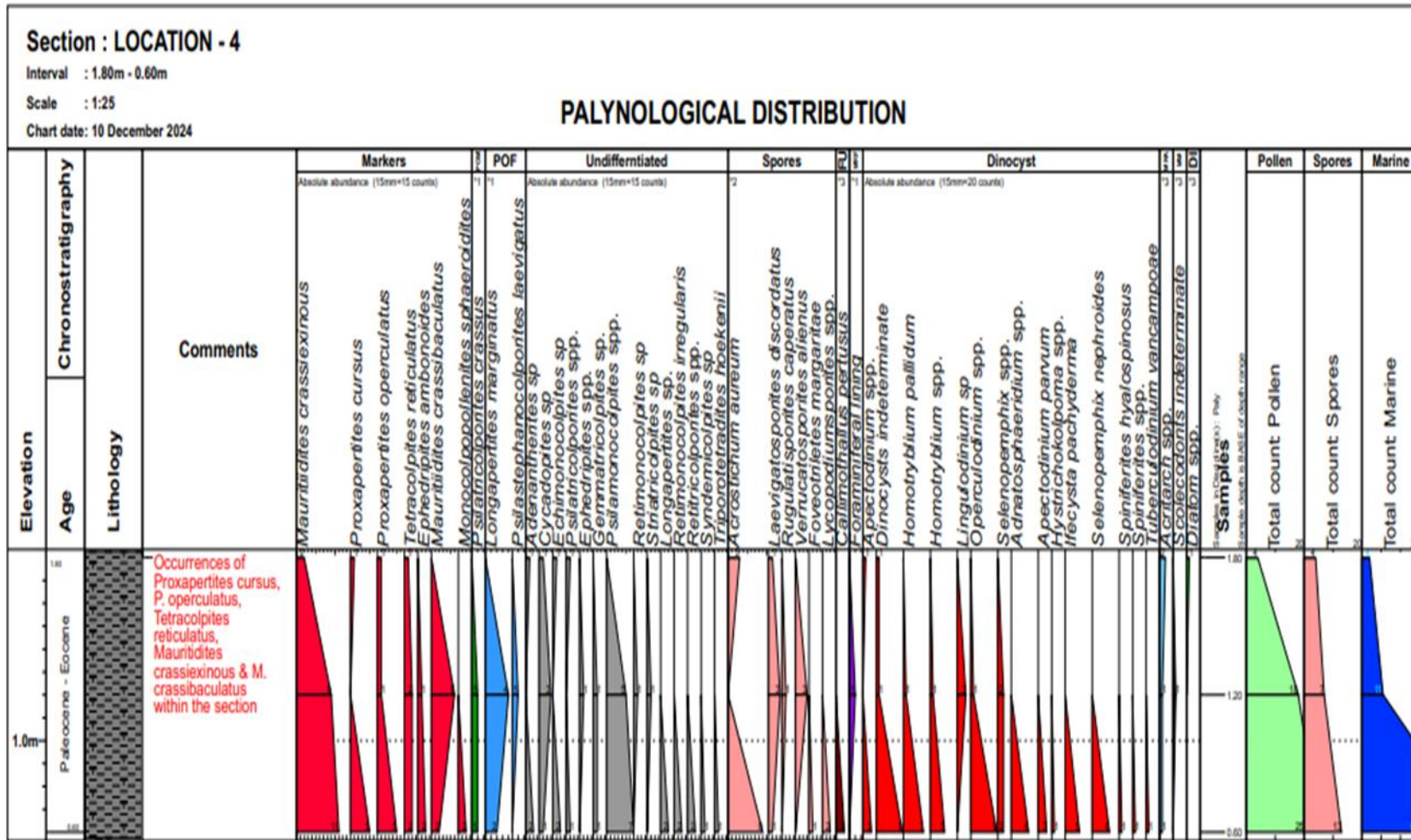


Figure 8: Summary of Chart at Ananamong

Figure 9, shows greenish grey shale rich in palynomorph like foraminiferal lining, and makers like spiniferites hyalospinosus, and polysphaeridium specie, with thickness of about 4.2m. The thickness of shale unit, suggesting a prolonged period of shale deposition in a low-energy, possibly marine environment where fin-

grained sediments could accumulate. Palynomorph recovery for this location was good to very good. The palynomorph counts in Table 3 and Figure 10 gives detailed distribution of location 4, as shown in Figure 11 at Ibam Edet.

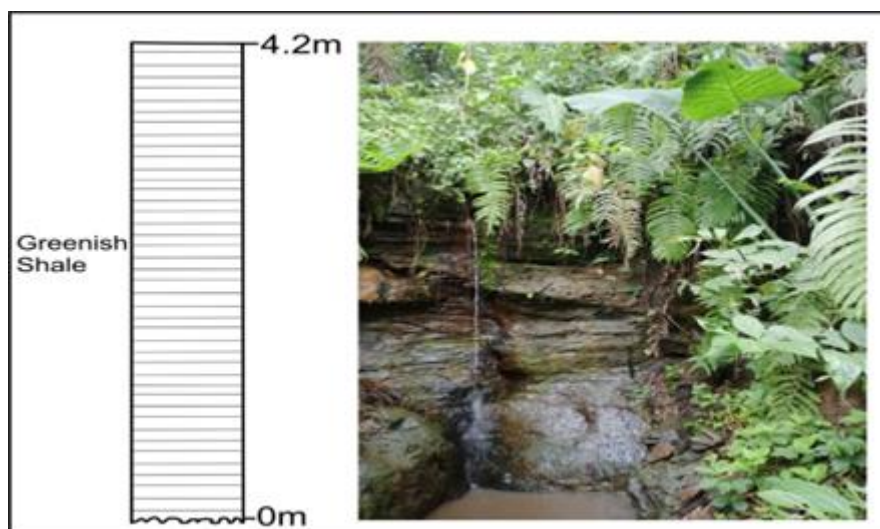


Figure 9: Lithological description of Sample at Ibam Edet

Location three Ibam Edet : Five samples were analysed for this location. Palynomorph yielded was very good. The Palynomorph content was dominated by organic wall microplanktons and other marine indicators. Species like *Mauritidites crassiexinous*, *Proxapertites operculatus*, *P. cursus* and *M. Crassibaculatus* indicates that the sediments were deposited during the Paleocene to Eocene times. Dynoflagellate cyst like *Selenopemphix nephroides*, *Apectodinium parvum*, *Spiniferites hyalospinosus*, *Lejeunacysta fallax*, gives a credence age interpretation.

Table 3: showing palynomorph count, Ibam Edet

S/NO	TAXON NAME	COUNT
1.	Foraminiferal lining	198
2.	Acritarch sp	5
3.	Cycadopites sp	1
4.	Mauritidites crassiexinous	1
5.	Psilamonocolpites sp	1
6.	Dino indet	8
7.	Spiniferites hyalospinosus	22
8.	Pterospermella sp	4
9.	Spiniferites sp	2
10.	Lingolodinium sp	1
11.	Proxapertites operculatus	1
12.	Leiosphaeridia sp	3
13.	Acrostichum aureum	1
14.	Cycadopites sp	1
14.	Longapertites sp	1
15.	Longapertites sp	1

16.	<i>Selenopemphix nephroides</i>	1
17.	<i>Spiniferites ramosus</i>	1
18.	<i>Operculodinium</i> sp	1
19.	<i>Lejeunacysta</i> sp	

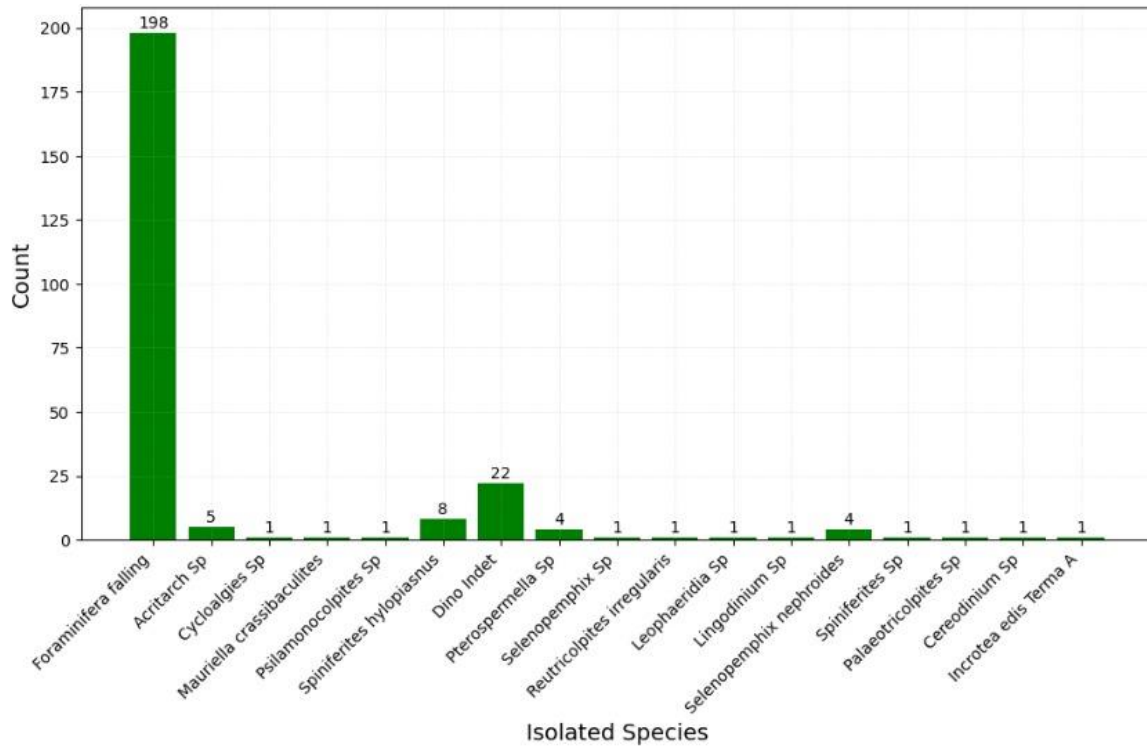


Figure 10: Palynomorph Counts, Ibam Edet

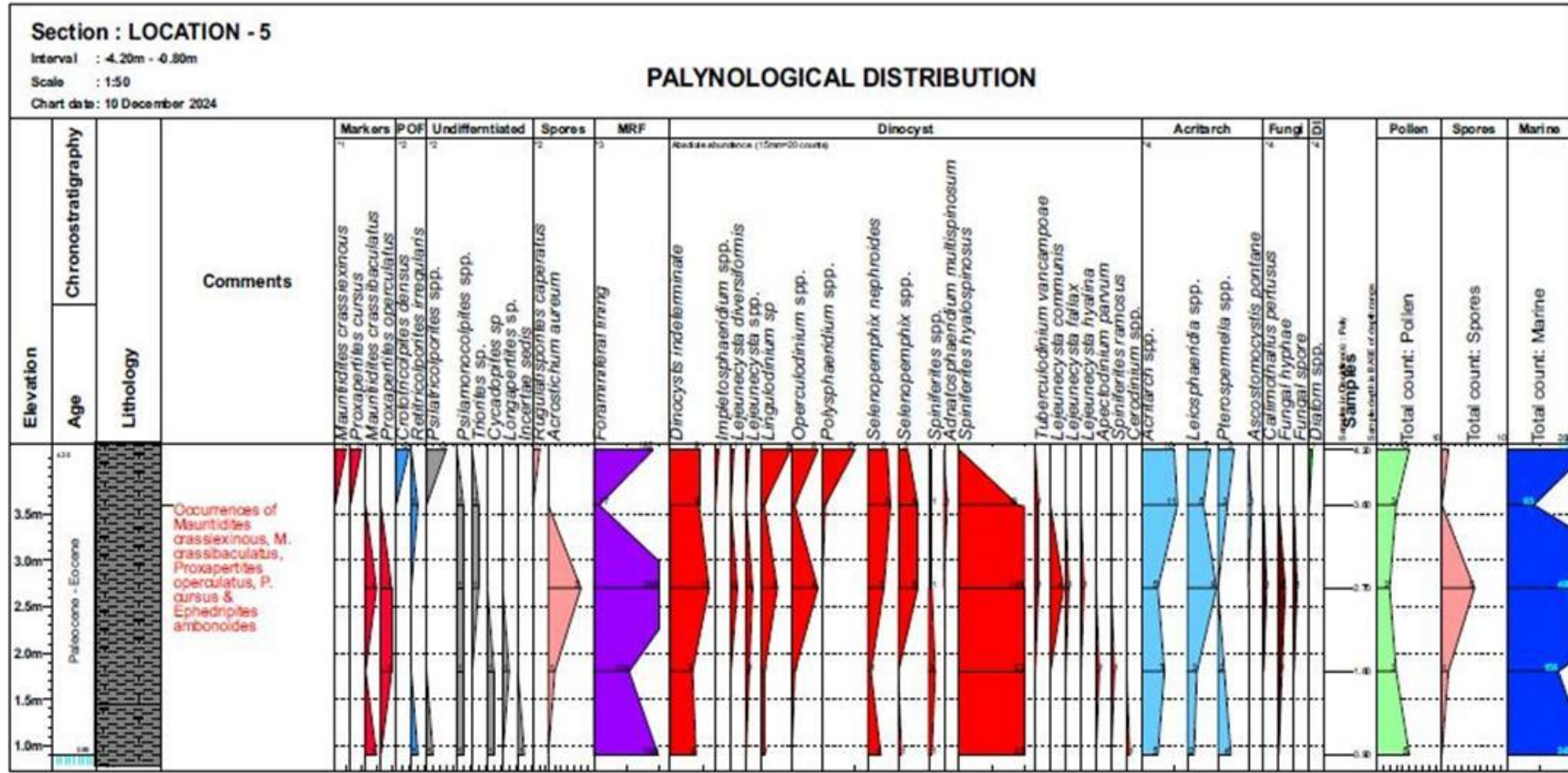


Figure 11: Summary of Chart at Ibam Edet

The diagram in Figure 12 shows the palynomorphs identified in the Study Area. The presence of these palynomorphs indicates a depositional setting influenced by coastal to shallow marine conditions, consistent with the known paleoenvironmental characteristics of the Imo Shale Formation. These dinoflagellate cysts are indicative of marine influence, reinforcing the interpretation of a predominantly marine depositional environment for the study sediments (Batten, 1996).

The palynomorph assemblage (Fig.12) recovered from the sample locations at Ikporom, (L1) Ananamong, (L2) and Ibam Edet, (L3) yielded good to very good palynomorphs, it consists of dominant pollen grains such as *Lejeunecysta communis*, *Mauritidites crassiexinous*, *Proxapertites operculatus*, *Retistephanocolpites williamsi*, *Proxapertites cursus*, and *Marginipollis concinnus*, from tropical plant species, along with marine indicators such as *Lejeunecysta fallax*, *Foraminiferal lining*, *Adnatosphaeridium multispinosum* commonly known as dinoflagellate cysts and rare spores (Tyson,1995).

The palynomorph assemblage suggests a deltaic or estuarine paleoenvironment, characterized by a mix of coastal, nearshore, and terrestrial vegetation.

The presence of mangrove and salt marsh pollen, such as *Mauritidites crassiexinous* and *Proxapertites operculatus*, indicates a brackish to saline water environment (Stach,1982; Jansonius & McGregor,1996). The abundance of terrestrial pollen, including *Marginipollis concinnus* and *Retistepha-nocolpites williamsi*, suggests a nearby landmass or riverine input.

The deltaic or estuarine environment likely had a complex network of distributaries, marshes, and mudflats, providing a habitat for a diverse range of plant species. The presence of *foraminiferal linings* and dinoflagellate cysts, such as *Lejeunecysta fallax* and *Adnatosphaeridium multispinosum*, further supports a marine influence and suggests a connection to the open ocean. This paleoenvironmental reconstruction is consistent with previous studies of the Imo Formation (Singh,1971) which have suggested a depositional environment characterized by fluvial to marine influences. The integration of palynological and sedimentological data provides a more detailed understanding of the paleoenvironmental evolution of the Imo Formation and has implications for hydrocarbon exploration and geological history in Southeastern Nigeria.

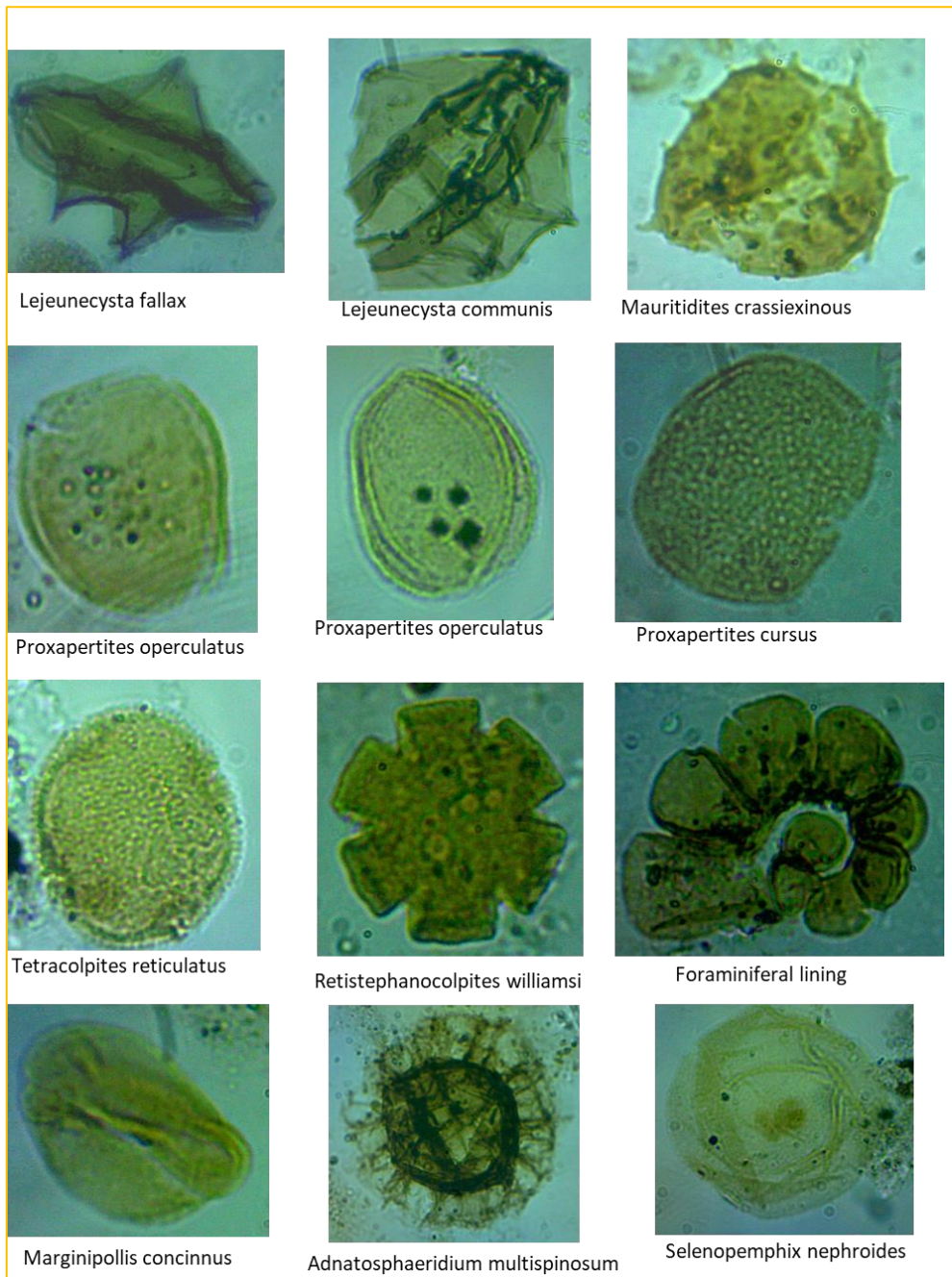


Figure 12: Palynomorphs recovery from the Study Area

4.0 Conclusion

The paleoenvironmental analysis of Imo Shale outcrops in Ini was successfully conducted through paleoenvironmental reconstruction, comparative analysis, and integration with specific geological data, with implications for hydrocarbon exploration. A total of 1,854 palynomorphs from 65 genera were recovered, including five (5) spores, twenty-five (25) pollen species, and twenty-four (24) marine indicators. Age interpretations were determined based on index species identified in the samples.

The palynomorph assemblage was dominated by marine indicators, suggesting a depositional environment ranging from lower shoreface to offshore. The inferred age of the sediments spans from the Paleocene to Eocene, with depositional settings fluctuating between upper and lower shoreface. The presence and variety of miospores suggest a predominantly tropical to subtropical paleoenvironment during deposition. The diversity of pollen and spores indicates a combination of coastal, nearshore,

and terrestrial vegetative ecosystems, pointing to a deltaic or estuarine setting with intermittent marine influence.

This study significantly enhances our understanding of the geological history, paleoenvironmental conditions, and sedimentary basin evolution of the region. The findings have critical implications for natural resource exploration, environmental monitoring, and broader geological research. Further palynological analysis is recommended to enhance interpretations of paleoenvironmental and paleoclimatic conditions in the region by focusing on miospore species diversity and their ecological ranges. Additionally, integrating palynological data with geochemical and isotopic analyses could provide deeper insights into past environmental fluctuations, including variations in temperature and salinity, which are crucial for understanding the depositional history of the Imo Shale.

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Conflict of Interest

The authors express no conflict of interest.

References

- Adeleye, M. A., et al. (2015). Sedimentology and paleoenvironmental reconstruction of the Imo Shale, southern Nigeria. *Journal of African Earth Sciences*, 101, 143-155.
- Adegoke, O. S. (2012). Palynological analysis of the Cretaceous sequence in the Benue Trough, Nigeria. *Journal of African Earth Sciences*, 66, 34-43.
- Adeyemo, A. (2007). Palynological studies of the Dahomey Basin, southwestern Nigeria. *Journal of African Earth Sciences*, 47(4), 137-146.
- Adeyemo, A. (2007). Palynostratigraphy and paleoenvironment of the Dahomey Basin, southwestern Nigeria. *Nigerian Journal of Mining and Geology*, 43(1), 1-12.
- Albani, A. E., Bergamasco, A., and Tosti, L. (2011). Palynology and stratigraphy of the Triassic-Jurassic boundary in the Carnia region (NE Italy). *Rivista Italiana di Paleontologia e Stratigrafia*, 117(1), 47-75.
- Batten, D. J. (1996). Palynofacies and palaeoenvironmental interpretation. In J. Jansonius & D. C. McGregor (Eds.), *Palynology: Principles and Applications* (Vol. 3, pp. 1011- 1024). American Association of Stratigraphic Palynologists Foundation.
- Doher, L. I. (1980). Palynology of the Cretaceous and Tertiary sediments in the southeastern Nigeria. *Journal of Mining and Geology*, 17(1), 33-45.
- Edet, A. E., & Okereke, C. S. (1997). Palynological evidence of paleoclimate fluctuations in the Calabar Flank, southeastern Nigeria. *Review of Palaeobotany and Palynology*, 96(3-4), 329-344.
- Ehinola, O. A., Ikhane, P. R., & Lambi, G. J. (2012). Organic geochemistry and hydrocarbon potential of Imo Shale, southeastern Nigeria. *International Journal of Geosciences*, 3(4), 872-879.
- Nwajide, C. S. (2013). *Geology of Nigeria's Sedimentary Basins*. CSS Bookshops Ltd.
- Etesin, U. M., Ite, A. E, Harry, T. A., Bassey, C. E. & Nsi, E. W. (2015). Assessment of Cadmium and Lead Distribution in the Outcrop Rocks of Abakaliki Antic-

- linorium in the Southern Benue Trough, Nigeria. *Journal of Environment Pollution and Human Health*, vol. 3, no. 3: 62-69. doi: 10.12691/jephh-3-3-2.
- Gemeraad, J. H., Van den Borg, K. & de Jong, A. F. M. (1968) Paleoenvironmental reconstruction of a tropical coastal plain during the Late Quaternary. *Quaternary Science Reviews*, 14 (7), pp 789-803
- Jan du Chene, R. J., Adediran, S.A., Petters, S. W. and Pospichal, J. J. (1978). Paleoenvironmental interpretation of dinoflagellates cysts and miospores from the Upper Cretaceous and Tertiary of the Niger Delta. Pp. 333-348.
- Jansonius, J., & McGregor, D. C. (1996). *Palynology: Principles and Applications*. American Association of Stratigraphic Palynologists Foundation.
- Kogbe, C. A. (1989). Paleoenvironmental reconstruction from the Late Quaternary pollen record of a Nigerian lake. *Review of Palaeobotany and Palynology*, 59(1-2), 107-123.
- Muller, J. (1961) A palynological study of the peat deposit of Sarawak. *Journal of the Linnean Society of London, Botany*, 56 (369), 365-384.
- Muller, J. (1961). Palynological study of the Tertiary sediments of the Timor Sea area. *Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen, Series B*, 64(3), 263-287.
- Nwajide, C. S. (2013). *Geology of Nigeria's Sedimentary Basins*. CSS Bookshops Limited.
- Nwajide, C. S. and Reijers, T. J. A. (1995). Sequence stratigraphy of the Niger Delta Basin. In: Ofoegbu, C. O. (Ed.), *Structural and Petroleum Geology of the Niger Delta*. *Journal of Petroleum Geology*, 18(2), 155-182.
- Nwajide, C. S., & Reijers, T. J. A. (1996). *Geology of the southern Anambra Basin*. SPDC Petrographic Services, E
- Okosun, E. A. (1995). Sedimentology and biostratigraphy of the Imo Shale, southeastern Nigeria. *Journal of Mining and Geology*, 31(1), 33-45.
- Petters, S. W., Fasola, M. A., & Okpoko, E. I. (2011). Late Quaternary palynological record from the Niger Delta. *Review of Palaeobotany and Palynology*, 165(1-2), 1-17.
- Ruddiman, W. F., Guo, Z., Zhou, X., & Wu, H. (2001). "Abrupt termination of the African Humid Period about 5,000 years ago". *Quaternary Science Reviews*, 20(1-3), 209-215.
- Stach, E. (1982). The use of palynology in petroleum exploration. In F. M. Gradstein (Ed.), *A Practical Guide to Microfossil Identification* (pp. 149-162). Ellis Horwood.
- Servais, T., Perri, M. C., and Dufka, P. (2007). Acritarchs and other non-dinoflagellate marine palynomorphs from the Ordovician and Silurian of the Czech Republic. *Bulletin of Geosciences*, 82(1), 25-40.
- Short, K. C., & Stauble, A. J. (1967). Outline of the geology of the Niger Delta. *American Association of Petroleum Geologists Bulletin*, 51(5), 761-779.
- Singh, C. (1971). Lower Cretaceous microfloras of the Peace River area, northwestern Alberta. *Research Council of Alberta, Bulletin* 28.
- Stoermer, E. F., Kreis, R. G., and Andresen, N. A. (1999). Checklist of Diatoms from the

- Laurentian Great Lakes. II. *Journal of Great Lakes Research*, 25(3), 515-566.:
- Tiwari, R. S., Rana, R. S., and Singh, V. K. (1995). Palynostratigraphy and paleoenvironment of the Mesozoic sediments of the Jharia Basin, Bihar. *Journal of the Geological Society of India*, 45(2), 147-164.
- Traverse, A. (1981). Pollen and Spores of the floras of the Anthophyta. In R. W. Fairbridge and D. Janbonski (Eds.), *Encyclopedia of the Geological Sciences* (pp. 849-855).
- Dowden, H. & Ross Traverse, A. (2007). *Paleopalynology*. Springer, 813 pp.
- Tyson, R. V. (1995). *Sedimentary organic matter: Organic facies and palynofacies*. Chapman & Hall.
- Witkowski, A., Lange-Bertalot, H., and Metzeltin, D. (1993). Diatomophyceae 2, Teil. In: Ettl, H., Gerloff, J., Heynig, H., and Mollenhauer, D. (Eds.), *Süßwasserflora von Mitteleuropa, Band 2/2*. Gustav Fischer Verlag, Stuttgart, Jena, New York, 438 pp.
- Wood, A. M., Gabriel, A. M., & Lawson, T. (1996). Palynological evidence for Late Cretaceous and Early Tertiary environments in the Bida Basin, Nigeria. *Review of Palaeobotany and Palynology*, 93(1), 1-25.