



(RESEARCH ARTICLE)



Palynofloral and dinoflagellate cysts changes in Afikpo syncline during the cretaceous period

Celestine Nwite Nwojiji *

Department of Geology, Faculty of Science, Ebonyi State University, Abakaliki, Nigeria.

International Journal of Science and Research Archive, 2025, 16(02), 401-415

Publication history: Received on 29 June 2025; revised on 06 August 2025; accepted on 08 August 2025

Article DOI: <https://doi.org/10.30574/ijrsra.2025.16.2.2333>

Abstract

This study presents a comprehensive palynological and kerogen analysis of the shale samples from the Afikpo Syncline, southeastern Nigeria. The main aim of this study is to determine the age, paleoenvironmental conditions, and hydrocarbon potential of the major outcrop exposure in the study area. The conventional palynological preparation technique was used to extract the palynomorphs and a diverse assemblage of terrestrial spores, pollen, and marine dinoflagellate cysts were recovered and quantitatively assessed. The palynomorph assemblages were dominated by terrestrial spores and pollen alongside marine dinocysts. The palynological association indicates mangrove affinities and a depositional environment oscillating between marginal marine proximal estuaries and shallow open marine shelf settings under predominantly brackish to normal marine salinities. Biostratigraphic correlation based on key miospore and dinoflagellate marker species, such as *Longapertites vaneedenburgi*, *Psilatricolporites operculatus*, *Proxapertites operculatus*, *Retidiporites magdalenensis*, *Spiniferites pseudofurcatus*, *Diphyescolligerum*, *Andalusiella polymorpha*, *Spinizonocolpites baculatus*, *Proteacidites miniporatus*, *Mauritidiites crassibaculatus*, *Proxapertites cursus*, *Echitriporites trianguliformis*, *Longapertites marginatus*, and *Dinogymnium acuminatum*, were used to constrain the sediments to the Campanian-Maastrichtian age, consistent with other Campanian-Maastrichtian sequences across tropical Africa and coeval basins globally. Quantitative kerogen result reveals a predominance of terrestrial-derived organic matter phytoclasts and opaques up to 80% with subordinate amorphous organic matter and palynomorphs, indicating a kerogen assemblage dominated by Type III and IV kerogens, typical of gas-prone source rocks but with potential for mixed oil generation in oxic to suboxic depositional settings. Thermal maturation inferred from spore coloration suggests early to mid-maturity stages, highlighting viable hydrocarbon generation potential. The integration of palynofacies data with paleoecological indicators provides basis for depositional environment reconstructions and contributing valuable insights into the palynofloral evolution of the Afikpo Syncline and its petroleum system implications.

Keywords: Afikpo Syncline; Palynomorphs, Kerogen; Cretaceous; Depositional environment; Hydrocarbon

1. Introduction

The Afikpo Syncline is a geologic depocentre located the southeastern part of Nigeria. It is stratigraphically and structurally significant component of the southern Benue Trough representing the post deformational basin formed after the Santonian tectonic inversion of the Abakaliki Anticlinorium [1]. The formation of this important structural feature is critical to the understanding of the tectonostratigraphic framework and depositional framework of the Benue Trough as it hold crucial information on past climatic, depositional, and biological changes [2, 3]. The stratigraphy of Afikpo Synclinorium consists of Cretaceous sedimentary units ranging from Ezeaku Group to Nsukka Formation [4]. The stratigraphy of Afikpo syncline consist of pre-Santonian sediments of Eze-Aku Groups (Turonian) and post Santonian Sediments comprising of Nkporo, Mamu, Ajali and Nsukka Formations deposited from Campanian – Paleocene [see 1] for more details on the stratigraphy of Southern Benue Trough.

*Corresponding author: Celestine Nwite Nwojiji

The palynological and palynofacies indicators preserved in sediments provide valuable proxies for reconstructing paleoenvironmental conditions and regional biostratigraphy. These indicators represented by spores, pollen grains, and dinoflagellate cysts provide insights into terrestrial-marine changes, sea-level fluctuations, and the paleoclimate of the period when the sediments were deposited.

The aim of this study is to examine the composition, distribution, and variation of palynomorphs and dinoflagellates in shale samples from the Afikpo Syncline. Palynological analysis, supported by kerogen and palynofacies evaluation, were used in delineating age zones, assessing depositional environments, and evaluating the hydrocarbon potential of the studied formations [5, 6]. Marine microfossils such as *Dinogymnium accuminatum*, *Spiniferites pseudofurcatus*, *Andalusiella polymorpha* and *Achomosphaera ramulifera*, along with terrestrial markers like *Longapertites vaneedenburgi*, *Psilatricolporites operculatus*, *Retidiporites magdalenensis*, *Spinizonocolpites baculatus*, *Proteacidites miniporatus*, *Mauritidiites crassibaculatus*, *Proxapertites cursus*, *Echitriporites trianguliformis* and *Longapertites marginatus* (Figures 1 & 2; table 1) form the key basis for stratigraphic dating and paleoenvironmental interpretation [7, 8].

The integration of palynofloral data with kerogen analysis provides a comprehensive understanding of the organic content and thermal maturity of the sediments. This is particularly useful in distinguishing between gas-prone and oil-prone source rocks, and in interpreting the paleosalinity and proximity of the depositional setting to marine or continental influence [9, 10]. The quantitative analysis of palynomorph groups spores, pollen, and marine dinocysts and the use of diagnostic markers provided the basis for the reconstruction of depositional environments interpreted to range from proximal estuarine to shallow open shelf conditions, with predominant brackish water.

The study not only contributes to the biochronology of the Afikpo Syncline but also provided regional correlations across the Anambra Basin and the broader West African Cretaceous strata. Through detailed palynological and organic geochemical investigations, this work will improve the resolution of Cretaceous paleoenvironmental models and support future petroleum exploration in the region.

2. Methodology

The sample preparation was done using standard and conventional method of acid demineralization and maceration technique for recovering acid-insoluble organic-walled microfossils from sediments. Each shale sample was carefully cleaned to remove field contaminants. 10 g of each sample was weighted out in a standard weighing balance and gently crushed with agate mortar and piston. The hydrochloric acid treatment was not applied since all the samples were non-calcareous. Each crushed sample was digested for 72 hours in 48% conc. hydrofluoric acid for removal of silicates. Distilled water was added for dilution of the digested samples and sieve-washed through 10 microns nylon mesh. The sieve-washed 10 g residues equivalent was partitioned into two parts, 5 g each, for oxidation and the other for kerogen study. The 5g residue extract was oxidized for 30 minutes in 70% HNO₃ and 5 minutes in Schulze solution to render the fossils translucent for transmitted light microscopy. The acid-free oxidized residues were rinsed in 2% KOH solution, to neutralize the remaining traces of acid; swirled to remove the resistant coarse mineral particles and undigested humic organic matter. The swirled residues were collected on the sieve and stained with Safranin, to increase depth of contrast for microscopic study and photography. Aliquot were dispersed with polyvinyl alcohol, dried on cover-slips and mounted in petro-poxy resin [11]. One slide was produced from each sample, in which microfossils were scanned, counted and recorded. Light photomicrographs were taken with a LABOMED binocular microscope.

In Kerogen analysis, unoxidized slides were prepared from 15 examined shale samples using the conventional method of acid demineralization. Each slide was examined using the transmitted light microscopy at X10 and X40 magnifications, with the aim to make a qualitative as well as a quantitative analysis of Particulate Organic Matter (POM), determine the palynofacies association and kerogen types, examine the spore /pollen colouration, estimate the Thermal Alteration Index (TAI), Vitrinite Reflectance (Ro %), as well as the degree of organic thermal maturation, (see table 2) (Fig. 3). Each slide was counted for its (POM) contents, in which the first 200 particles were counted in terms of abundant (>35 %), frequent (16-35 %), common (5-15 %) and rare (<5 %) [10-. 12- 5].

The kerogen assemblages were categorized into four main groups similar to those identified by [10] (see table 1). These include:

- Phytoclasts, refer to all structured yellow to brown colour dispersed clay- to fine sand sized particles of plant derived kerogen other than palynomorphs.
- Opaques, refer to all structured brownish black to black colour oxidized or carbonized particles of plant derived kerogen.

- Palynomorphs refer to all structured HCl and HF resistant organic-walled microfossils.
- Amorphous Organic Matter (AOM) refers to all structure less dispersed clay-to fines sand sized particles of plant derived kerogen.

The simple classification mentioned in [6, 10] for rapid evaluation of hydrocarbon potentialities were used as follows:

- Kerogen type I (highly oil-prone material): It includes alginitic material derived from chlorococcale algae, prasinophyte algae, cyanobacteria and some of the bacteria. Resins are the only significant terrestrially derived components belonging to this group.
- Kerogen type II (oil-prone material): It includes amorphous organic matter, but sporopollenin palynomorphs, cuticle and non-cellular membranous debris are also included.
- Kerogen type III (gas-prone material): Orange or brown, translucent, phytoclasts or structureless materials. Woody fragments are typical.
- Kerogen type IV (inert material): Opaque to semi-opaque, black, or very dark brown particles, representing oxidized or carbonized phytoclasts.

3. Results

3.1. Palynomorphs occurrence in the surface outcrops across Afikpo syncline

The analysis of 15 outcrop shale samples shows good occurrence and distribution of palynomorph species present in Afikpo syncline (Table 1). The shale samples generally recorded moderately rich palynomorph assemblage. Terrestrial species such as fern spores were the most abundant in almost all the examined samples, while pollen species of mangrove affinity were more diverse. Marine species such as dinoflagellate cysts also yielded moderately rich counts. Among the dinoflagellates, the Peridinioid species of near-shore brackish water predominate over the gonyalacean, with chorate cyst affinity of open marine condition.

Table 1 Occurrence and distributions of palynomorphs species counts across the studied samples (1 – 15)

Sample No.	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
Palynomorphs species															
Terrestrial Species															
Spores															
<i>Laevigatosporites ovatus</i>	39	27	3	5	8	12	18	8	10	13	10	15	19	11	9
<i>Polypodeasioeporites reticulatus</i>	1	-	-	-	-	-	-	-	-	-	-	2	1	2	-
<i>Verrucatosporites usmensis</i>	3	1	-	-	-	-	-	2	1	2	3	-	-	-	-
<i>Leiotriletes minor</i>	-	1	-	1	-	1	2	-	-	3	2	-	-	-	1
Pollen															
<i>Longapertites vaneedenburgi</i>	1	-	1	-	-	-	1	-	-	-	-	-	-	-	-
<i>Psilatricolporites operculatus</i>	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Proxapertites operculatus</i>	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
<i>Retidiporites magdalenensis</i>	-	1	-	2	-	-	-	-	-	-	-	2	1	1	-
<i>Spinizonocolpites baculatus</i>	16	9	3	3	6	4	5	-	-	-	-	-	-	-	2
<i>Proteacidites miniporatus</i>	-	-	-	-	-	1	3	2	1	-	-	-	-	-	-
<i>Longapertites marginatus</i>	9	11	4	2	4	6	7	3	2	6	5	4	3	1	4
<i>Monoporites annulatus</i>	-	-	-	-	-	1	1	-	-	-	-	1	1	2	-

<i>Grimsdalea polygonalis</i>	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Mauritidiites crassibaculatus</i>	4	2	2	-	9	7	4	2	1	-	-	-	-	-	-
<i>Proxapertites cursus</i>	-	-	-	-	1	1	-	-	-	2	2	-	2	1	-
<i>Echitriporites trianguliformis</i>	9	5	-	1	1	3	4	-	-	-	-	-	-	-	-
<i>Striatopolis striatulus</i>	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
<i>Tricolpites hians</i>	-	-	-	-	-	-	-	1	2	-	-	-	-	-	-
<i>Monocolpites marginatus</i>	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
MARINE SPECIES															
Dinoflagellates cyst															
<i>Fibrocystaaxialis</i>	1	2	1	3	2	1	2	-	-	-	-	6	11	5	-
<i>Cometodinium whitei</i>	2	3	3	1	1	3	2	-	-	-	-	3	1	2	2
<i>Andalusiella manthei</i>	-	1	3	3	5	4	5	-	-	-	1	-	-	-	-
<i>Dinogymnium accuminatum</i>	1	2	3	2	1	3	2	1	1	3	2	1	3	2	1
<i>Paleocystodinium australinum</i>	-	-	-	1	1	1	-	-	-	-	-	-	-	-	-
<i>Ceratiopsis deibeli</i>	-	-	1	-	1	2	-	-	-	2	1	-	-	-	-
<i>Senegalinium striatulus</i>	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-
<i>Achomosphaera ramulifera</i>	-	-	8	6	-	-	-	-	-	2	1	-	-	-	-
<i>Oligosphaeridium complex</i>	-	-	5	3	-	-	-	-	-	-	-	3	1	-	-
<i>Spiniferites ramosus</i>	-	-	3	4	-	-	-	-	-	-	-	-	-	-	-
<i>Spiniferites pseudofurcatus</i>	-	-	11	7	-	-	-	-	-	-	-	-	-	-	-
<i>Diphyescolligerum</i>	-	-	-	-	-	-	-	-	-	2	1	2	1	-	-
<i>Andalusiella polymorpha</i>	-	-	2	-	-	3	1	-	-	-	1	-	-	-	-
Total	88	67	54	44	40	53	58	19	20	35	30	39	44	27	19

3.2. Palynomorphs percentage

Sample No (S1)-Chinese Quarry Akpoha

Terrestrial species: Spores = 49 %

Pollen = 47 %

Marine species: Dinocysts= 4 %

Age: Late Campanian- Maastrichtian

Paleoenvironment: (Proximal Estuary)

Paleo-salinity: Brackish water

Sample No (S2)- Chinese Quarry Akpoha

Terrestrial species: Spores = 43 %

Pollen = 45 %

Marine species: Dinocysts = 12 %

Age: Late Campanian- Maastrichtian

Paleoenvironment: (Proximal Estuary)

Paleo-salinity: Brackish water

Sample No (S3)-Ogbu

Terrestrial species: Spores = 5 %

Pollen = 19 %

Marine species: Dinocysts = 76 %

Age: Late Campanian- Maastrichtian

Paleoenvironment: (Shallow/Open Shelf)

Paleo-salinity: Normal Marine

Sample No (S4) AsagaAmangwu

Terrestrial species: Spores = 14 %

Pollen = 18 %

Marine species: Dinocysts = 68 %

Age: Late Campanian- Maastrichtian

Paleoenvironment: (Shallow/Open Shelf)

Paleo-salinity: Normal Marine

Sample No (S5) Amaiyi

Terrestrial species: Spores = 20 %

Pollen = 53 %

Marine species: Dinocysts = 27 %

Age: Maastrichtian

Paleoenvironment: (Intermediate Estuary)

Paleo-salinity: Brackish water

Sample No (S6)- Base of Nguzu hill

Terrestrial species: Spores = 25 %

Pollen = 43 %

Marine species: Dinocysts = 32 %

Age: Late Campanian- Maastrichtian

Paleoenvironment: (Intermediate Estuary)

Paleo-salinity: Brackish water

Sample No (S7) Eburnwana 1

Terrestrial species: Spores = 35 %

Pollen = 43 %

Marine species: Dinocysts = 22 %

Age: Maastrichtian

Paleoenvironment: (Proximal Estuary)

Paleo-salinity: Brackish water

Sample No (S8) Eburnwana 2

Terrestrial species: Spores = 53 %

Pollen = 42 %

Marine species: Dinocysts = 5 %

Age: Maastrichtian

Paleoenvironment: (Proximal Estuary)

Paleo-salinity: Brackish water

Sample No (S9) Iyere River cut

Terrestrial species: Spores = 55 %

Pollen = 40 %

Marine species: Dinocysts = 5 %

Age: Maastrichtian

Sample No (S10)- Base of Nguzu hill road cut

Terrestrial species: Spores = 51 %

Pollen = 23 %

Marine species: Dinocysts = 26 %

Age: Maastrichtian

Paleoenvironment: (Proximal Estuary)

Paleo-salinity: Brackish water

Sample No (S11) Nguzu hill road cut 1

Terrestrial species: Spores = 50 %

Pollen = 27 %

Marine species: Dinocysts = 23 %

Age: Maastrichtian

Paleoenvironment: (Proximal Estuary)

Paleo-salinity: Brackish water

Sample No (S13) Nguzu hill road cut 3

Terrestrial species: Spores = 45 %

Pollen = 16 %

Marine species: Dinocysts = 39 %

Age: Maastrichtian

Paleoenvironment: (Distal Estuary)

Paleo-salinity: Brackish water

Sample No (S15) Nguzu hill fault plain

Terrestrial species: Spores = 53 %

Pollen = 32 %

Marine species: Dinocysts = 15 %

Age: Maastrichtian

Paleoenvironment: (Proximal Estuary)

Paleo-salinity: Brackish water

Paleoenvironment: (Intermediate Estuary)

Paleo-salinity: Brackish water

Sample No (S12)- Base of Nguzu hill road cut 2

Terrestrial species: Spores = 44 %

Pollen = 18 %

Marine species: Dinocysts = 38 %

Age: Maastrichtian

Paleoenvironment: (Distal Estuary)

Paleo-salinity: Brackish water

Sample No (S14) Nguzu hill road cut top

Terrestrial species: Spores = 48 %

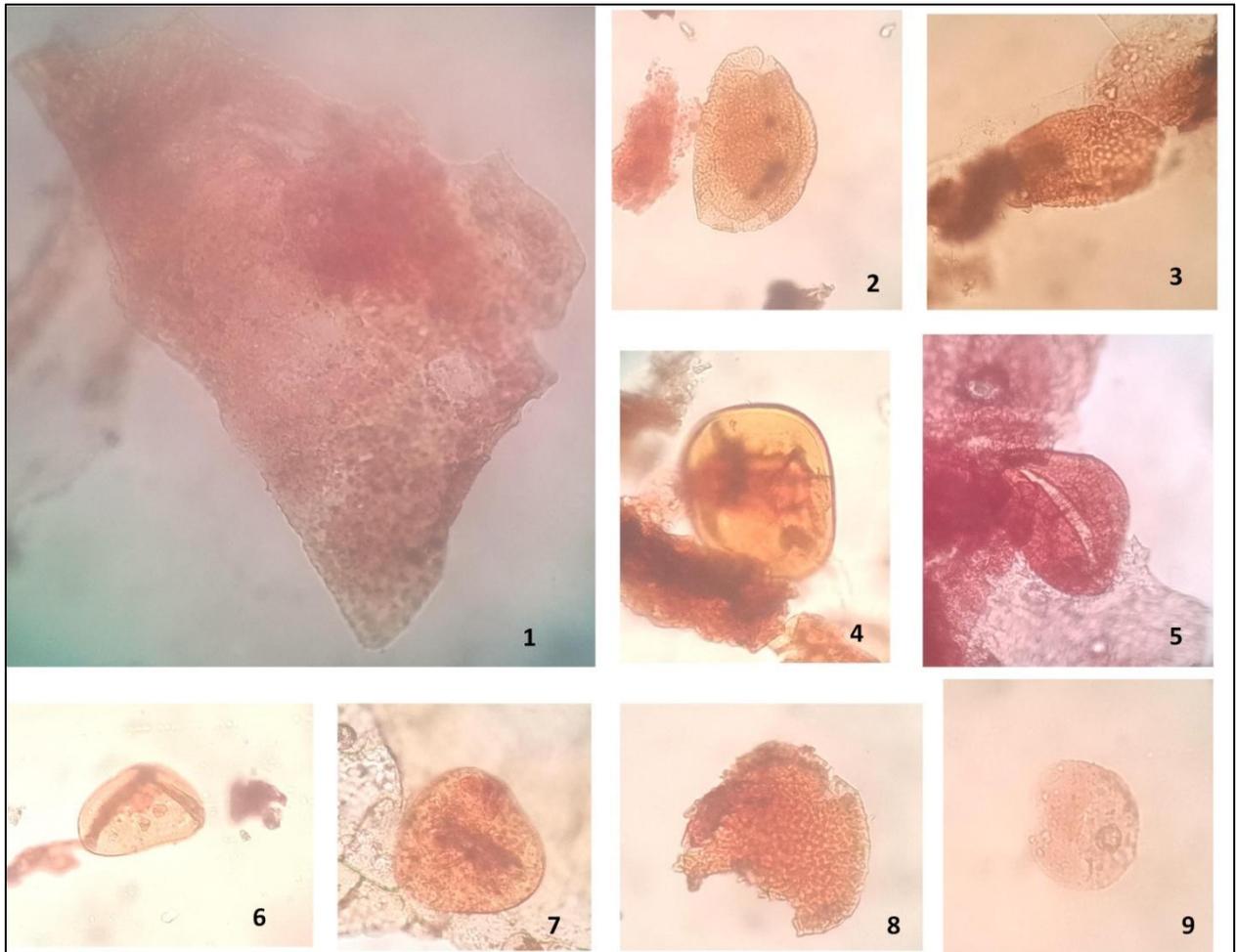
Pollen = 19 %

Marine species: Dinocysts = 33 %

Age: Maastrichtian

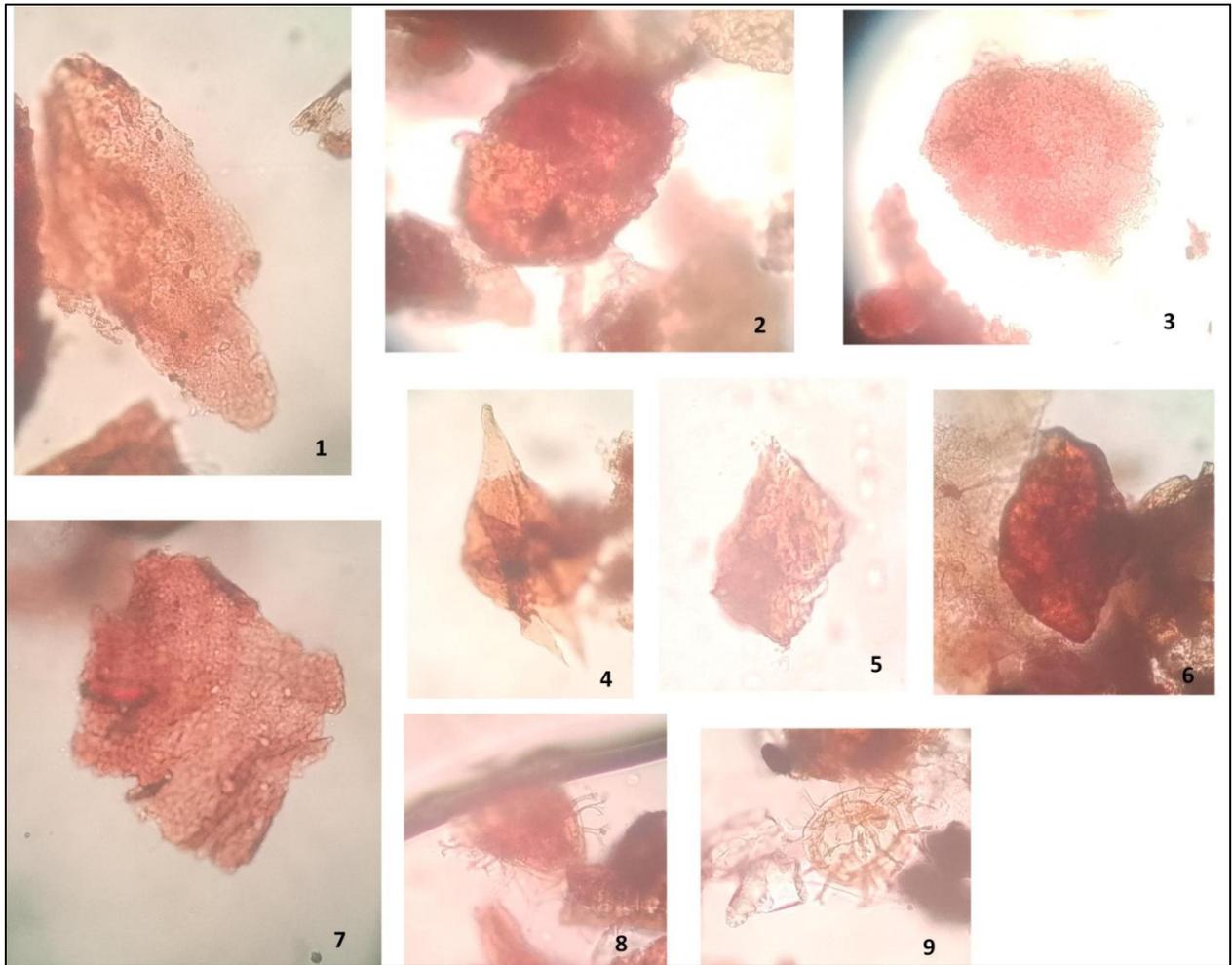
Paleoenvironment: (Intermediate Estuary)

Paleo-salinity: Brackish water



1. *Longapertites vaneedenburgi*; 2. *Longapertites marginatus*; 3. *Retidiporites magdalensis*; 4. *Laevigatosporites ovatus*; 5. *Monocolpites marginatus*; 6. *Laevigatosporites ovatus*; 7. *Leiotriletes minor*; 8. *Proxapertites cursus*; 9. *Monoporites annulatus*

Figure 1 Photomicrograph of some selected sporomorphs recovered from examined samples



1. *Dinogymnium acuminatum*; 2. *Fibrocysta axiali*; 3. *Cometodinium whitei*; 4. *Ceratiopsis diebeli*; 5. *Andalusiella polymorpha*; 6. *Andalusiella polymorpha*; 7. *Dinogymnium acuminatum*; 8. *Spiniferites pseudofurcatus*; 9. *Spiniferites ramosus*

Figure 2 Photomicrographs of some selected dinoflagellates cysts recovered from the examined samples

3.3. Kerogen analysis

Table 2 below shows the percentage (%) frequency distribution of the total Particulate Organic Matter (POM) present in the given examined samples. The percentage (%) frequency is illustrated in the histogram chart below (Figs. 1 and 2). It is clearly observed that POM such as the opaque debris and phytoclasts predominated up to (80 %), 40 % respectively, of the examined samples, followed by AOM (13 %), which frequently occurred, and then palynomorphs (7 %) which are common to rare (see table 3).

Table 2 Summary of % frequency distribution of the total Particulate Organic Matter (POM) present in the analyzed samples.

Sample no.	Phytoclast (%)	Opagues (%)	Aom (%)	Palynomorphs (%)
S1	20	60	0	20
S2	25	55	2	18
S3	30	10	50	10
S4	25	5	55	15
S5	38	50	0	12
S6	50	32	0	18

S7	65	20	0	15
S8	55	40	0	5
S9	20	70	0	10
S10	30	60	0	20
S11	60	25	5	10
S12	45	32	5	18
S13	50	30	15	5
S14	48	40	5	7
S15	30	55	0	15

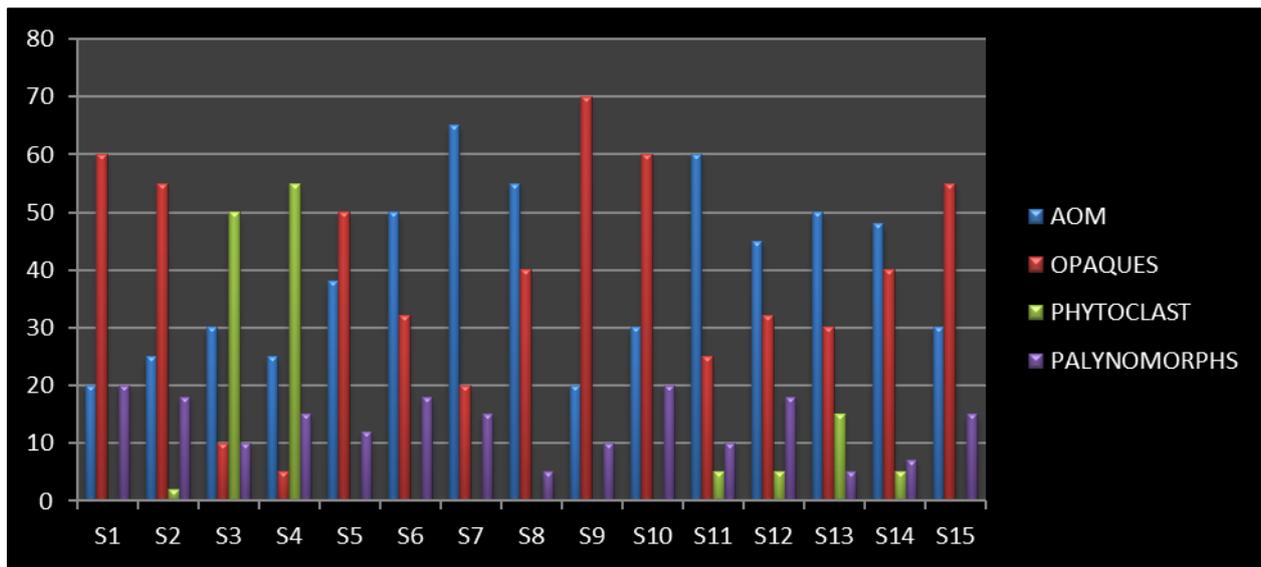


Figure 3 Histogram % frequency distribution of the total particulate organic matter (POM) present in the studied samples

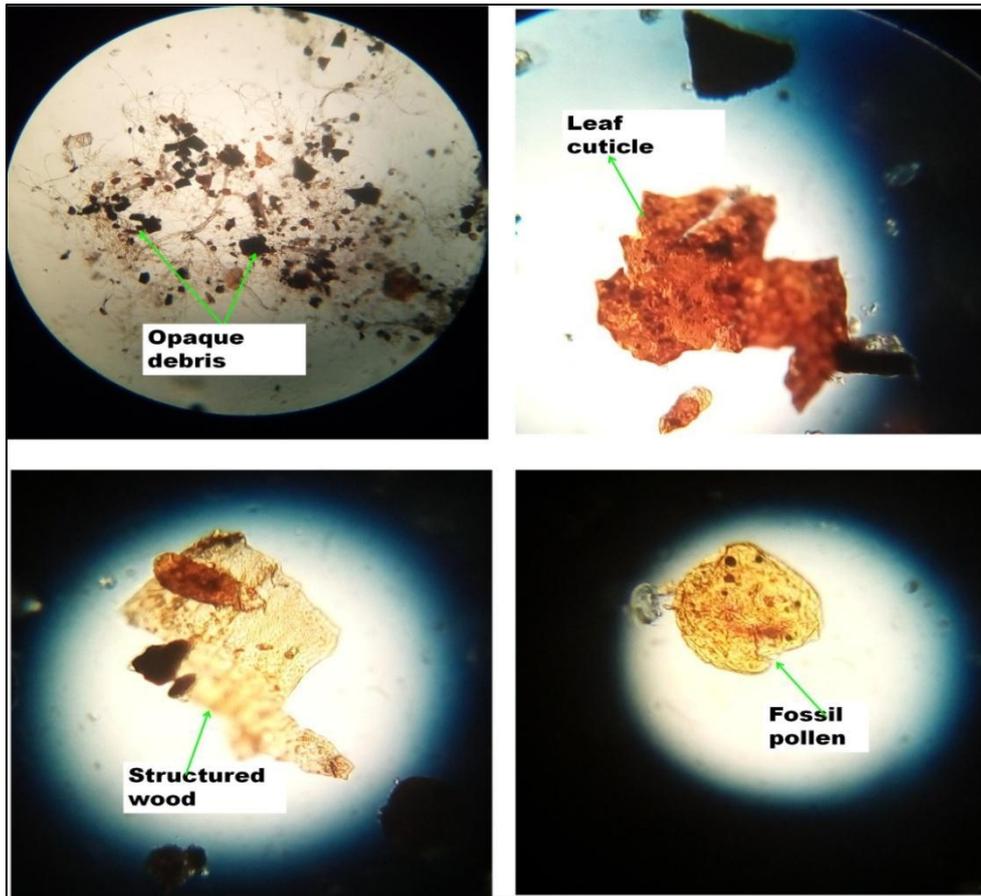


Figure 4 Photomicrographs of the kerogen slides showing the various (POM) in the examined samples

Table 3 Summary of the kerogen characterization with their interpretations

SAMPLE NO	PALYNOFACIES ASSOCIATION	S/P COLOUR	VITRINITE REFLECTANCE (Ro%)	TAI	THERMAL MATURATION	KEROGEN TYPE	SOURCE ROCK POTENTIAL
S1	Abundant opaque & Frequent phytoclast	Pale yellow - yellow	0.3 % - 0.4 %	1+ to 2-	Immature	TYPE III	Gas prone
S2	Abundant opaque & Frequent phytoclast	Pale yellow - yellow	0.3 % - 0.4 %	1+ to 2-	Immature	TYPE III	Gas prone
S3	Abundant AOM & Frequent Phytoclast	Pale yellow - yellow	0.3 % - 0.4 %	1+ to 2-	Immature	TYPE II/III	Oil - Gas prone
S4	Abundant AOM & Frequent Phytoclast	Pale yellow - yellow	0.3 % - 0.4 %	1+ to 2-	Immature	TYPE II/III	Oil - Gas prone
S5	Abundant opaque & Frequent phytoclast	Pale yellow - yellow	0.3 % - 0.4 %	1+ to 2-	Immature	TYPE III	Gas prone
S6	Abundant opaque & Frequent phytoclast	Pale yellow - yellow	0.3 % - 0.4 %	1+ to 2-	Immature	TYPE III	Gas prone
S7	Abundant phytoclast & Frequent opaque	Yellow - yellow brown	0.3 % - 0.5 %	2+ to 2	Immature – slightly mature	TYPE III	Gas prone
S8	Abundant phytoclast & Frequent opaque	Yellow - yellow brown	0.3 % - 0.5 %	2+ to 2	Immature – slightly mature	TYPE III	Gas prone
S9	Abundant opaque & Frequent phytoclast	Pale yellow - yellow	0.3 % - 0.4 %	1+ to 2-	Immature	TYPE III	Gas prone
S10	Abundant opaque & Frequent phytoclast	Pale yellow - yellow	0.3 % - 0.4 %	1+ to 2-	Immature	TYPE III	Gas prone
S11	Abundant phytoclast & Frequent opaque	Pale yellow - yellow	0.3 % - 0.4 %	1+ to 2-	Immature	TYPE III	Gas prone
S12	Abundant phytoclast & Frequent opaque	Pale yellow - yellow	0.3 % - 0.4 %	1+ to 2-	Immature	TYPE III	Gas prone
S13	Abundant phytoclast & Frequent opaque	Pale yellow - yellow	0.3 % - 0.4 %	1+ to 2-	Immature	TYPE III	Gas prone
S14	Abundant phytoclast & Frequent opaque	Pale yellow - yellow	0.3 % - 0.4 %	1+ to 2-	Immature	TYPE III	Gas prone
S15	Abundant opaque & Frequent phytoclast	Pale yellow - yellow	0.3 % - 0.4 %	1+ to 2-	Immature	TYPE III	Gas prone

4. Discussions

4.1. Age determination and correlation

The abundance of stratigraphically significant miospore species as well as the presence of some marker taxa in the examined samples has assisted in designating the age of the examined samples (see table 1). The shale samples were dated Late Campanian-Maastrichtian age based on the following species assemblage: *Psilatricolporites operculatus*, *Mauritidiites crassibaculatus*, *Longapertites marginatus*, *Longapertites vaneedenburgi*, *Retidiporites magdalenensis*, *Echitriporites trianguliformis*, *Spinizonocolpites baculatus*, and *Monocolpites marginatus* (Fig. 1 and 2). This assemblage is similar to those of the Campano–Maastrichtian interval of coeval tropical-subtropical Africa, South America and India [12, 13, 14, 2, 7, 3, 11, 15, 4]. However, the age was confirmed by co-occurrence of typical West African Campanian–Maastrichtian endemic dinoflagellate cysts species *Dinogymnium* spp. alongside *Achomosphaera ramulifera*, *Andalusiella manthei* and *Andalusiella polymorpha* [7]. The present palynofloral association encountered contains several palmae palynomorphs species that are usually found in sediments of Campanian -Maastrichtian age [5, 16]. This is evident from the occurrence of some Palmae (Monocolpites, Syncolpites, Triporates and Protacean) angiospermic pollen in all the samples [8]. The age therefore correlates well with the Campano- Maastrichtian assemblage of [16, 3] based on *Longapertites marginatus*, *Echitriporites trianguliformis*, *Monocolpites marginatus*, *Dinogymnium acuminatum* and *Andalusiella polymorpha*. The age is also in agreement with the Campanian -Maastrichtian palynomorphs assemblage of [16] in the Patti Formation, based on *Echitriporites trianguliformis*, *Monocolpites marginatus*, and *Syncolporite*. It also correlates well with the Campano-Maastrichtian assemblage of [5, 11], based on *Longapertitesmarginatus*, *Echitriporites trianguliformis*, *Monocolpites marginatus*, *Dinogymnium acuminatum* and *Andalusiella polymorpha*.

4.2. Paleoenvironments of deposition

Table 4 below shows the summary of palynomorphs percentage (%) frequency distribution and their paleoenvironmental inferences for the examined samples. Palynological data have been found useful as paleoenvironmental synthesis tool [17,9, 19] Here, the interpretation was based on the ratio of land derived miospores (spores and pollen) to marine dinoflagellates and also the morphology of the dinocysts, [9]. [20] Posited that a palynomorph assemblage with higher content of land derived miospores indicates terrestrial influence and vice versa. The high occurrence of well-known terrestrial miospores such as *Laevigatisporites ovatus*, *Longapertites marginatus*, *Monocolpites marginatus*, with few marine dinoflagellates cysts of peridinioid affinity, such as *Andaluseilla* spp., *Dinogymnium* spp., and *Senegalinium* spp., in most of the examined samples, generally indicate strong terrestrial condition, with little marine influence. On the other hand, some other samples demonstrated high species dominance of open marine dwellers, such as *Spiniferites* spp. and *Achomosphaera* spp., signaling deposition under a strong marine condition (see table 4). In general, the sedimentary environments therefore oscillate from marginal marine to shallow shelf/ open marine depositional settings.

Table 4 Summary of the palynomorphs (%) frequency distribution, with their paleoenvironmental inferences.

Sample no.	Palynomorphs (%) frequency			Paleo-salinity	Paleoenvironments of deposition
	Spores (%)	Pollen (%)	Marine Species (%)		
S1	49	47	4	Brackish water	Marginal marine (proximal estuary)
S2	43	45	12	Brackish water	Marginal marine (proximal estuary)
S3	5	19	76	Normal marine	Shallow marine (Open shelf)
S4	14	18	68	Normal marine	Shallow marine (Open shelf)
S5	20	53	27	Brackish water	Marginal marine (Intermediate estuary)

S6	25	43	32	Brackish water	Marginal marine (Intermediate estuary)
S7	35	43	22	Brackish water	Marginal marine (proximal estuary)
S8	53	42	5	Brackish water	Marginal marine (proximal estuary)
S9	55	40	5	Brackish water	Marginal marine (proximal estuary)
S10	51	23	26	Brackish water	Marginal marine (Intermediate estuary)
S11	50	27	23	Brackish water	Marginal marine (proximal estuary)
S12	44	18	38	Brackish water	Marginal marine (Distal estuary)
S13	45	16	39	Brackish water	Marginal marine (Distal estuary)
S14	48	19	33	Brackish water	Marginal marine (Intermediate estuary)
S15	53	32	15	Brackish water	Marginal marine (proximal estuary)

4.3. Thermal maturation and hydrocarbon prospectivity of Afikpo syncline deposit

The kerogen analysis of the 15 shale samples was used in interpretation of the organic matter composition, hydrocarbon generative potential, and depositional environments of the studied sediments. The dominant distribution of particulate organic matter (POM) reveals a complex interplay of terrestrial input and varying degrees of preservation, significantly influencing the overall hydrocarbon prospectivity [21]

The predominance of opaques (up to 80%) and phytoclasts (up to 65%) kerogen across the majority of the examined samples indicates a significant influx of terrigenous organic matter into the depositional basin. The high percentage of opaques, particularly in samples from Chinese Quarry Akpoha (S1&2), Iyere River road cut (S9), Base of Nguzu hill road cut (S10), and Nguzu hill fault plain (S15), strongly indicates that a substantial portion of the organic material has undergone extensive oxidation or carbonization. Such highly altered organic matter is classified as Kerogen Type IV, signifying inert material with negligible to no hydrocarbon generative potential [6]. This suggests conditions during or post-deposition that led to the degradation of a considerable fraction of the organic input, potentially involving oxic bottom waters or subaerial exposure prior to burial.

Conversely, the abundance of phytoclasts, particularly in samples Base of Nguzu hill (S10), Ebuwana (S7&8), and Nguzu road cut (S11,12&13), points towards the prevalence of Kerogen Type III. When translucent and exhibiting an orange or brown coloration, these woody fragments are indicative of gas-prone source rocks. This substantial contribution of Kerogen Type III highlights a consistent input of higher plant material, implying proximity to a continental landmass and fluvial or deltaic influence during sedimentation [23].

More so, the identification of Amorphous Organic Matter (AOM) in samples from Ogbu, Amaiyi, Nguzu Road cut (S3, 4, 11-13), reaching up to 55% in samples S3 (Ogbu) and S4 (Amaiyi), is a key indicator of oil-prone potential, characteristic of Kerogen Type II. AOM typically originates from algal or bacterial biomass deposited under anoxic conditions, which are conducive to the preservation of lipid-rich organic matter. The relative abundance of AOM in these specific samples suggests localized anoxic conditions within an otherwise predominantly oxic depositional setting, or during the periods of enhanced marine productivity. The consistent low abundance of palynomorphs (7% overall, with individual sample percentages ranging from 5% to 20%) also contributes to the Kerogen Type II classification, reinforcing the mixed oil and gas potential, as sporopollenin palynomorphs are also considered oil-prone.

The heterogeneous distribution of kerogen types across the samples (Table 3) points to dynamic variations in paleo-depositional environments and organic matter input mechanisms. The contrasting prevalence of inert/gas-prone

organic matter (opaques and phytoclasts) versus oil-prone organic matter (AOM and palynomorphs) suggests fluctuating oxygen levels, sediment source changes, and potentially varying water depths within the basin. For instance, samples dominated by opaques and phytoclasts might represent shallower, higher-energy environments with greater oxygen exposure or proximal terrestrial input, while samples with higher AOM content could indicate deeper, more restricted, and anoxic conditions conducive to the preservation of marine or lacustrine organic matter [22]

5. Conclusions

The palynological and palynofacies analysis of Campanian- Maastrichtian shale samples from the Afikpo Syncline has provided critical insights into the stratigraphic, paleoenvironmental, and hydrocarbon-generating characteristics of the sediments. The study successfully established the Campanian - Maastrichtian age of the sedimentary sequence based on the occurrence and distribution of diagnostic palynomorphs and dinoflagellate cysts. Key age-indicative terrestrial palynomorphs such as *Mauritidiites crassibaculatus*, *Proxapertites cursus*, *Echitriporites trianguliformis*, *Longapertites marginatus*, and *Monocolpites marginatus*, alongside marine dinoflagellates like *Dinogymnium accuminatum*, *Andalusiella polymorpha*, and *Achomosphaera ramulifera*, provided a robust biostratigraphic framework. These taxa align with known Campanian - Maastrichtian assemblages documented in other parts of West Africa and globally, thereby validating the regional correlation [2]. The variation in palynomorph distribution across samples also enabled the reconstruction of the depositional environments in the studied area. The results revealed a range of settings from proximal estuarine to shallow marine open shelf, reflecting a dynamic paleoenvironment influenced by transgressive-regressive events. Samples with higher terrestrial palynomorph content were interpreted as having been deposited in brackish water estuarine settings, while those dominated by marine dinoflagellate cysts suggested deposition under normal marine conditions in shallow offshore environments. These oscillations imply fluctuating sea levels changes and shifting sediment sources during the Late Cretaceous. Additionally, the study highlighted changes in paleosalinity, inferred from the composition of dinoflagellate assemblages. The dominance of peridinioid cysts in several samples is consistent with low-salinity, brackish conditions, whereas the presence of chorate cysts like *Spiniferites* species indicates normal marine salinity. This points to a complex depositional system, where fluvial and marine influences alternated periodically. A key contribution of the study lies in the kerogen and palynofacies evaluation, which offered insights into the organic matter content and thermal maturity of the sediments. The predominance of phytoclasts and opaque debris indicates a strong terrestrial influence and the presence of Type III kerogen, typically associated with gas-prone source rocks. The presence of amorphous organic matter and well-preserved palynomorphs, though less abundant, suggests the presence of Type II kerogen, pointing to limited oil-generating potential. Thermal Alteration Index (TAI) values and organic matter coloration suggest that the sediments have undergone moderate thermal maturation, supporting the interpretation of fair to moderate hydrocarbon potential in the region.

References

- [1] Nwajide, C.S. Geology of Nigeria's sedimentary Basin. CSS Bookshops, 2013
- [2] Lawal, O and Moullade, M. Palynological biostratigraphy of the Cretaceous sediments in the Upper Benue Basin. N.E Nigeria. Rev. Micropaleontol., 1986; 29(1): 61-83.
- [3] Umeji, O. P.. Palynological evidence for the Turonian / Campanian boundary between the Abakaliki and the Anambra Basins as exposed at Leru along the Enugu-Port Harcourt expressway, southeastern Nigeria. Journal of Mining and Geology, 2006; 42 (2): 141-155
- [4] Nwojiji C.N, Lawal A.Y and Edegbai A.J Late Cretaceous deposits in Afikpo sub-Basin, Southern Nigeria: Evidence from Palynomorphs. WJARR 2025; 27(01); 1159-1172
- [5] Chiaghanam O.I, Ikegwuonu O.N, Chiadikobi K.C, Nwozor K.K, Ofoma A.E and Omoboriowo AO Sequence Stratigraphy and Palynological Analysis of the Late Campanian to Maastrichtian Sediments in the Upper-Cretaceous, Anambra Basin (A Case Study of the Okigwe and its Environs, South-Eastern Nigeria). Pelagia Research Library (Advances in Applied Science Research) Journal, 2012; 3(2): 962-979.
- [6] Tyson, R. V. Palynofacies analysis. Applied Micropalaeontology, Kluwer Academic Publishers, 1993
- [7] Edet, J.J., and Nyong, E.E. Palynostratigraphy of Nkporo Shale exposures (Late Campanian -Maastrichtian) on the Calabar Flank, S.E Nigeria. Review of paleobotany and Palynology. 1994. 8: 131-147.
- [8] Herengreen G.F.W Palynology of middle and upper Cretaceous strata in Brazil. Meded Ryks Geol Dienst n.s. 1975; 26:39-91

- [9] Ojo O.J, Ajibola U.K and Akande S.O Depositional Environments, Organic richness and Petroleum generating potential of the Campanian to Maastrichtian, Enugu Formation, Anambra Basin, Nigeria. *The Pacific Journal of Science and Technology*. 2009; 10: 614-628.
- [10] Ibrahim, M.Y.A., Abdul Ela, N.M and Kholeif, S.E. Paleoecology, Palynofacies, thermal Maturation and hydrocarbon source-rock potential of the fossil lower cretaceous sequence in the subsurface of the north eastern Desert, Egypt *Qatar University Science Journal*, 1997; 17 (1): 153-172.
- [11] Ikegwuonu, O. N., Chiaghanam, O. I., Nwakoby, N. E., Aniwetalu, E. U., and Chiadikobi K. C. Occurrence of some Campanian-Maastrichtian organic-walled microfossils from Enugu Shale, Anambra Basin, southeastern Nigeria: Implications for age and Paleoenvironments. *Global Journal of Geological Sciences*. 2021; 19(9):1-13.
- [12] Van Hoeken-Klinkenberg. P.M.J. A palynological investigation of some UpperCretaceous sediments in Nigeria. *Polen et spores*, 1964 6(1): 209-231
- [13] Van Hoeken-Klinkenberg. P.M.JMaastrichtian Paleocene and Eocene pollen and spores from Nigeria. *GeologischeMededelingen*, . 1966; 38:37-48
- [14] Jan du Chene, R.E., and Salami, M.B. Palynology and micropaleontology of the upper Eocene of the well Nsukwa-I, Niger Delta.Nigeria, 13 centuries *Recherches des séances SPHN Geneve*, 1978; 5-9.
- [15] Okon S. O, Bolaji, T.A, Ikegwuonu, O.N, Oyebamiji, A.R, Kolade, O.B Palynological analysis of the Maastrichtian Patti Formation in Gehuku and Ahoko area, southern Bida Basin, Nigeria: implications for age and paleoenvironments, *Discover Geoscience* 2025; 3: (24)
- [16] Okoro, A. U., Nwojiji, C. N. Osegbo F.N., Ndubueze V.O. Palynological analysis of late Cretaceous Nkporo Formation in the Afikpo Sub-basin, Southeast Nigeria. *Asian Transactions on Science and Technology* 2012; 2 (3), 35-46.
- [17] Oloto, I.N., A palynological study of the late Cretaceous and Tertiary boreholes from Southern Nigeria sedimentary basins. PH.D .thesis, Univ. of Scheffield (unpublished), 1984.
- [18] Onuigbo, E.N., Etu- Efiotor, J.O., and Okoro, A.U. Palynology, paleoenvironment and sequence stratigraphy of Campanian- Maastrichtian Deposits in the Anambra Basin, southeastern Nigeria. *European Journal of Scientific Research* 2012;78, (3), 333-348.
- [19] Ikegwuonu O.N, Umeji O.P, Chiaghanam O.I, Nwozor K.K, Ndukwe O.S, Chiadikobi K.C. Palynomorph assemblage biozonation of Paleogene strata in Bende-Umuahia area, Niger Delta Basin, southeastern Nigeria. *J Palaeogeogr*. 2020; 9:1-13.
- [20] Schrank, E., Organic-Geochemical and palynological studies of a Darkhla Shale profile (Late Cretaceous) in southeast Egypt. Part A: Succession of microfloras and depositional environment. *Berl. Geowiss. Abh. (A)*, 1984; 50: 189-207.
- [21] Zobaa, M.K, Zavada, M.S. and White law, M.J. Palynofacies analysis, source rock evaluation and organic thermal maturation of the Gray Fossil Site, Gray, Tennessee. In: *Eastern Section, AAPG 36th Annual Meeting, Abstract*, Lexington, Kentucky, USA, 2007
- [22] Tyson, R. V. *Sedimentary organic matter—Organic facies and palynofacies*: Chapman and Hall, London, U.K. 1995
- [23] Zobaa, M., C. Sanchez Botero, C. Browne, F. E. Oboh-Ikuenobe, and M. I. IbrahimKerogen and palynomorph analyses of the mid-Cretaceous Bahariya Formation and Abu Roash “G” Member, North Western Desert, Egypt: *Gulf Coast Association of Geological Societies Transactions*, 2008, 58:. 933-943.