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(Research Article)

Palynostratigraphical evaluation of outcropping units of the Eze-Aku Formation in the Afikpo basin, South Eastern Nigeria

Frances Nkiru Melifonwu, Geoffrey Chijioke Soronnadi-Ononiwu, Fortune Ijeoma Chiazor * and Michael Monday Inyang

Department of Geology, Faculty of Science, University of Port Harcourt, Choba, Port Harcourt. Nigeria.

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Abstract

A total of thirty-one samples from three outcropping units of the Eze-Aku Formation at the Julius Berger Quarry site, after Akpoha, Afikpo Basin, in Ebonyi State South Eastern Nigeria was subjected to lithological/ Sedimentological descriptions and palynological analysis to determine the fossil assemblage of the samples in relation to its lithological variations in order to determine the age of deposition. The samples were further subjected to conventional maceration technique for recovering of an acid insoluble organic-walled microfossil The results from the lithological/ Sedimentological descriptions showed that the samples varied from grey to brown Sandy Shale. From the maceration technique, thirty-three species of pollen and spores was identified and the palynomorphs forms include the following: *Laevigatosporites* sp, Fungal Spores, *Verrucosisporites* sp, *Pseudoschizaea* sp, *Triletes* and *Charred Graminae Cutile.* Land derived forms such as pollen and spores and fungal spores in most of the samples suggest that the depositional environment is a marshy/swampy environment in a marine setting. The wet sieve analysis done on the samples showed a high value of shale to sand ratio all of which further depicts a marginal marine to marine depositional environment.

Keywords: Microfossils; Palynological; Fossil Assemblage; Environment And Eze-Aku Formation

1. Introduction

The Eze-Aku Formation is a geological formation within the Afikpo Basin, which is situated in South Eastern Nigeria. The Afikpo Basin is part of the larger Benue Trough, a major geological structure in Nigeria. The Eze-Aku Formation is primarily composed of sedimentary rocks that were deposited during the Cretaceous period, specifically during the Albian to Turonian ages, which corresponds to a time frame of approximately 112 to 89 million years ago. This formation consists of alternating layers of shale, sandstone, limestone, and coal seams believed to have been formed in a variety of environments, including marine, deltaic (river delta), and coastal plain settings. The formation is known for its significant coal resources, which have been economically important for the region. In terms of its paleontological significance, the Eze-Aku Formation contains fossil remains of various organisms, including plant materials, invertebrates, and occasionally vertebrate fossils. These fossils provide valuable insights into the ancient flora and fauna that existed during the deposition of the formation. Petters (1978, 1980) advocated a Late Turonian to Coniacian age to the Eze-Aku Group based on foraminifera analysis of the Nkalagu Limestone. Oti *et al*. (2015) analyzed the palynological assemblages from the Ezeaku Formation in the Afikpo Basin, southeastern Nigeria. From the study, they identified various palynomorphs, including pollen grains, spores, and micro foraminiferal linings, and concluded that the Ezeaku Formation was deposited in a palustrine and fluviatile environment with a marginal marine influence. In 2017, Egboka *et al*. carried out a study on the palynology and sedimentology of the Eze-Aku Formation in the Cross River Basin. The study identified several palynomorphs, including spores and pollen grains, and determined that the sedimentary deposits were primarily fluvial in nature. The results of the study suggest that the Eze-Aku Formation was deposited in

* Corresponding author: Chiazor FI

a tropical floodplain environment during the early Cretaceous period. Again, Egboka *et al.* (2018) investigated the sedimentology and palynology of the Eze-Aku Formation in the Okigwe area of the Cross River Basin. The study identified several palynomorphs, including pollen and spores of angiosperms, ferns, and gymnosperms and also revealed that the sedimentary deposits were primarily alluvial in nature and were deposited in a coastal plain environment. Adegoke *et al*. (2020), carried out a palynological study of the Eze-Aku Formation in the Anambra Basin and provided new insights into the depositional environment and paleoenvironmental conditions during the Early Cretaceous. The Eze-Aku Formation is composed of sandstones, shales, and siltstones and is characterized by abundant fossil plant remains, including stems, leaves, and fruits. The palynological analysis of the formation revealed the presence of diverse pollen and spore assemblages, with angiosperms and ferns dominating the assemblages. The authors suggested that the formation was deposited in a low-energy environment with a warm and humid climate.

The geological and paleontological study of the Eze-Aku Formation and the wider Afikpo Basin contributes to our understanding of the regional geology, paleoenvironmental conditions, and the tectonic history of southeastern Nigeria. It also has implications for the exploration and exploitation of natural resources, such as coal and hydrocarbons, within the basin.

Recently, the excavation of a pit by Julius Berger Nigeria Limited, at Akpoha exposed the subsurface outcrops enabling the outcrop to be logged, samples collected and subject them to palynological analysis. The outcrop as exposed is made up of fine-grained intercalations of siltstone and shale lamina which were used for the palynostratigraphy and paleoenvironmental study of the area.

The present work is intended to utilize the palynological assemblage from the exposed outcrop in the excavated pit, to understudy the stratigraphy of the study area, determine the age, decipher the depositional environment, and characterize the sediments, vis-a-vis earlier works on the area.

1.1. Regional geology of afikpo basin and the study area.

The Afikpo Basin was formed during the Santonian Orogeny in the upper Cretaceous time. The Cretaceous tectono - sedimentary evolutions of the Afikpo domains are presented through six stages. The first stage involved the breakup of Afro-Brazilian plate at the triple junction. In the second stage, Benue Trough developed as a graben between the on-shore extensions of oceanic fracture zones. The third stage involves the formation of the Benue Trough as a rifted depression in response to a regional stress field due to active or passive lithospheric extension. The fourth stage involved minor folding in parts of the trough (late Cenomanian); renewed transgression and regression and the deposition of the Late Cenomanian- Coniacian rocks (Eze-Aku Group). The fifth stage involved compressional folding, tectonic inversion, faulting, and alkaline-sub alkaline magmatism (including volcanic sills, dykes, Eziatormicrodiorites, Afikpo dolerites, Ugepmicrodiorites, and dolerites-micro grabbros). The folding resulted into the formation of the Afikpo Basin. The deformed and uplifted (Benue-Abakaliki) trough became a positive element to shed sediments; the depressed platforms Afikpo became the major depocenters. In environments ranging from marine to paralic to fluvial, about 4000m post Santonain sediments were deposited in the Afikpo Basin. These post-Santonian pro to-Niger Delta deposits were formed between Campanian-Maastrichtian. The sixth stage was characterized by tectonic inversion, deformation, faulting and magmatism of post-Santonian sediments including the Afikpo micro gabbros marking the termination of Cretaceous sedimentation and the evolution of the Cenozoic Niger Delta (Odigi, 2012).

Earlier, Reyment (1965) had assigned the Afikpo Basin as a syncline. The Afikpo Syncline was accorded the status of a basin by Odigi and Amajor, (2009) and Odigi(2012). Folding resulted into the formation of the Afikpo Basin; the depressed Afikpo platform became a major depocenter after the deformation and uplift of the Benue-Abakaliki Trough, thereby making it a basin for the deposition of the Pre-Santonian and Post-Santonian Sediments (Odigi, 2012). According to Ojoh (1990), “the lithic-fill in the Afikpo Basin is considered a part of the Anambra Basin. Although the lithic-fill in the Afikpo syncline postdates to the Santonian folding event the basin is not really folded itself.”

The study area (Fig. 1) lies between latitude $7^{0}51'$E and $8^{0}00'$E and latitude $5^{0}55'$N and $6^{0}00'$N within the Afikpo Syncline and the Cross River Basin of the Benue Trough. The area of the study is accessible through the main roads, minor roads and foot paths.

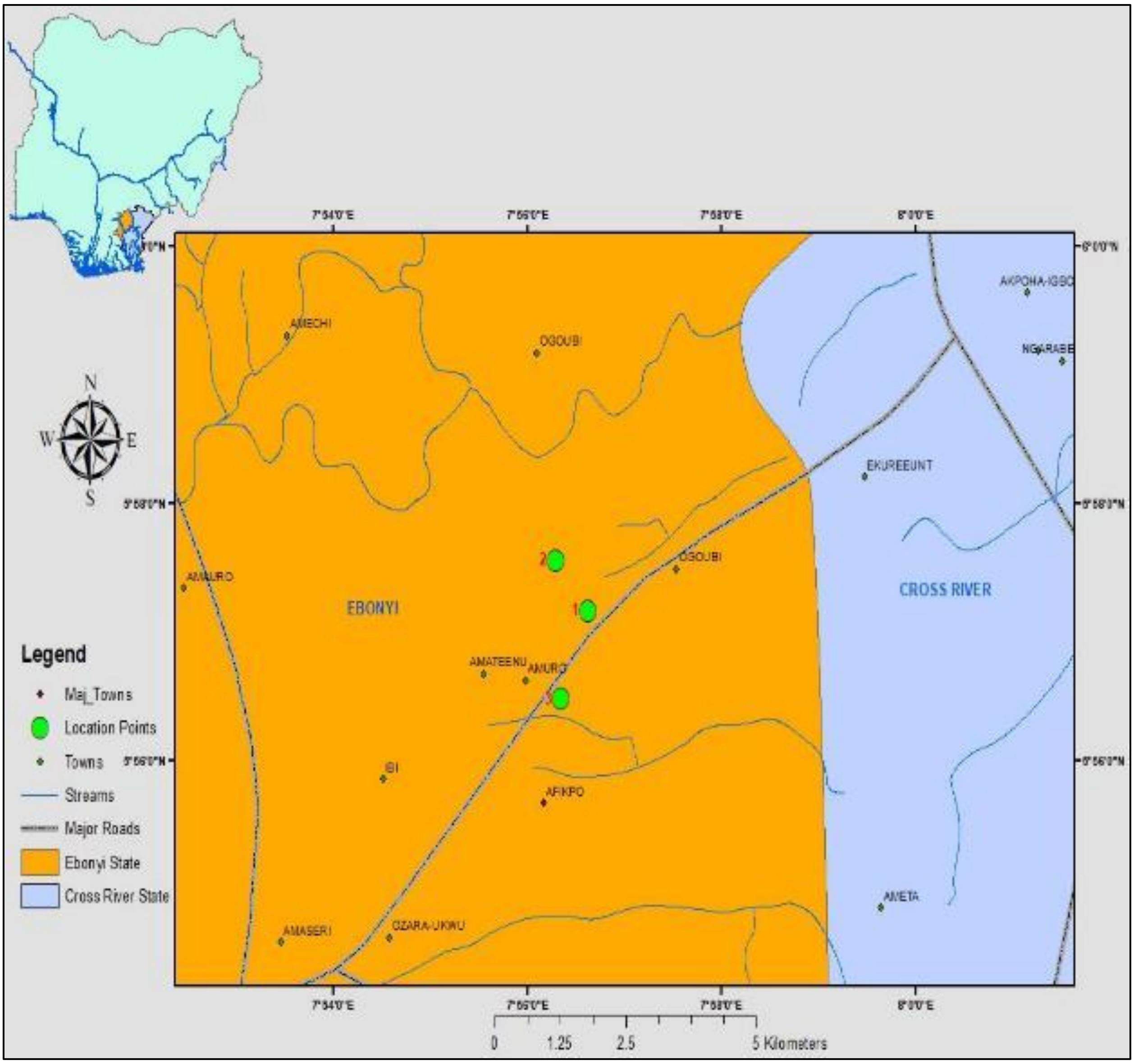

Figure 1 Location map of study area

2. Materials and method

The research work encompassed two aspects: field collection of samples and laboratory analysis.

The materials used for the field work includes the following: Global Positioning System, Digital Camera, Base Map, Geologic Hammer, Chisel, Hand trowel Hand auger, Measuring Tape, Field notebook Masking Tape, Compass Clinometers, Sample Bags, Stationeries, Hand lens etc.

Materials used for the Masking tape, Sieves (106µm, 63µm, 53µm), Hot plate, Pipette, Filter papers, Aluminum plates, Spatula, Picking tray, Brush, Sodium carbonate. Reagents used was Dilute Hydrochloric Acid (HCl) and Distilled water.

The field collection of samples, involved the collection of samples from 3 outcrop locations around the Julius Berger Quarry site, Uroro, South-Eastern Nigeria located between latitude 5^{0}53’00’’N and longitude 7^{0}56’0” E. The locations were situated within, behind and in front of the quarry site represented as Location 1, Location 2 and Location 3 respectively. A total of thirty-one (31) samples were collected. The outcrops were logged from the bottom.

3. Results and discussion

3.1. Lithostratigraphic description

The lithostratigraphic units identifield in the three locations encountered, were recognized and defined, based on the observable physical rock characteristics (lithology).

In Location 1(Akpoha Quarry Site), the studied outcrop ranges from (0m - 1.969m). A lithological framework was established and the total thickness of the studied outcrop was 2.0m. Eleven units were delineated (Fig. 2)

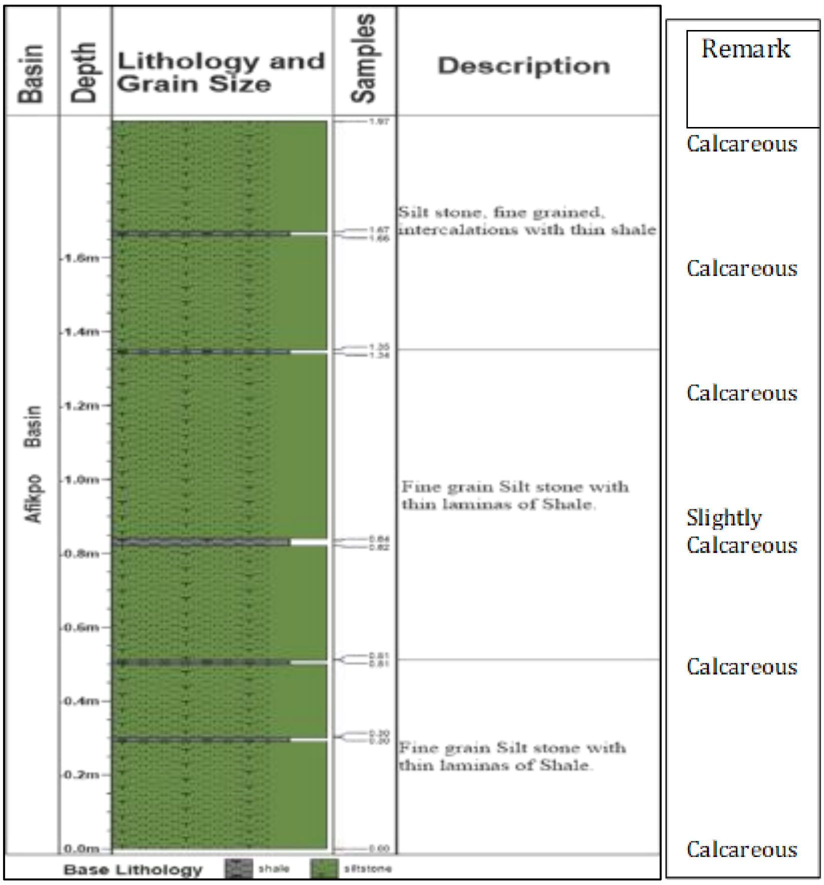

Figure 2 Graphic log of the sequence in Location 1, showing the lithostratigraphic framework

In Location 2(Front of Akpoha quarry site), the lithostratigraphic units identified are shale and sandy shale (Fig. 3)

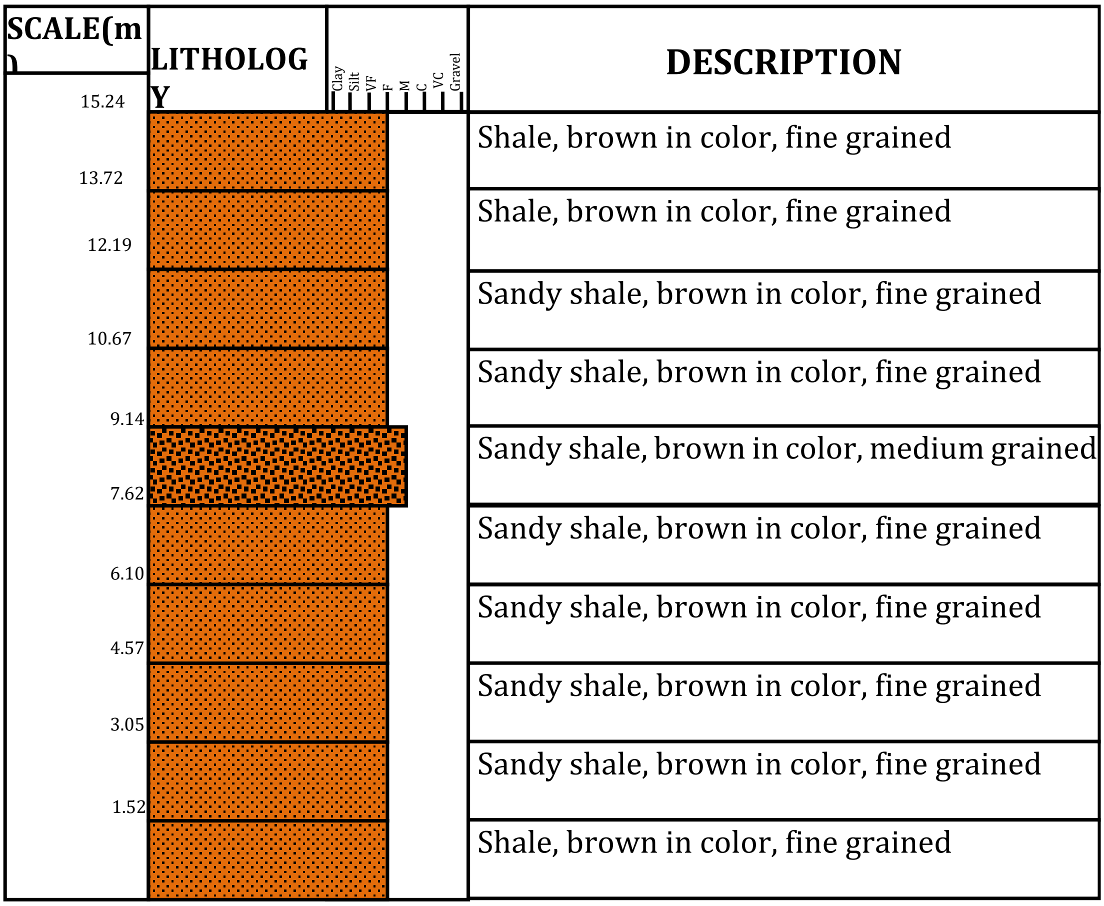

Figure 3 Graphic log of the sequence (Location 2), showing the lithostratigraphic units

At Location 3 (Back of Akpoha quarry site), the studied section ranges from (0m - 6.0m). the lithostratigraphic units encoutered are muddy shale, siltstone and sandston (Fig.4).

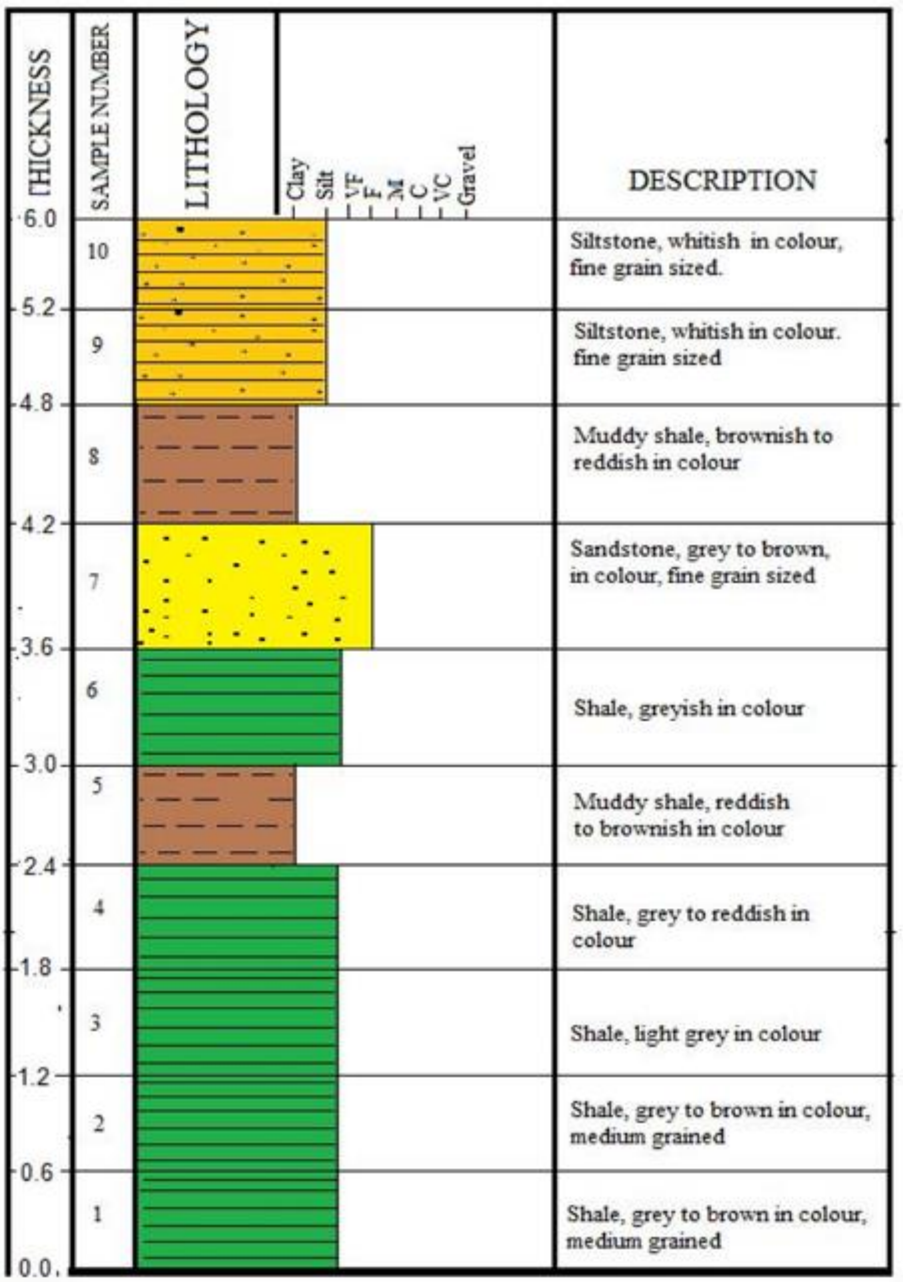

Figure 4 Graphic log of the sequence (Location 3), showing the lithostratigraphic units

3.2. Biostratigraphic Description

In location 1, the palynomorphs distribution varied considerably from depth to depth. The samples of the following depths yielded no palynomorphs; 0 - 0.302m and 0.51 - 0.820m. However, the list of palynomorphs encountered according to their groupings,

Pollens: *Zonocostites ramonae, Psilatricolsporites crassus,* Spores: *Laevigatosporites discodatus, Cyathidite*s sp*, Verrucatosporites farvus, Pteris dentata* Fungal spores, Acritarchs.

Using the depth to depth percentage distribution table displayed in Table 1, a Pollen/Spore, Fungal spore and Acritarchs graph was plotted in (Fig 2). It is plotted by calculating the percentage occurrence of the terrestrial derived palynomorphs (pollen and spores), the fungal spores and the Acritarchs in depth using a suitable scale. These provided information on the paleoenvironment of the studied area. The terrestrial percentage of palynomorphs showing depth to depth percentage of occurrence of pollens, spores, fungal spores and Acritarchs are shown in Tables 2

Table 1 Depth to Depth assemblage distribution of palynomorphs (Location One)

Depth (m)	Palynomophs	Numerical count	% of occurrence
0 - 0.302	PNP	-	-
0.302 - 0.304	Fungal spore *Cyathidites* sp *Acritarchs*	2 1 1	50 25 25
0.304 - 0.511	*Verrucatosporites farvus*	1	100
0.511 - 0.513	Fungal spore *Psilatricolsporites crassus* *Laevigatosporites-discordatus*	1 1 1	33.3 33.3 33.3
0.513 - 0.820	PNP	-	-
0.820 - 0.835	*Verrucatosporites farvus* *Psilatricolsporite* sp *Zonocostites ramonae*	1 1 1	33.3 33.3 33.3
0.835 - 1.342	Fungal spore	5	100
1.342 - 1.352	*Pteris dentate* *Verrucatosporites farvus* *Pseudoschizaea*	2 1 1	50 25 25
1.352 - 1.658	Fungal spore	1	100
1.658 - 1.669	*Verrucatosporites farvus* *Pteris dentate* Fungal spore	1 1 1	33.3 33.3 33.3
1.669 - 1.969	*Acritarchs*	2	100

Table 2 Percentage summary of the major forms per depth (Location One)

Depth (m)	Total palynomorphs	Pollen %	Spores%	Fungal spores %	Acritarchs %
0 - 0.302	-	-	-	-	-
0.302 - 0.304	4	-	25	50	25
0.304 - 0.511	1	-	100	-	-
0.511 - 0.513	3	33.3	33.3	33.3	-
0.513 - 0.820	-	-	-	-	-
0.820 - 0.835	3	66.7	33.3	-	-
0.835 - 1.342	5	-	-	100	-
1.342 - 1.352	4	-	75	25	-
1.352 - 1.658	1	-	-	100	-

In location 2, the results of the analysis of the outcrop samples; 3 (3.05 – 4.57m), 5 (6.10 – 7.62m), 7 (9.14 – 10.67m), and 9 (12.19 – 13.72m) yielded practically no palynomorphs, while samples 1 (0 – 1.52m), 2 (1.52 – 3.05m), 4 (4.57 – 6.10m), 6 (7.62 – 9.14m), 8 (10.67 – 12.19m) and 10 (13.72 – 15.24m) yielded mostly fungal spores and few sporomorphs. This is shown as the distribution chart (fig. 3) and table 3

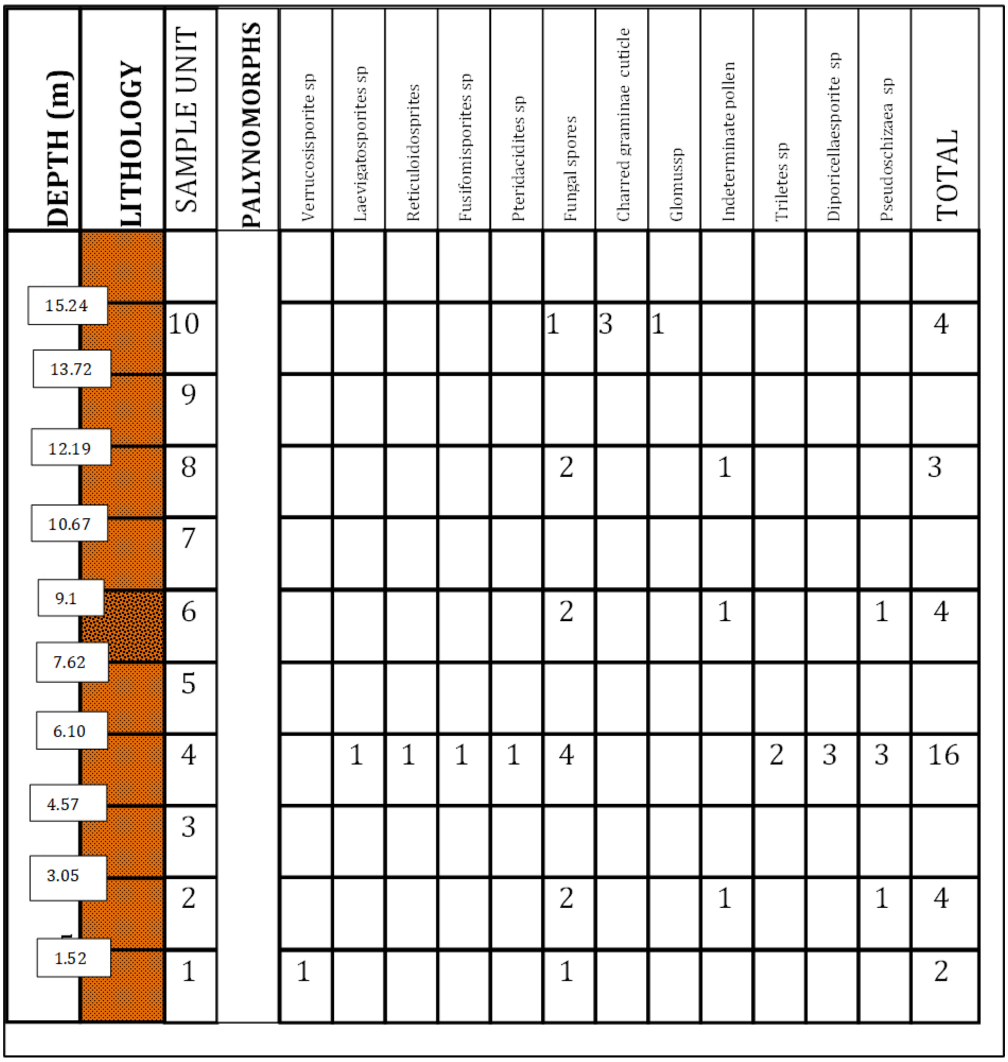

Figure 5 Distribution chart of palynomorphs recovered from outcrop

Furthermore, a depth-to-depth percentage distribution (table 4) was calculated from the distribution chart of palynomorphs.

Table 3 Depth to depth percentage distribution of palynomorphs (Location 2)

Sample number	Depth(m)	S/N	Palynomorphs	Numerical count	Percentage occurrence
1	0 – 1.52	1	Fungal spore	1	50
		2	*Verrucosisporites* sp	1	50
2	1.52 – 3.05	1	Fungal spore	2	66.7
		2	*Pseudoschizaea* sp	1	33.3
3	3.05 – 4.57				
4	4.57 – 6.10	1	*Triletes* sp	2	12.5
		2	Fungal spore	4	25
		3	*Pteridacidites* sp	1	6.3
		4	*Pseudoschizaea* sp	3	18.8
		5	*Laevigatosporites* sp	1	6.3

		6	*Reticuloidosprites*	1	6.3
		7	*Diporicellaesporites* sp	3	18.8
		8	*Fusifomisporites* sp	1	6.3
	6.10 – 7.62				
6	7.62 – 9.14	1	Fungal spore	2	50
		2	*Pseudochizaea* sp	1	25
		3	Indeterminate pollen	1	25
7	9.14 – 10.67				
8	10.67 – 12.19	2	Indeterminate pollen	1	33.3
		1	Fungal spore	2	66.7
9	12.19 – 13.72				
10	13.72 – 15.24	1	*Charred graminaecutile*	3	60
		2 3	*Glomus* sp Fungal spore	1 1	20 20

Table 4 Percentage (%) abundance of palynomorphs based on their paleoenvironmental distribution

Depth (ft)	Total palynomorphs	% Pollen/Spores	% Fungal Spores	% Others
0 – 1.52	2	50	50	_
1.5 – 3.05	3	33.3	66.7	_
3.05 – 4.57	_	_	_	_
4.57 – 6.10	16	75	25	_
6.10 – 7.62	_	_	_	_
7.62 – 9.14	4	50	50	_
9.14 – 10.67	_	_	_	_
10.67 – 12.19	3	33.3	66.7	_
12.19 – 13.72	_	_	_	_
13.72 – 15.24	5	_	20	80
Total	33	51.5	36.3	12.1

In location 3, a total of ten outcrop samples were analysed, the analysis yielded practically very poor amount of palynomorphs with no index species for the age of the samples to be determined.

The yielded palynomorphs and their percentage occurrence include *Glomus* (27.88%), *Botryococcus* (2.88%), Fungal spore (22.12%), Diatom (20.19%), *Pluricelaesporites* sp (0.96%), *Psilatricolporites* sp (2.88%), *Multicellites sp (*2.88%), *Polypodiaceiosporites* sp *(*0.96%), *Verrucatosporites farvus* (0.96%), *Rugulatisporites caperatus* (0.96%), *Hillidicellites* sp (0.96%) and Polyadosporites sp (16.35%).

The grouping of the palynomorphs is shown in (Table 6) and their percentage per depth in (Table 5). This distribution is used to plot a distribution chart (Fig, 4) of palynomorphs per depth in the studied outcrop.

3.3. Palynological Analysis

Table 5 Depth to depth percentage distribution of palynomorphs (Loc.3)

Depths (m)	Palynomorphs	Numerical Count	% count of occurrence
0 – 0.61	Glomus	5	41.7
	Botryococcus sp	2	16.7
	Fungal spore	3	25
	Diatom	1	8.3
	Pluricelaesporites sp	1	8.3
	Cuticular materials and brown wood		
0.61 – 1.22	Diatom	2	66.7
	Fungal spore	1	33.3
1.22 – 1.83	Diatom	4	44.4
	Psilatricolporites sp	3	33.3
	Multicellites sp	2	22.2
1.83 – 2.44	Diatom	2	33.3
	Fungal spore	3	50
	Polyapodiaceiosporites sp	1	16.7
	+ wood parcles		
2.44 – 3.05	Diatom	3	75
	Verrucatosporites farvus	1	25
3.05 – 3.66	Fungal spore	2	66.7
	Diatom	1	33.3
	+ brown wood		
3.66 – 4.27	Fungal spore	4	100
4.27 – 4.88	Fungal spore	6	18.2
	Glomus	24	72.7
	Diatom	1	3.0
	Rugulatisporites caperatus	1	3.0
	Hillidicellites sp	1	3.0
	Abundant annelids		
4.88 – 5.49	Diatom	6	22.2
	Fungal spore	3	11.1
	Polyadosporites sp	17	63.0
	Botryococcus sp	1	3.7
	+ plant remains & aleter		
5.49 – 6.10	*Multicellites* sp	1	33.3
	Fungal spore	1	33.3
	Diatom	1	33.3

Table 6 Percentage summary of major groups of palynomorphs

Depths (m)	Total palynomorphs	Pollens (%)	Spores (%)	Algae (%)
0 – 0.61	12	-	75	25
0.61 – 1.22	3	-	33.3	66.7
1.22 – 1.83	9	33.3	22.2	44.4
1.83 – 2.44	6	-	66.7	33.3
2.44 – 3.05	4	-	25	75
3.05 – 3.66	3	-	66.7	33.3
3.66 – 4.27	4	-	100	-
4.27 – 4.88	33	-	96.9	3.0
4.88 – 5.49	27	-	85.2	14.8
5.49 – 6.10	3	-	33.3	66.6

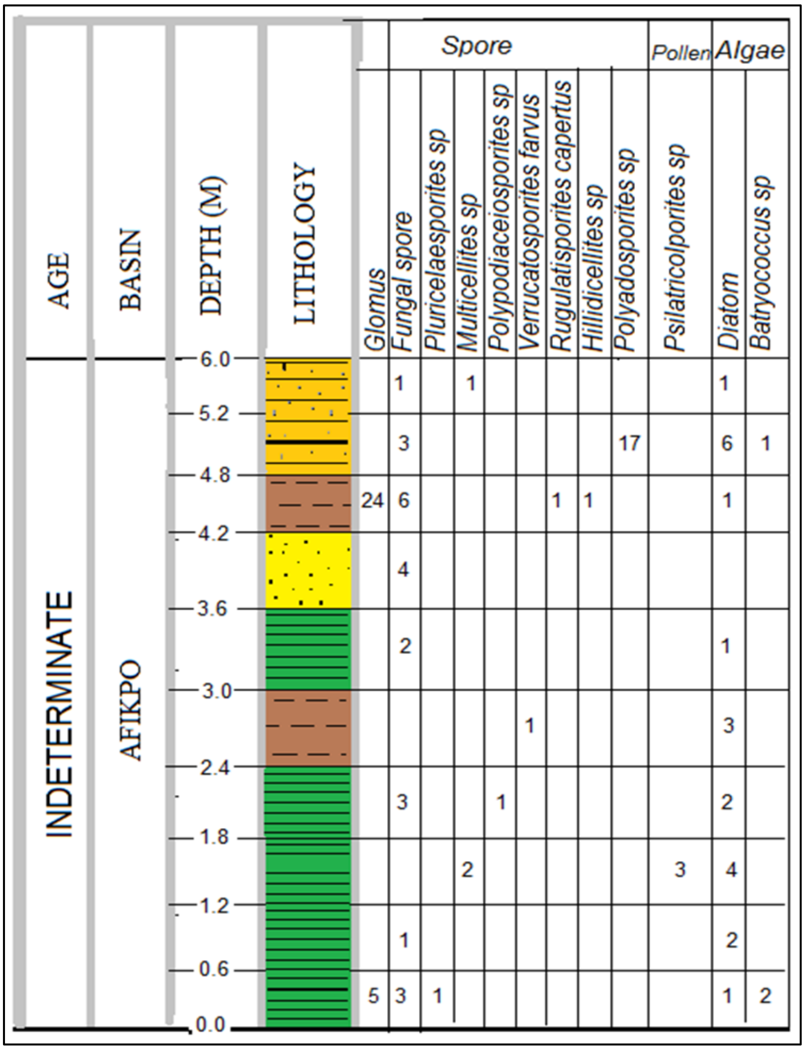

Figure 6 Distribution chart of palynomorphs in the location 3

3.4. Paleoenvironment

From the studied section in location 2, the percentage of palynomorphs per depth based on paleoenvironmental distribution table (table 4) was used to generate a biostratigraphic plot (fig.5), which explains the paleoenvironment of the outcrop. From the plot, it can be seen that pollen and spores dominates, followed by fungal spores and then the others have very little percentage of occurrence. The high occurrence of pollen and spores suggests that the environment is terrestrial.

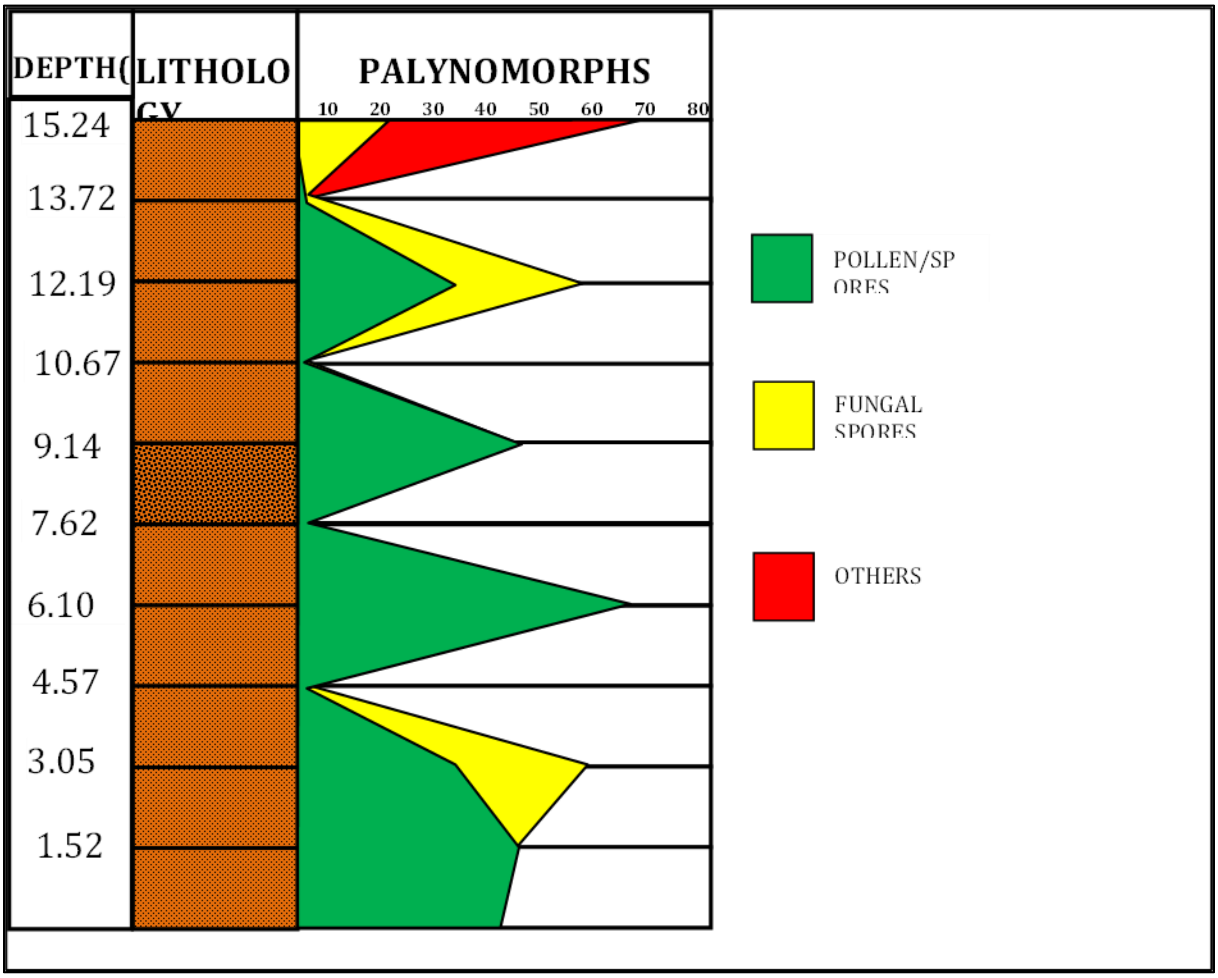

Figure 7 Biostratigraphic plot of outcrop (LOCATION 2)

The fungal spores which are second in scale of abundance are also suggestive of a terrestrial environment. It points more to a marsh/swampy environment or a fluviomarine environmental setting.

Using the results gotten from the analysis in location 3, a distribution chart of the palynomorphs found in the outcrop was generated (Fig. 4) and this was used to produce a depth to depth percentage distribution table (Table 5) and grouping of the various palynomorphs was done on the basis of their paleoecological occurrence. The various groups are (a) Pollen and spores (b) fungal spores (c) others. Paleoenvironmental interpretation was attempted using the recovered diatom fostules with fungal spores in most of the samples. The fungal spore with cuticular materials and plant remains observed in the samples portray that the samples were probably deposited in a near shore environment but within a marine influence.

3.5. Age Determination

The age of the studied area was attempted using the palynological information obtained. Age was indeterminate due to scarcity of age determinant forms. Therefore, this writer relied on index forms from similar work in Afikpo-4 well where the author used *Longapertites marginatus, Echitriporites trianguliformis, Periretisyncolpites magnosagenatus, Cricotriporites fragilis, Senegalinium bicavatum, phelodinium gaditanum, polysphaeridium subtile, Cribroperidinium orthoceras, Exochospaeridium phragmites* to date the Afikpo Syncline to be Campanian – early Maastrichtian. The samples involved yielded practically very poor amount of palynomorphs with no index species for the age of the samples to be determined. Thus, the ages of the samples were indeterminate.

4. Conclusion

The Afikpo Basin, which is part of the larger Benue Trough, situated in southeastern Nigeria has been a subject of discussion by various researchers. This research has used palynology as a tool to contribute to these discussions through field and laboratory analysis. The geological and paleontological study of the Eze- Aku Formation and the wider Afikpo Basin through analyzing the assemblages of palynomorphs found in different rock units, contributes to determining their depositional environment and to our understanding of regional geology, paleoenvironmental conditions, and the tectonic history of southeastern Nigeria. The spores, pollens and fungal spores identified provided insights into their depositional environments. This study also has implications for the exploration and exploitation of natural resources, such as coal and hydrocarbons, within the basin. This will help future palynologists reach further success very effectively.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that there is no conflict of interest.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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