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AN INTEGRATED FACIE STUDY OF AN OUTCROPPING UNIT OF THE EZE-AKU FORMATION AT IBII QUARRY SITE, AFIKPO BASIN, SOUTH EASTERN NIGERIA

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ABSTRACT

An integrated Facie studies of an outcropping unit of the Eze-Aku Formation at the Ibii quarry site, Afikpo Basin, South Eastern Nigeria was carried out to determine the fossil assemblages of the outcrop and the lithologic variations in order to determine the age and paleoenvironment of deposition, using a total of ten samples obtained from the field. The outcrop is composed of intercalation of fine-grained siltstone and shale with varying thicknesses. The samples were subjected to Sedimentological and palynological analyses. The results for the Sedimentological analysis which involved lithologic description, lithofacies analysis and wet sieve analysis show that the samples were highly calcareous. The presence of authigenic minerals such as quartz, heavy minerals, muscovite, gypsum, and mica flakes; and a high value of shale to sand ratio, all infer a marginal marine to marine depositional environment. The palynological analysis yielded practically no palynomorph to very scanty to low quantity of palynomorphs. The palynomorphs include; Psilatricolporites SP, Laevigasporites discordatus, Diatom and Fungal spore. Although the analysis yielded no environmentally significant Palynomorph, the presence of Diatom and Fungal spore in most of the samples and the occurrence of amorphous materials infer that the outcrop was deposited in a marine setting. The age of the Formation could not be determined due to the paucity and the scantiness in the palynological assemblage.

INTRODUCTION

The Afikpo Basin has been a subject of discussion by many researchers, It is composed of three main Cretaceous lithostratigraphic units namely: Asu River Group, the Eze-Aku Group and the post Santonian proto-Niger Delta successions. The Eze-Aku Group consist of shales, limestone and sandstone ridges, with the beds of the Eze-Aku Group overlying the Asu River Group. It has strike ranging from 40º E to 45º E and dip ranging from 20º – 68º. The Sandstone bodies are in parallel to elongate features. The Eze-Aku Group represents the second transgressive depositional cycle that occurred during the upper Cretaceous (Murat, 1972). The Afikpo basin, being a product of the Santonian orogeny, became a significant depocenter after the event. Thus, Post Santonian sediments deposited in the Afikpo Basin include the Eze-Aku Formation. An outcropping unit of the Formation at Ibii quarry site is used as a case study for this work. The sediments involve varying lithology of highly calcareous shales and siltstone. Thus, this research as part of contributing to the wealth of knowledge in the area, intends to determine the lithofacies variation within the Formation, fossil assemblage, age and the depositional environment with a case study of an outcropping unit at Ibii quarry site, employing both Sedimentological and Biostratigraphic analyses. Integrated facie analyses is built on the premise that, the determination of

environmental controls on fossil distribution are commonly established when extant fossil assemblages are correlated to specific lithofacies. Hence, occasions of extensive lithofacie continuity symbolizes low severity of environmental influences, irrespective of certain exceptions (Steven et, al., 2001). Determining the lithofacies variations, fossil assemblage, age and depositional environment of any outcropping unit can be instrumental in reconstructing certain preliminary infrastructures that may reveal or trace the presence of hydrocarbon or economic minerals.

GEOLOGICAL SETTINGS

A century of geological studies have enabled a broad understanding of the geology of the Benue Trough. But it was only in the later part of the 20th century that a picture of the structural framework, within which the Benue Trough evolved emerged. The controversies surrounding the tectonic evolution of the Benue Trough have been largely resolved, with the overwhelming evidence leaning towards the interpretation of the so-called French school of structural Geologists which sees the Benue Trough as a collection of pull apart basins, related to transcurrent or strike-slip movement along deep-seated basement shear zones of Pan African origin reactivated as Oceanic transform faults (Benkhelil, 1982; 1989; Guiraud, 1993). This view is supported by field evidence in the Northern Benue Trough, where the climate and the nature of the sedimentary units allow for classic geologic study. In the Southern Benue Trough, the fine-grained nature of most of the units and the dense vegetation as a result of a wet tropical climate have hindered field studies and created a missing link in the proper explanation of the structural framework of the basin (Okonkwo, 2014).

According to King (1950), Farrington (1952), Nwachukwu (1972), Murat (1970), the Benue Trough originated as a failed arm at the time of the opening of the South Atlantic Ocean during the separation of the African plate and the South American Plate. Benue Trough is defined as an intercontinental Cretaceous basin about 1000km in length stretching NE-SW direction and resting unconformably upon the Precambrian Basement Complex. It is subdivided into the upper, middle and lower region, extending from the Niger delta to the Northeast Chad Basin.

The Lower Benue Trough comprises of the Abakaliki Anticlinorium, Afikpo Basin to the east and Anambra Basin to the west. The Afikpo Basin originated during the Santonian Orogeny in the Upper Cretaceous time, during the Santonian tectonism; older strata were folded, faulted, intruded and uplifted. The folding resulted into the formation of 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 Anambra Basin. Although the lithic fill in the Afikpo syncline postdates to the Santonian folding event. There is therefore no justification for according the Afikpo Syncline the status of a Basin distinct from the Anambra Basin, Nwajide, (2013).

LOCATION OF STUDY AREA

The study area as shown in Fig (1.) lies within longitude N5^{0}56’55.83” and latitude E7^{0}57’11.1”. The quarry site is located along a road into Ibii, the area has good road network and is easily accessible by main roads and minor roads including foot paths. The major access roads into the study area include the Abakaliki –Afikpo road, Okigwe- Afikpo road.

Fig 1: Map of Nigeria Showing Area of Study (Ogbonnaya, 2012)

LITERATURE REVIEW

Several academic scholars have invested in the study of the Benue Trough and the Sub-basins within it.

Prominent amongst them are: Reyment (1965), who gave detailed lithostratigraphic and biostratigraphic description of the Cretaceous rocks of Benue Trough, establishing faunal units, some of which are still in use today. These descriptions have been built upon by further works undertaken in the Southern Benue Trough ((Murat, 1972; Ojoh, 1992; Peters, 1980; Umeji, 2000). A summary of the stratigraphy of the Nigerian sedimentary basins have been provided by Kogbe (1989) and Nwajide (2013).

Studies have also been carried out on the sedimentology of Afikpo Basin, establishing the different facies and environment of deposition as well as reservoir potential (Amajor, 1987; Banerjee, 1980; Odigi and Amajor, 2009b).

Works of Oloto and Ilagha (2013) provides petrographical analysis on the rocks of the Afikpo syncline. Short and Stauble (1967) also noted the stratigraphic unit of south eastern Nigeria with their respective associated age. Simpson (1954) noticed that the high angle of the dip in the Eze-Aku group was as a result of the post-Turonian tectonic unit. Reyment (1965) presented a biostratigraphic correlation of the southern Nigeria using Pelecypoda, Ammonite and Foraminiferals index fossils.

Odigi and Amajor, (2009) noted the results from regional tectonics and micro-tectonic analysis of the micro faults at the North central part of the Basin, this enabled them to accord the Afikpo syncline the status of a Basin.

Much work has not been done in the Afikpo Basin in terms of paleontology, until recently Umeji, (2000) assigned the age and paleoenvironment of Afikpo Basin from the study of the Shell petroleum development Afikpo-4 well. Results from palynological analysis gave the age as Campanian-Maastrichtian and the environment of deposition to be near shore and marginal marine based on the specie assemblage.

Okoro et.al., (2012) dated the Afikpo Basin to be Campanian-Maastrichtian, and depositional environment to be marginal to open marine environment using palynological data.

MATERIALS AND METHOD

Samples were collected in an outcropping unit of Ezeaku Formation at the Ibii quarry site, Afikpo Basin of South Eastern Nigeria. The studied outcrop is composed of a succession of shale and inter-beds of siltstones respectively (Figs 2 and 3). A total of ten (10) samples were collected carefully using shovels and geologic hammers in other to obtain fresh samples. Collection was made in increasing depth, using the measuring tapes for measurements owing to the occurrence of shale and siltstone beds. The collected samples were then put into a nylon/polythene sample bag all labeled accordingly using the masking tape to avoid contaminants and for ease of identification. The samples were then analyzed in the laboratory to describe the lithostratigraphy and lithofacies, where the samples were subjected to wet-sieve analysis to evaluate for sand/shale ratio, the data generated from this analysis was used to plot a sand/shale ratio plot. Also, the identification of mineral constituents and the various percentages of their occurrence in each sample was studied. The paleontological analysis was also done to determine the fossil assemblage.

RESULTS AND DISCUSSIONS

The results generated from the study carried out were tabulated to ensure for clarity and easy reading.

LITHOSTRATIGRAPHY

Lithostratigraphy is a subdivision or an element of stratigraphy that deals with the identification, characterization and nomenclature of the rocks of the earth based on their lithology and their stratigraphic relation. Sedimentological characteristics utilized in this study include; Lithology, texture, colour, mineralogy, fossil content and environmentally sensitive index minerals and accessories. Chemical test was carried out in order to determine the presence of calcareous forms by using dilute Hcl, thus on application of dilute Hcl, a high degree of effervescence was obtained showing the samples were highly calcareous (Table 1).

The result showed that the samples from base to the top consist of an intercalation of shale and siltstone grading from light grey to dark grey in colour (Fig 3.).

Table 1: Showing Lithological Description

Sample no	Depth (m)	Description	Remark
1	0.9	Shale, grey in colour, fine grained and fissile	Highly calcareous
2	1.42	Siltstone, grey in colour and fine grained	Highly calcareous
3	1.46	Shale, grey in colour, fine grained and fissile	Highly calcareous
4	1.56	Shale, grey in colour, fine grained and fissile	Highly calcareous
5	2.07	Shale, grey in colour, fined grained and fissile	Highly calcareous
6	2.21	Shale, grey in colour, fine grained and fissile	Highly calcareous
7	3.61	Siltstone, grey in colour, fine grained	Highly calcareous
8	3.77	Shale, grey in colour, fine grained and fissile	Highly calcareous
9	4.52	Siltstone, grey in colour, fine grained.	Highly calcareous
10	4.60	Shale, grey in colour, fine grained and fissile	Highly calcareous

Fig 2.: Showing an outcropping unit of Ezeaku Formation shale and siltstone interbeds at the Ibii quarry site in the Afikpo Basin, South Eastern Nigeria.

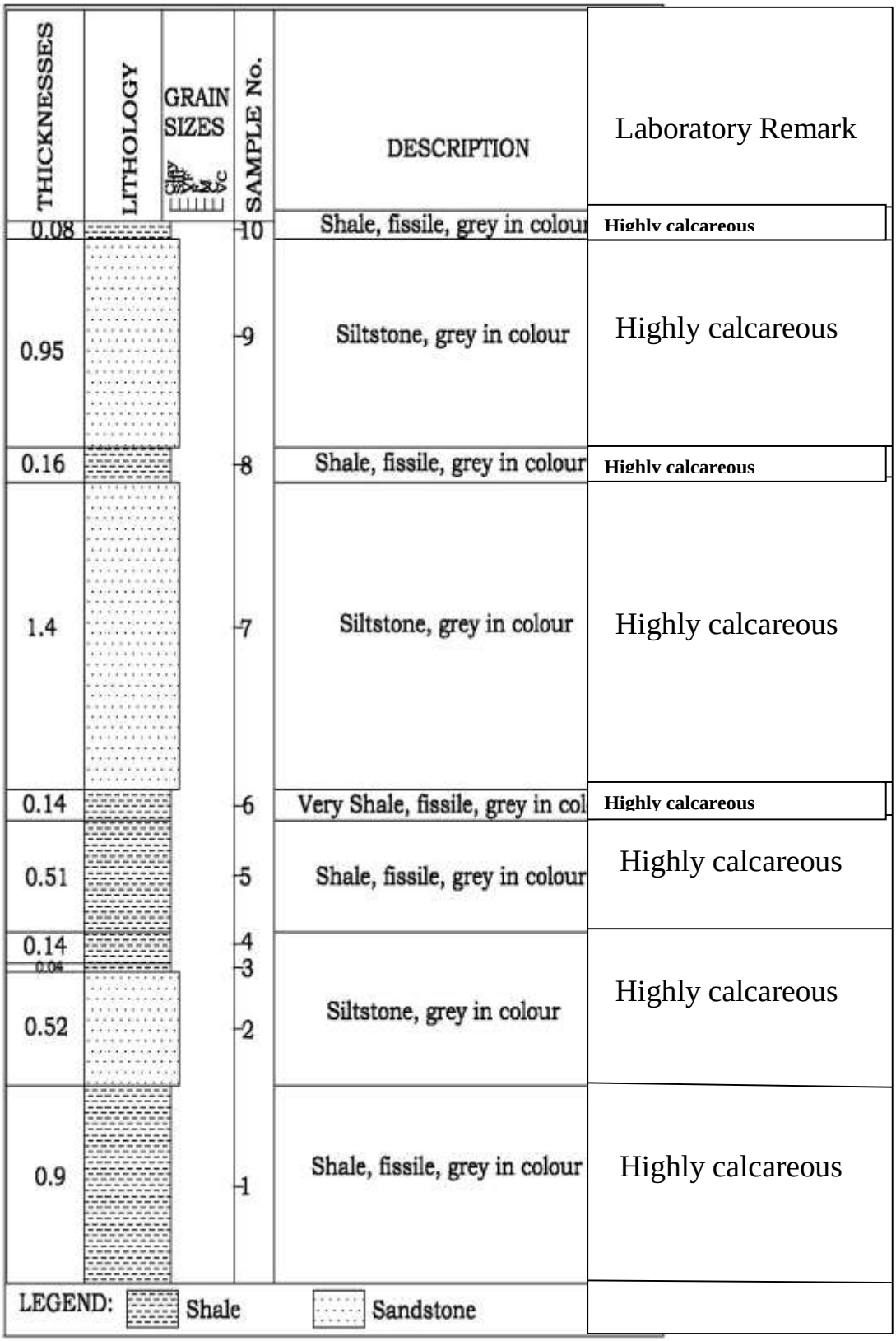

Fig 3.: Showing graphic log and Laboratory Description of the Samples

LITHOFACIE ANALYSIS

Table 2: Showing Lithofacies Percentage Analysis

Sample no	Quartz (%)	Rock fragments (%)	Muscovite (%)	Heavy mineral (%)	Gypsum (%)	Ferruginized fragments (%)	Mica flake(%)
1	15	55	15	10		5	
2	10	30	10	40			10
3	70	5	10		5	10	
4	65	10	15	5		5	
5	45	5	5	15	5	20	5
6	70	5	10	5	5	5	
7	60	10	10	20	20		
8	65	10	15	5	5	5	
9	70	5	10	10	10		
10	65		10	10	10	5	

The result generated from lithofacies analysis as shown in (Table 2.) was used to plot the lithofacies against the depth at which samples were collected as shown in (Fig 4.). Thus, the plot shows a high occurrence of authigenic minerals such as quartz increasing from the base to the top which suggests environment of deposition to be likely near shore or shore face which is typical of a shallow marine environment. The occurrence of other authigenic minerals such as gypsum, heavy minerals, and mica flakes further supports this interpretation.

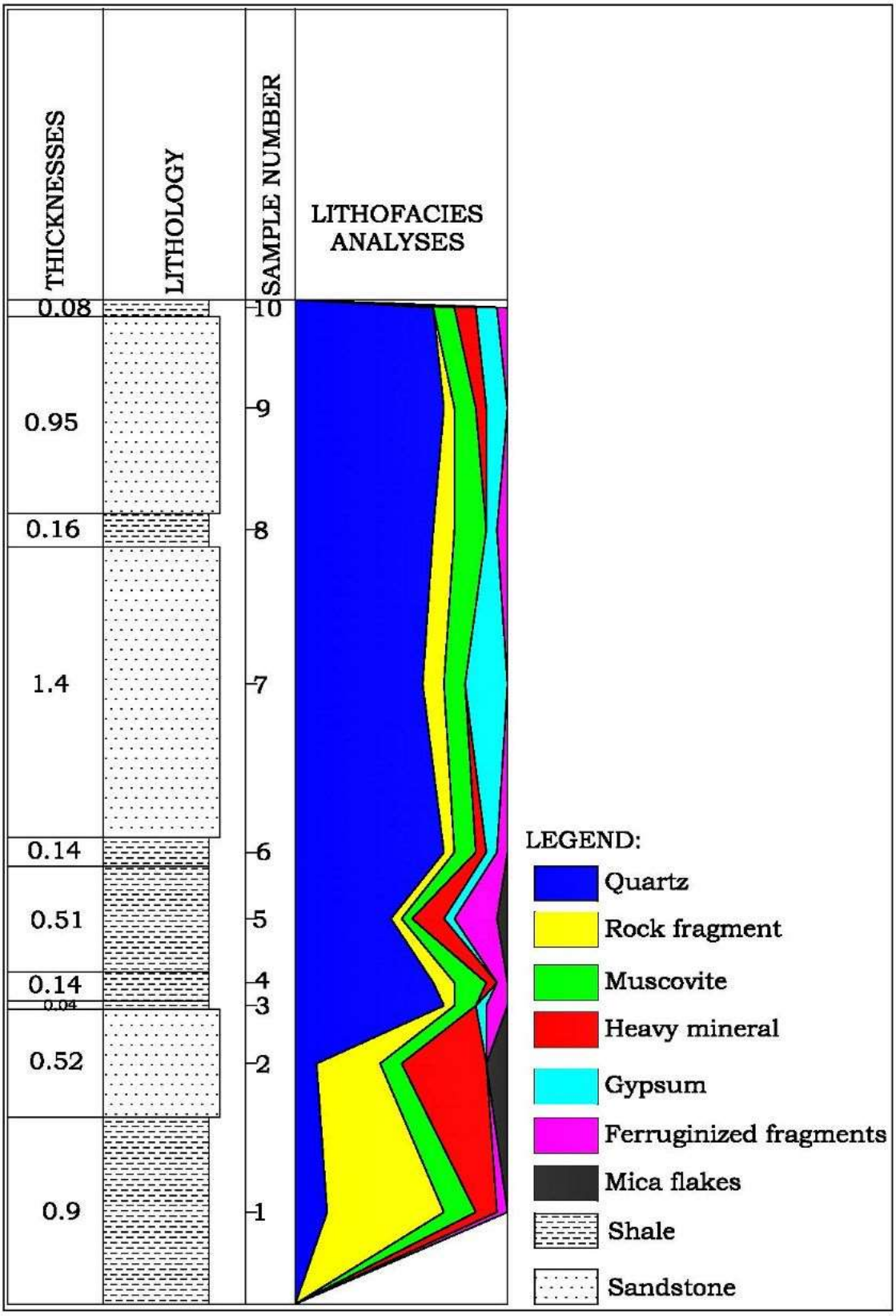

Fig 4: Showing lithofacies analysis plot of the studied area

SAND/SHALE RATIO

The wet-sieve analysis that was carried out on each of the (10) samples yielded the following:

Table 3. ; Showing the weight retained and weight lost from wet-sieve analysis

Sample no	Total weight (grams)	Weight retained sand (grams)	% Sand retained	Shale weight lost	% lost.
1	5	1.9	38	3.1	62
2	5	3.9	78	1.1	22
3	5	1.6	32	3.4	68
4	5	1.8	36	3.2	64
5	5	1.9	38	3.1	62
6	5	1.9	38	3.1	62
7	5	3.1	62	1.9	38
8	5	2.1	42	2.9	58
9	5	2.9	58	2.1	42
10	5	2.1	42	2.9	58

The result generated from wet-sieve analysis as shown in Table 3 was then used to plot a sand/shale ratio log shown in (Fig 5.), The plot shows a high value of shale to sand ratio of an inner neritic and delta front environment all of which depict a marine environment.

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SAND/SHALE RATIO LOG PLOT AGAINST DEPTH

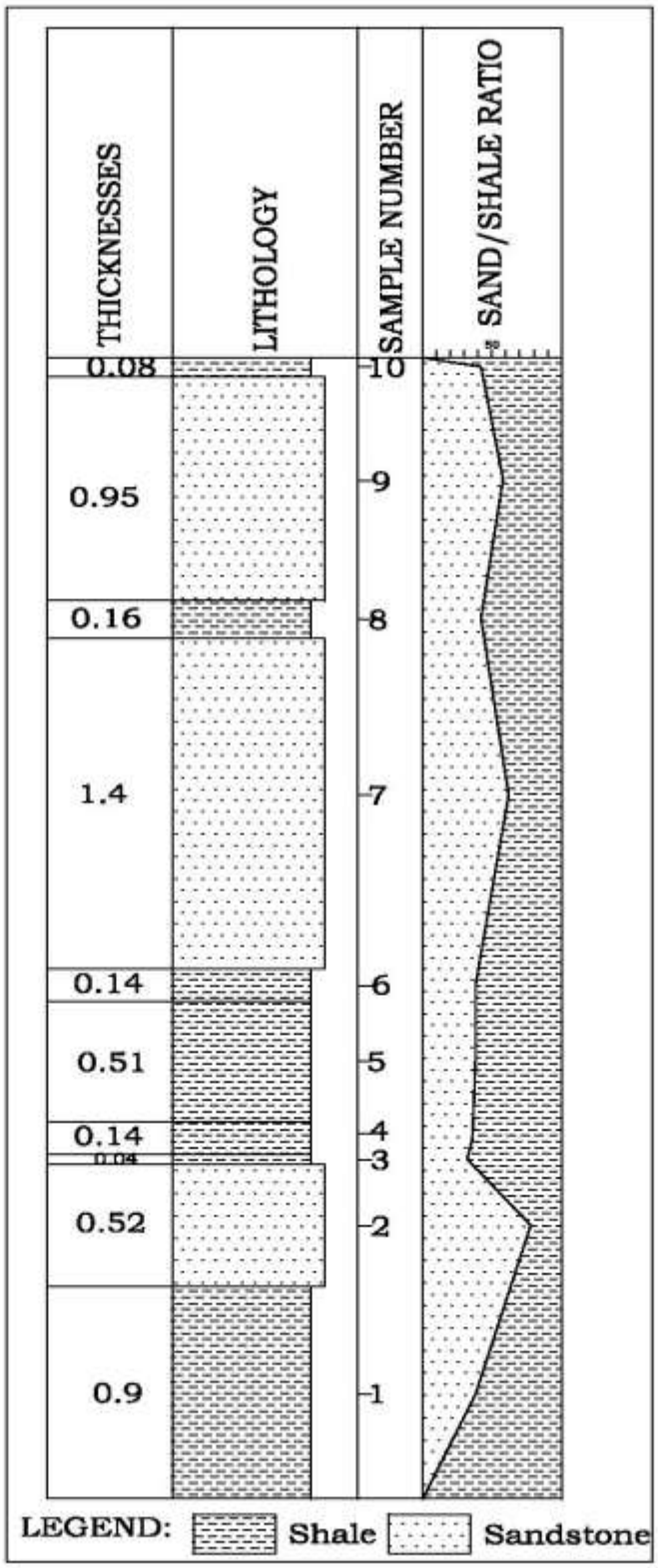

Fig 5:

Showing Sand/Shale Ratio Plot

BIOSTRATIGRAPHY

Biostratigraphy is also a subdivision or an element of stratigraphy that deals with the characteristics and identification of rocks based on their fossil content in relation to stratigraphy. The biostratigraphy of the studied outcrop is therefore based on the fossil assemblage recovered from the laboratory analysis.

The samples were subjected to palynological analysis which yielded practically no palynomorphs to very scanty and low quantity of palynomorphs. The result was used to plot abundance and diversity plot against depth (Fig 6).

Table 4: Showing Abundance and Diversity Distribution

Sample No	Taxom Name	Count
1	Diatom	1
	Fungal Spore	3
2	Diatom	1
	Fungal Spore	2
	Psilatricolporites Sp	1
3	Diatom	6
	Fungal Spore	1
4	Barren	Barren
5	Diatom	1
	With Amorphous Materials	
6	Barren	Barren
7	Diatom	3
8	Diatom	1
9	Diatom	2
	Fungal Spore	1
10	Diatom	6
	Fungal Spore	1
	Laevigasporites Discordatus	1

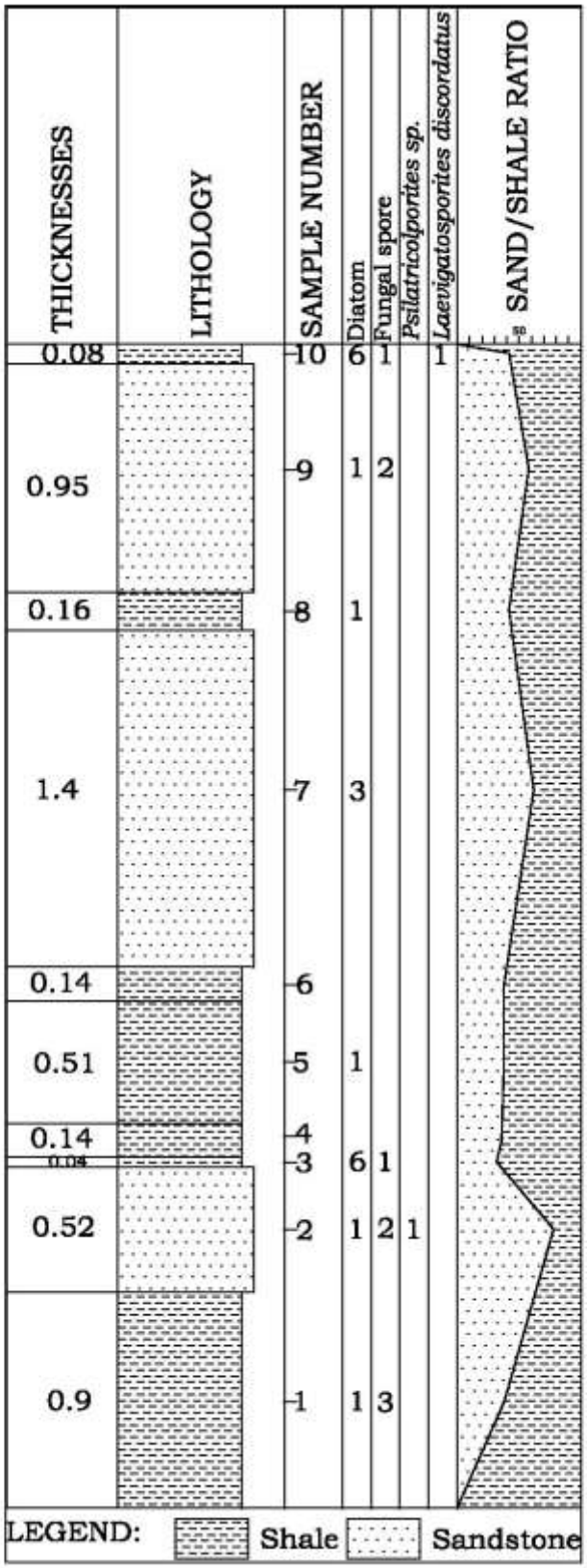

Fig 6: Showing the distribution chart

A distribution chart showing the distribution of the fossils against their depth of occurrence is made alongside with a graphic log and a sand/shale ratio plot of the studied outcrop. A total of four (4) species were encountered with Diatom dominating the chart both in abundance and in frequency, which further suggests the environment of deposition is marine environment.

PALEOENVIRONMENT

The aim of paleoenvironmental analysis is to reconstruct the biological, chemical and physical nature of the environment at the time of deposition, based on the rocks, paleontological records can be reconstructed for ancient depositional environments.

Thus, from the biostratigraphic analysis that was carried out, no environmentally significant palynomorphs were recovered from the samples, however the occurrence of Diatom fostules with Fungal spores in most of the samples shows that the Eze-Aku Formation was probably deposited in a marine setting. The occurrence of amorphous material supports this interpretation.

AGE DETERMINATION

The samples involved yielded practically no palynomorphs to very scanty and low quantity of palynomorphs. Due to this paucity, the age of the samples could not be determined.

DISCUSSION.

From the lithofacies analysis carried out, it can be inferred that the sediments are of marine environment. Most of the environmental interpretations in this study, are mainly based on the affinities of minerals which are useful in determining the depositional environments. In the analyzed samples, moving from sample 1 to sample10, there is a mark increase in quartz with relative minimum scale fluctuations in samples 2 and 10, except for sample 5 which decreased outrageously compared to sample 2 and 10. There is also a relative decrease in rock fragments and minor scale fluctuation in muscovite. There is increase in abundance of heavy minerals with no occurrence of gypsum and accessory compositions of ferruginized fragments and mica flakes in sample 1 and 2. Samples 4-10 marks relative fluctuations of increase and decrease in muscovite as well as heavy minerals although samples 7 and 8 are entirely lacking of heavy minerals. Samples 5-10 mark an increase with minimum scale fluctuation in gypsum. Thus, the occurrence of gypsum from samples 5-10 is an indication of shallow marine or lagoonal environment showing there was reduction or fall in sea level exposing its shoreline. The occurrence of authigenic minerals such as quartz, heavy minerals, gypsum, and mica flakes further suggest possible environment of deposition to be likely nearshore or shore face which suggest continental shelf and shallow marine environment. This interpretation is based on the assertion that authigenic minerals are the main constituents of marine sedimentation.

The occurrence of Diatom fostules in almost all the samples, provides additional evidence on the environment of deposition. Its occurrence evidences shallow marine to marine environment, because, it lives in all forms of sub-aquatic to aquatic environments within the confines of the photic zone. This interpretation follows the precept that the distribution of fossil assemblage in any stratigraphic section may be controlled by paleo ecological factors Hamza et al, (2002). As such any significant change in fossil assemblage that corresponds with a relative change in lithology is probably due to the environmental tolerance of the fossil species. Therefore, some fossils serve as environmental indicators and are used to interpret ancient environments of deposition.

Hence in general the rock fragments found within the lithofacies are indicative of the fact that volcanic rocks from high mountainous area have been eroded and transported to the basin, which is also responsible for the abundance of quartz.

Furthermore, the result generated from the wet sieve analysis, which depicts high value of shale to sand in the sand/shale ratio plot, indicates an inner neritic and delta front environment of deposition all of which are of marine environments.

SUMMARY AND RECOMMENDATIONS

An integrated Facie study of an outcropping unit of the Ezeaku Group at Ibii quarry site, Afikpo Basin, South Eastern Nigeria was carried out. The study involved both processes of field and laboratory analyses. A total of ten samples were obtained from a section of the outcrop logged accordingly from the base and further used to produce a lithologic graphic log as shown in Fig (3). The samples were made up of fine-grained siltstone and intercalation of shale. The samples were subjected to Sedimentological and palynological analysis respectively. The lithological analysis was done as it relates to colour, grain size and rock type. The samples were tested with dilute HCL to determine carbonate content, those that showed effervescence were termed calcareous and those that did not show effervescence were termed non-calcareous. Furthermore, the samples were subjected to wet-sieve analysis to evaluate for sand/shale ratio, the data generated from this analysis was used to plot a sand/shale ratio plot which showed a relatively high value of shale to sand. This inferred a marginal marine to marine depositional environment. The samples were also subjected to lithofacies analysis which shows occurrences of authigenic minerals such as quartz, heavy minerals, muscovite, gypsum and mica flakes which also infer a marginal marine depositional environment. A lithofacies plot was produced from the analysis.

The samples after being subjected to palynological analysis yielded practically no palynomorph to very scanty and low quantity of palynomorphs. The palynomorphs include; Psilatricolporite SP, Laevigasporites discordstus, Diatom and Fungal spore. A fossil abundance and diversity chart was generated using the depth-to-depth occurrences. Although the analysis yielded no environmentally significant palynomorphs, the presence of Diatom and Fungal spores in most of the samples infers that the Ezeaku Group was probably deposited in a marine setting, which is further corroborated by the occurrence of amorphous material. However, due to the paucity in the nature of the palynological analysis result, the age of the outcrop could not be determined.

REFERENCES

[1] Amajor, L. C. (1987). The Eze-Aku Sandstone ridges (Turonian) of south eastern Nigeria: A reinterpretation of their Depositional origin. Nigerian Journal of Mining and Geology, 23(1), 17–26.

[2] Amajor, L. C (1985). The Cenomanian hiatus in the Southern Benue Trough, Nigeria .Geological Magazine, 122(01),3950.doi:10.1017/S 0016756800034063.

[3] Banerjee, I. (1980). A Subtidal bar model for the Eze-Aku Sandstones, Nigeria. Sedimentary Geology, 25(4), 291–309. doi:10.1016/0037-0738(80)90066-4.

[4] Benkhelil, J. (1989). The origin and evolution of the Cretaceous Benue Trough (Nigeria). Journal of African Earth Sciences (and the Middle East), 8(2–4), 251–282. Doi:10.1016/S0899-5362(89)80028-4.

[5] Benkhelil, J. (1982). Benue Trough and Benue Chain. Geological Magazine, 119(02), 155–168. doi:10.1017/S001675680002584X.

[6] Farrington, J. L. (1952). A preliminary description of the Nigerian lead-zinc field. Economic Geology, 47(6), 583–608.

[7] Guiraud, M. (1993). Late Jurassic rifting-early Cretaceous rifting and late Cretaceous transpressional inversion in the upper Benue basin (NE Nigeria). Bulletin DesCentres de Recherches Exploration-Production Elf Aquitaine, 17(2), 371–383.

[8[Hamza, H. Obaje, N. G, and Obiso, E. O. (2002). Foraminifera assemblage and Paleoenviroment of the Fika Shale Bornu Basin, Northeastern Nigeria.Journal of Mining and Geology, Vol. 38(No.1), pp. 49-55.

[9] King, L.C., (1950). Outline and disruption of Gondwanaland. Geological Magazine 87, 353–359.

[10] Kogbe, C. A. (1989). Paleogeographic history of Nigeria from Albian times. In Geology of Nigeria. Elizabethan Publishers, Lagos (pp. 237–252).

[11] Murat, R. C. (1972). Stratigraphy and paleogeography of the Cretaceous and lower Tertiary in Southern Nigeria. In Proc. of the Conf. on African Geology held at Ibadan, Nigeria. pp (pp. 251–266).

[12] Murat, R. C., (1970). Stratigraphy and Palaeogeography of the Cretaceous and Lower Tertiary in Southern Nigeria. African Geology, University of Ibadan press, p. 251 – 268.

[13] Nwajide, C. S. (2013). Geology of Nigeria's Sedimentary Basins. Lagos: CSS Press.

[14] Odigi, M. I., (2012) Sedimentology of the Nkporo Campanian-Maastrichtian Conglomeratic Formation, Afikpo Sub-Basin, Southeastern Benue Trough, Nigeria. Journal of Minning and Geology. Vol. 48(1) 2012, pp.45-55.

[15[Odigi, M. I., & Amajor, L. C. (2009b). Geochemical characterization of Cretaceous sandstones from the Southern Benue Trough, Nigeria. Chinese Journal of Geochemistry, 28(1), 44–54. doi:10.1007/s11631-009-0044-7.

[16] Odigi, M. I., & Amajor, L. C. (2009a). Brittle deformation in the Afikpo Basin (Southeast Nigeria): Evidence for a terminal Cretaceous extensional regime in the Lower Benue Trough, Nigeria. Chinese Journal of Geochemistry, 28(4), 369–376. doi:10.1007/s11631-009-0369-2.

[17] Ojoh, K. A. (1992). The southern part of the Benue Trough (Nigeria) Cretaceous stratigraphy, basin analysis, paleogeography, and geodynamic evolution in the equatorial domain of the South Atlantic. NAPE Bull, 7(2), 131–152.

[18] Ojoh, K. A. (1990). Cretaceous geodynamic evolution of the southern part of the Benue Trough (Nigeria) in the equatorial domain of the south Atlantic: stratigraphy, basin analysis, and paleogeography. Bull. Centres Rech. Explor-Prod. Elf-Aquitaine 14, 2, pp. 419-442.

[19] Okoro A. U., Ofuegbu, C, O. and Ige, O. E., (2012). A review of the Geology of the Benue Trough, Nigerian Journal of African Earth Sciences, Vol.55(2) pp. 45-52.

[20] Oloto, I. N., Ilagha, A., (2013) Petrographical studies of Amate Area, Afikpo Basin Southern Benue Trough. International Journal of Innovative Research in Science, Engineering and Technology.

[21] Petters, S. W. (1980). Biostratigraphy of Upper Cretaceous foraminifers of the Benue Trough, Nigeria. The Journal of Foraminiferal Research, 10(3), 191–204.

[22] Reyment, R. A. (1965). Aspects of the Geology of Nigeria: The Stratigraphy of the Cretaceous and Cenozoic Deposits. Ibadan University Press.

[23] Short, K. C. and Stauble, A. J., (1967). Outline of Nigeria Delta. American Association Petroleum Geologist. Bulletin, V. 5, p. 761 – 779.

[24] Simpson, A. (1954). The Nigerian Coal Field, Geology of Parts of Onitsha, Owerri and Benue Provinces. Bull. Geol. Surv. Nig. 24, 1 – 31.

[25] Umeji, A. C. (2000). Evolution of the Abakaliki and the Anambra Sedimentary Basins, Southeastern Nigeria [R]. A Report Submitted to the Shell Petroleum Development Company Ltd, 155.

KEYWORDS: Biofacie, Lithofacie, Eze-Aku Formation, Paleoenvironment, Sand/shale ratio, Afikpo basin, Ibii.