AGE DETERMINATION AND DEPOSITIONAL ENVIRONMENT OF THE NSUKKA FORMATION IN IHUBE OKIGWE AREA, SOUTH-EASTERN NIGERIA

[1]ODUMOSO, S.E, [2]NFOR, B.N, [3]VINCENT, C.P.

[1,3]DEPARTMENT OF EARTH SCIENCES, FEDERAL UNIVERSITY OF PETROLEUM RESOURCES, EFFURUN, DELTA STATE

[2]DEPARTMENT OF GEOLOGY CHUKWUEMEKA ODUMEGWU OJUKWU UNIVERSITY, ULI ANAMBRA STATE

ABSTRACT
Biostratigraphy investigation of Nsukka Formation was carried out by subjecting well samples obtained from various locations in Ihube Okigwe Local Government area of imo state to palynological studies with the view towards determining the relative geologic age and depostional environment of the sediments. The Samples obtained were treated in the laboratory through digestion with hydrofluoric acid (as all the samples were non-calcareous), thorough washing and sieving with a 10micro meter sieve , oxidation(1) with Nitric acid.oxidation (2) with the Schulze solution.cleansing with potassium hydroxide.swirling and mounting of the slides into sections with DPX mountant. A fairly high abundance and diversity of miospores were recovered, while the interval (847–1372 m) contains distinctive and diagnostic palynomorphs which are stratigraphically important.
A Spinizonocolpites baculatus assemblage zone was established based on the basal occurrence of S. baculatus, Spinizonocolpites echinatus, Constructipollenites ineffectus, Periretisyncolpites sp. Periretisyncolpites giganteus, Monocolpites sp 1, Foveotriletes margaritae, Syncolporites marginatus, and Longapertites marginatus. The upper part of the interval is marked by association of Anacolosidites luidonisis (at top), Mauritiidites crassibaculatus, Retistephanocolpites williamsi, Proteacidites dehaani, Echitriporites trianguliformis, Proxapertites cursus, Retidiporites magdalenensis, S. baculatus, Retitricolpites gigeonetti, F. margaritae and Araucariacites sp. The Nsukka Formation is dated as Late Maastrichtian based on the co-occurrence of recovered index fossils. Importantly, Cretaceous–Tertiary (K/T) boundary is marked by high fossil content in the Maastrichtian sediments compared to paucity in palynomorph that characterise the overlying Paleocene facies. Palaeoenvironment of the analyzed section varies alternately from marginal marine to continental setting based on the presence of land-derived miospores and dinoflagellates.

Keywords: Nsukka Formation, Palynology, Sedimentary Environment

I. INTRODUCTION

This work is primarily concerned with the Geologic Age and sedimentary environment of deposition of the Nsukka Formation exposed at Ihube town Okigwe Area of Imo State, which is part of the Anambra Basin.

The Anambra Basin is an inland intracratonic basin located adjacent to Niger Delta, Nigeria. Its study continues to attract attention of many geologists because of proven hydrocarbon reserves present. The Anambra Basin ranks almost next to Niger Delta in terms of richness in hydrocarbon reserves. Despite enormous amount of work done on the geology of the basin including the petroleum geology, biostratigraphy and sedimentology, there are no much details available on the biostratigraphy of Nsukka Formation. Therefore, there is need to further understand the stratigraphic stacking pattern especially the biostratigraphy of Nsukka Formation in terms of age and paleo environment of deposition which could serve as a correlation platform for regional stratigraphic study.

The basin is exposed over a roughly triangular territory, estimated at some 95,000 km2 (Nwajide, 2005). The Anambra Basin is separated from the Dahomey Basin by a basement high-the Okitipupa Ridge and the Abakiliki Anticlinorium to the west and east, respectively. Its demarcation from the Bida Basin to the Northwest is less clear and is arbitrarily placed. The north-eastern and southern boundaries of the basin bordering some parts of the Benue Trough and the Niger Delta are still not very clear due to the stacking of the basins (Onyekuru et al, 2010).

In the light of establishing geologic Age and depositions environment of the Nsukka formation in ihube Oliver of the anambra Basin is the major aim of this project work, field relationships as such basic sedimentological tools were used for depth analysis of these formation

The samples collected from the study area were subjected to laboratory studies basically sieve analysis.The geological field data collected and that of result interpretations from laboratory studies were used to establish the Age and depositional environment.

II. AIM AND OBJECTIVES

The fundamental aim and objective of this project is determine;

- the Geologic Age
- Depositions environment of the Nsukka formation with a study area of Ihube and okigwe Area of IMO state through basic field relationship and grain size distribution studies.
- Grain size analysis of sediments as a descriptive parameter and as an aid to the interpretation of depositional processes
- Palynological studies aimed at dating the rock units

III. LITERATURE REVIEW

The stratigraphic sequence of the Anambra Basin has been discussed extensively by several workers including Agagu et al., 1985, Dessauvagie, 1975, Ladipo, 1986; Murat, 1972, Nton and Bankole, 2013, Ola-Buraimo and Akaegbobi, 2013b, Reyment, 1965; Though, sedimentation in the Anambra Basin was based on the long standing assumption that it started and ranged from late Santonian to Eocene but recent research work of Ola-Buraimo and Akaegbobi (2012) on Ogwashi–Asaba Formation has shown that the formation in actual fact is of Late Miocene to Pliocene age based on the presence of dinoflagellate cysts. It has also been advanced that the oldest sediment in the basin like the other known parts is Asu-River Group, dated as Albian to early Cenomanian (**Ola-Buraimo and Akaegbobi, 2013b**) through the use of pollen and spores assemblages.

The Ogwashi-Asaba Formation is made up of variable succession of clays, sands and grits with seams of lignite. It also forms part of the study area. The Ameki Formation consists of greenish-grey clayey sandstones, shales and mudstones with interbedded limestones. This Formation in turn overlies the impervious lmo Shale group characterized by lateral and vertical variations in lithology. The lmo Shale of Paleocene age is laid down during the transgressive period that followed the Cretaceous. It is underlain in succession by Nsukka

Formation, Ajali Sandstones and Nkporo Shales.(**L.I. Nwosu, C.N. Nwankwo and A.S. Ekine 2013)**

Short and Stauble (1966) also outlined the geology of the area of Anambra basin and inferred that subsidence in the Santonian resulted in the deposition the Nkporo Shale and the coralliferous Mamu Formation, Ajali Formation and Nsukka Formation. **Kogbe (1989**) was of the view that after the deposition of the Nkporo Shale and its lateral equivalents (the Enugu Shale and the Owelli Sandstone) in Campanian, the broad shallow sea gradually becomes, shallower and the paralic sequence of the Mamu Formation was deposited. He further said that this formation was overlain by the continental sequence of the Ajali Formation followed by a return to partially paralic conditions with the deposition of the Nsukka Formation. Also, the Mamu Formation is restricted to the Anambra Basin in SE Nigeria-West of the River Niger.

Agagu et al. (1985) carried out a study of the stratigraphy and sedimentation in the Senonian Anambra basin of Eastern Nigeria and noted that the depositional pattern has resulted in a general consistent alteration of sandstone and shale unit, an incidence that is propitious for petroleum generation and accumulation. They also proposed an additional depositional sequence (Ogugu Formation, Owelle Formation) identified in the Santonian-Maastrichtian section of the Anambra basin.

Sedimentologic studies on some sandstone unit in the Anambra Basin have been carried out by some workers including Jones and Hockey (1964), Reyment (1965), Murat(1972), Agagu (1979),

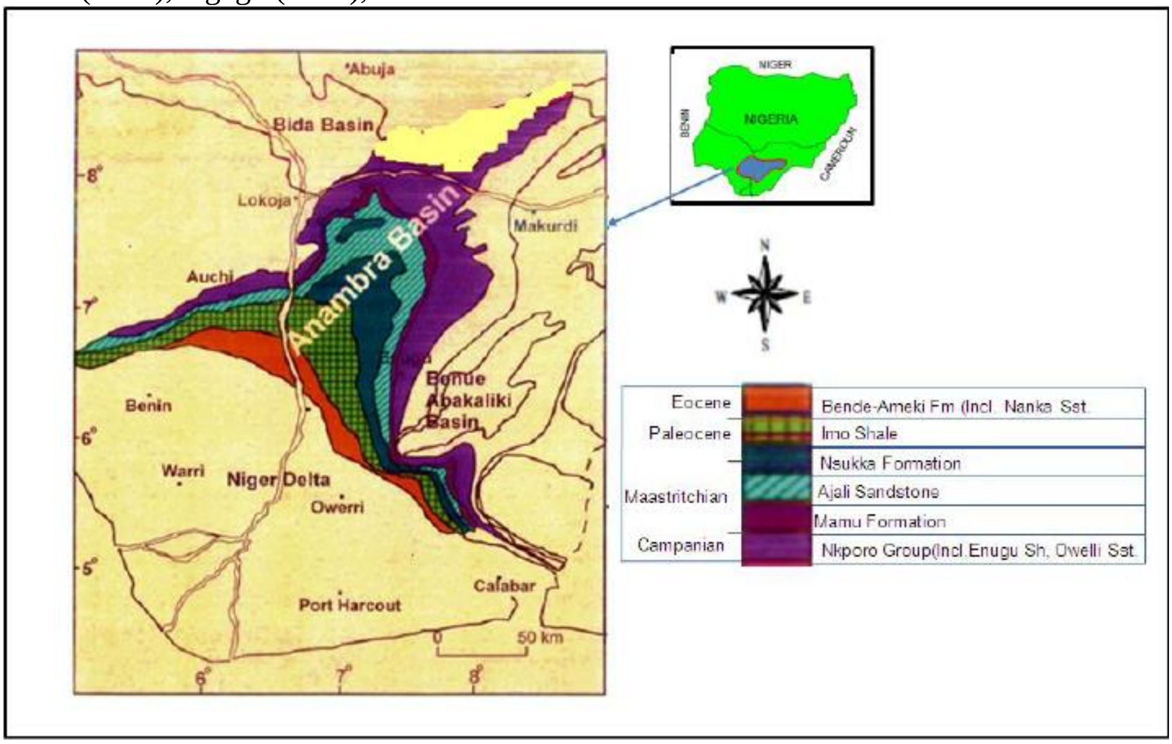


Fig 2.2: Map showing the Regional Stratigraphy of the Anambra basin.

The Anambra Basin, is strongly folded Albuian-Coniacian succession (Santonian sediments) is overlained by nearly flat-lying Campanian-Eocene succession .

The structural setting and geoloy of the Anambra Basin have been documented by various workers. Sedimentation in the Anambra Basin commenced with the Nkporo Group (Nwajide,

1990). it was deposited into the Basin in the Late Campanian, comprising of the Nkporo Shales , Owelli Sandstone and the Enugu SHALE (Reyment, 1965 and Obi, 2001) .
The Nkporo is overlain by the Mamu Formation, it was deposited in Early Maastrichtain(Kogbe, 1989 and Obi,2000) . The Ajali sandstone overlies Mamu formation(Reyment,1965 and Nwajide, 1990) which is mainly unconsolidated coarse fine grained , poorly cemented; mudstone and siltstone(Kogbe,1989).
The Ajali sandstone is overlain by diachronous Nsukka Formation (Maastrichtain-Danian) which is also as the Upper coal measure. The Imo shales overlie Nsukka Formation (Nwajide, 1990). It comprises of clayey shale with occasional ironstone and thin sandstone in which carbonized plants remains may occur (Kogbe, 1989). the Eocene stage was characterized by regressive phase that led to deposition of Ameki Group(Obi, 2000).

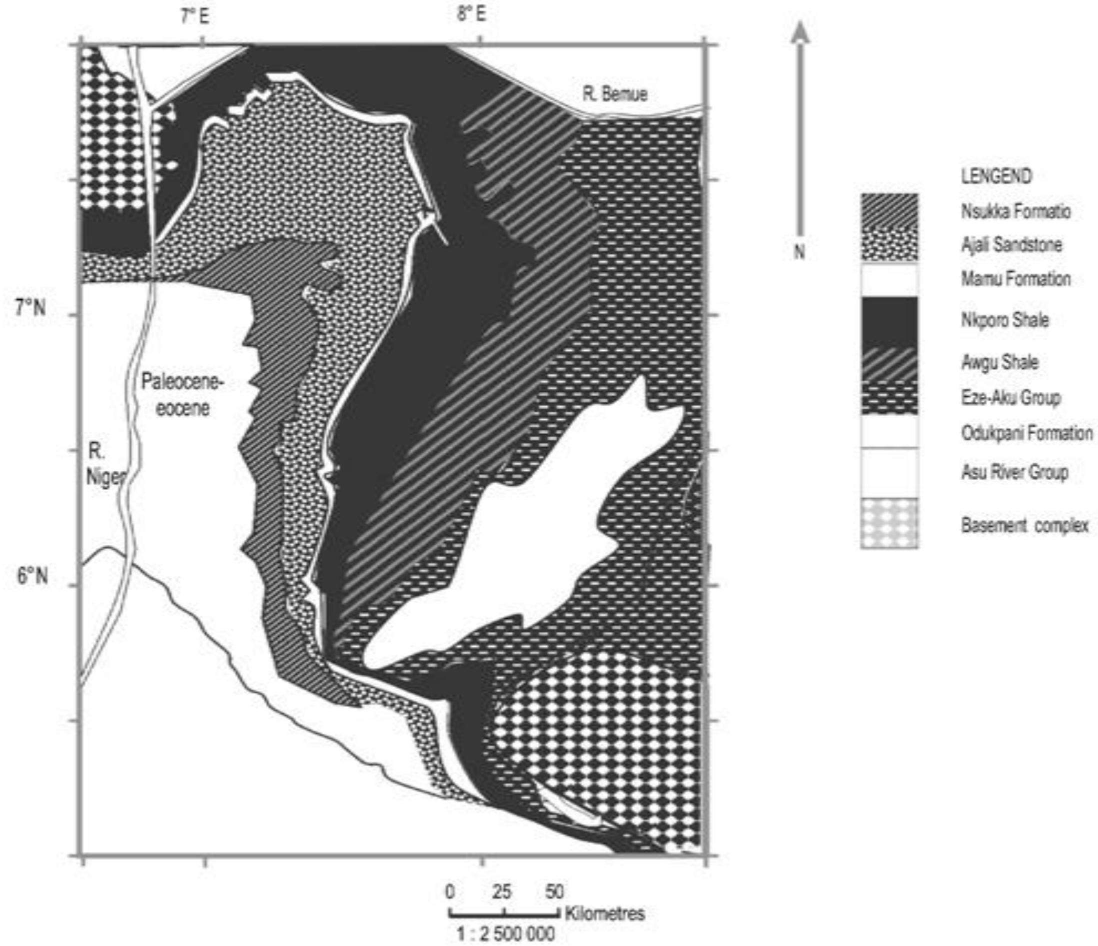


Fig 2.3: map showing the Regional stratigraphy of the Southeastern Nigeria (after Nwajide 1990)
Referring to the stratigraphic setting of southern Nigeria established by (Nwajide, 1990) it ccomprises of sediments which are of three major sedimentary cycles. The firdt two cycles belongs to the Pre-Santonian sediments while the third cycle belongs to the Post -Santonian sediments which are found in the Anambra Basin and Afikpo Syncline.

Table 2.1: correlation chart for the Early Cretaceous tertiary stiary strata in the southeastern Nigeria(after Nwajide 1990)

Age		Abakaliki-Anambra Basin	Afikpo Basin
m.y 30	Oligocene	Ogwashi-Asaba Formation	Ogwashi-Asaba Formation
54.9	Eocene	Ameki/Nanka Formation/ Nsugbe Sandstone (Ameki Group)	Ameki Formation
6.5	Palaeocene	Imo Formation Nsukka Formation	Imo Formation Nsukka Formation
73	Maastrichtian	Ajali Formation Mamu Formation	Ajali Formation Mamu Formation
83 87.5	Camparian	Npkoro Oweli Formation/Enugu Shale	Nkporo Shale/ Afikpo Sandstone
	Santonian	Agbani Sndstone/Awgu Shale	Non-deposition/erision
88.5	Coriacian		Eze Aku Grupo (incl. Amasiri Sandstone)
	Turonian	Eze Aku Grupo	
93 100	Cenomanian- Albian	Asu River Group	Asu River Group

IV. METHODOLOGY

LABORATORY STUDY

Granulometric Analysis

Fresh samples of sands were collected from each outcrop studied, Five representative samples were collected from the study area, these were unconsolidated sandstone.

Each of these samples were taken from;

- **Ihube**:I kpankwu section and
  Along ihube Oliver road.
- **Umuasua section**
- **Amaba section**
- **Okigwe junction.**

The samples were subjected to grain size analysis in the federal university of petroleum resources laboratory, and equipment used during the laboratory studies include;

Weighing balance, result sheet, stop watch, mechanical sieve shaker, set of sieve, Oven (for drying of wet samples)

SAMPLE PREPARATION

In order to get an accurate result samples were prepared carefully in stages Drying; this is done usually when the sample collected were wet or in moist conditions. This can be done by sundering or the Oven drying to desired temperature.

CRUSHING; this is done in order to disaggregate this samples, each of the samples are gently crushed to avoid crushing them to powder form. After this, the mortar and pestle are washed to avoid contamination.

GRAIN SIZE ANALYSIS

After the pre-preparation, the samples cone and quartering so as the get an even representation of the sample, one quarter is chosen from which 100gm/50gm was obtained . The 100gm of the sample is sieved using a mechanical sieve shaker for about 10 minutes. The fraction in each of the pan is weighed to get the mass retained for each.

Certain parameters are computed in a tabular form in order to plot the cumulative curve and histogram from the sieve results. The univariate, bivariates and multivariate parameters were also plotted alongside the formulas of mean size, sorting, soreness, kurtosis are used to compute the sandstones of the study area.

The parameters are necessary for construction of scatters needed for environmental interpretation because size frequency distribution among sands may sometimes correlate with their various origin and terminal environment of deposition (Boggs, 1987). The parameters were evaluated using the following formulas:

PALYNOLOGICAL ANALYSIS

PALYNOLOGICAL MATERIALS USED

- Penknife:
- Weighing balance:
- Agate mortar and pestle:
- glass beaker:
- plastic pipette:
- Glass slides:
-

CHEMICALS USED FOR ANALYSIS

- Araldyte (mounting agent);
- Schulze solution:
- Safranin-O:
- polyvinyl alcohol:
- HF (40% conc.):

For the purpose of this analysis; A total of 7 non-calcareous shale samples were processed for palynological content. Ten grams of each shale samples were used for the analysis. These samples were processed following standard palynological acid maceration techniques for recovering acid insoluble organic microfossils from sediments for qualitative and quantitative studies.

STEP ONE - CLEANING AND REMOVAL OF FIELD CONTAMINANTS

The samples were scraped clean with penknife to remove any contaminations or encrustations of fungus and algae.

STEP TWO - CRUSHING OF SAMPLES.

Ten grams of each sample were weighed and crushed into smaller pieces of 1-3 mm fractions with agate mortar and pestle to increase the surface area of reaction with chemicals in the next steps as the coarser crushing may leave the core of the rock not acted upon by the acids. This was done carefully in order to avoid fragmenting the large palynomorphs. It is necessary to wash the mortar and pestle thoroughly with clean water, brush and detergent after each crushing to avoid contamination.

NOTE: HCL DIGESTION WAS NOT CARRIED OUT IN THIS ANALYSIS: this is because the shale samples were non-calcareous when tested.

STEP THREE - REMOVAL OF SILICATES (HF DIGESTION)

This is done in order to remove the silicates minerals from the samples, 40 % HF was added to each sample and stood for about 48-72 hours (the longer the duration the more digested it becomes)' during which it was stirred from in intervals with plastic stirring rod. . After dissolution, when all grittiness was lost, the HF acid supernatant was diluted, decanted and disposed off. The residue left in the plastic beaker was transferred into a litre beaker and topped with water to 1 litre. This was in order to keep the residue in suspension and bring the HF acid to a safe dilution for sieve washing. Each sample was sieve-washed in 10 μ nylon mesh with a directed gentle jet of water. The residue containing dissolved substances and broken-down particles smaller than 10 μ size were washed off until neutral pH was achieved. After each sample washing, the nylon sieve was scrubbed using plastic brush and detergent solution, and then reused many times before disposal. This was to avoid the contamination of one sample with another. Sample was examined under the microscope at X 40 magnification in order to ensure the complete removal of silicates and release of palynomorphs. Sample was pipette into two 5 ml plastic vials, each containing 10 grams equivalent of organic residue.

STEP FOUR - HN03 DIGESTION (OXIDATION-1)

. The 10 grams equivalent of sample recovered after HF treatment above was transferred into a glass beaker for oxidation. 70 % HN03 was added to the sample residue and stood for 20 minutes. After dilution with water, the degree of oxidation was checked on strew mount.

NOTE: Oxidation was carried out using glass wares as HNO3 attacks plastic

As oxidation reaction occurred, the colour of the sample gradually changed to brown and then to deeper brown. There was no colour change when no oxidation occurred. However, strew mounts were carried out under the microscope and a complete oxidation was observed when black organic matter became lighter coloured and the fossils dispersed and translucent under transmitted light.

The essence of oxidation was to dissolve and reduce the amount of amorphous organic matter that mask the palynomorphs; get the fossils disaggregated and translucent to enhance identification. The 10 g equivalent of residue was transferred into 1 litre beaker and diluted with water up to 800 ml. The essence was to reduce the concentration of the acid, for safety of handling and prevent melting of nylon sieve by concentrated acid. Nylon sieve withstands only neutral solutions. The organic residue of each sample was recovered by washing thoroughly through a 10 micro nylon sieve mesh until neutral pH was attained.

STEP FIVE - SCHULZE SOLUTION (OXIDATION – 2)

Schulze solution was prepared by dissolving granules of potassium chlorate in 70 % HN03 until it became supersaturated. The second oxidation in Schulze solution was carried out because some samples were not rendered translucent after oxidizing them in HN03. This was observed when the palynomorphs were still dark and opaque or were still clumped together and covered by amorphous materials after HN03 oxidation. In such cases additional oxidation was needed. Schulze solution has a rapid action and tends to fade off after about 30 minutes.

STEP SIX – GRAVITY SEPARATION
This involves the removal of undigested mineral matter which was carried out either by heavy liquid (ZnCl2) separation which depend on specific gravity contrast separation method or by method of swirling. These aimed at removing the persistent mineral grains such as quartz and biotite that passed undissolved through the various stages of sample processing. However, swirling method was found to be faster and more effective than the heavy liquid (ZnCl2) separation method, and therefore was adopted at this stage. This was so because there were only few mineral grains left after each check of strew mounts.
Swirling: After HNO3 and Schulze treatments, each sample was transferred into a glass bowl for swirling. A gentle jet of water from wash bottle was directed to the water surface towards the edge of the glass bowl. This was done in order to initiate a swirling (circular) motion to the water in the swirling glass. The heavier quartz and coarse organic matter were allowed to settle to the bottom while the palynomorphs were still in suspension. The suspended palynomorphs were gently decanted into the sieve.

STEP SEVEN - STAINING.
Each sample was stained in order to restore depth of colour and contrasts for easy identification and for photomicrography. This was necessary because oxidation bleaches the fossils. Safranin-O produced better contrasts for micrographs than Bismarck Brown and sS therefore, was used for staining. Before staining, the sample was rinsed in 2 % KOH to clear off the humic and cellulosic substances together with the remains of oxidation products. It also helps to (disperse the fossils and) make the specimens pick up the stain. A few drops of the **s** were let on the organic residue in the nylon sieve and allowed to act for a few seconds. The excess stains were washed off with cold water in order to fix the stain and to avoid bleeding.

STEP EIGHT - DISPERSAL OF ORGANIC SUSPENSION
About 2 or 3 drops of polyvinyl alcohol was added to the organic residue in order to keep the organic particles dispersed. The organic residue tends to settle out of suspension in water and clump together unless suspended in a dispersant.

STEP NINE - QUANTITATIVE SLIDE PREPARATION – MOUNTING
Three to five drops of polyvinyl alcohol dispersant were added in one of the organic suspensions with a disposable plastic pipette and mixed thoroughly by shaking it. Check if the palynomorphs are well dispersed; if yes stop and if no, add more drops until they are dispersed. Dense samples were diluted with more water to avoid the clustering of palynomorphs on the slide. The palynomorphs suspension was spread evenly on each cover slip and placed on a neat flat surface then left to dry for the final permanent mount on a glass slide. Five cover slips were placed on a hot plate at 800 – 900 C. ‘‘Araldyte’’ was used as a mounting medium. A drop of it was placed on each slide with the tip of a rod. The cover slip carrying the dried organic residue was gently inverted and lowered onto the slide and beginning from the far edge of the mountant. This was carefully done in order to avoid trapping air bubbles below the cover slip. Small thin cover slips of (22 mm x 22 mm) were used.

STEP TEN- LOGGING
Five slides were made from each sample in which a minimum of two hundred grains were counted from each sample under the microscope. The grains were taken from a minimum of

two slides. Where the sample was rich, the other remaining three slides were scanned for rare species. For poor samples, the contents of the five slides were counted. The slides were placed with the label to the left-hand side of the microscope. The absolute counts were converted to percentage frequencies to eliminate the differences in the counts. Frequency is shown as <15 % = very abundant; 10-15 % = abundant; 5-10 % = common; 1-5 % = occasional; >1 % = rare.

V. DESCRIPTION AND RESULT INTERPRETATIONS

Description of Lithostratigraphic Sections

LITHOSTRATIGRAPHIC DESCRIPTION OF NSUKKA FORMATION AT IHUBE

IT IS EXPOSED ALONG IHUBE-OKIGWE ROAD

LATITUDE: N 05^0 51’ 55”

LONGITUDE: E007^0 21’ 33”

ELEVATION: 300M ABOVE SEA LEVEL

Fig 4.1 collection of samples at an outcrop at Ihube.

The outcrop exposed here is massive, section begins with of Shale/mudstone of about 1.4m thick Its colour as seen is black, the overlying bed is a fissile yellowish fine grained ferruginous clayey of about 2m .

Sedimentary structures present include sole marks or load structures in the coarse grained sandstone and bioturbated fine grained siltstone with shale interbeds of about 0.5m.

Vertical succession range from black shale to fine grained sandstone and medium grained sandstone.

Outcrop 2

IT IS EXPOSED AT IKPANKWU SECTION (ALONG IHUBE –OKIGWE ROAD)

LATITUDE: N05^0 51’ 18”

LONGITUDE: E OO7^0 22’ 21”

ELEVATION: 301M ABOVE SEA LEVEL

fig 4.2&4.3 Outcrop at Ikpankwu

OUTCROP THREE
IT IS EXPOSED AT OKIGWE JUNCTION
LATITUDE: NO5^{0} 49’ 13”
LONGITUDE: E OO7^{0}20’15”
DISTANCE:299M ABOVE SEA LEVEL.

Fig 4.4 Shaly-sand Outcrop at Okigwe Junction

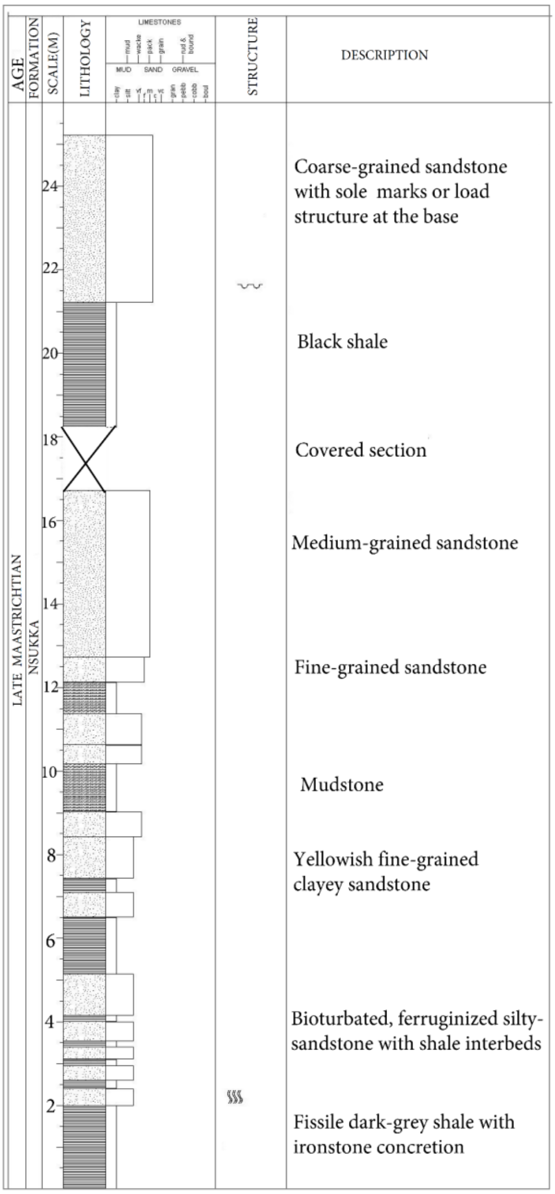
It comprises of yellowish brown Shaly-sand which is about 2m to 1.5m in thicknes. Sedimentary structure present in the shaly-sand are Ripple laminated of about 2.5cm to 5.1cm bed thickness

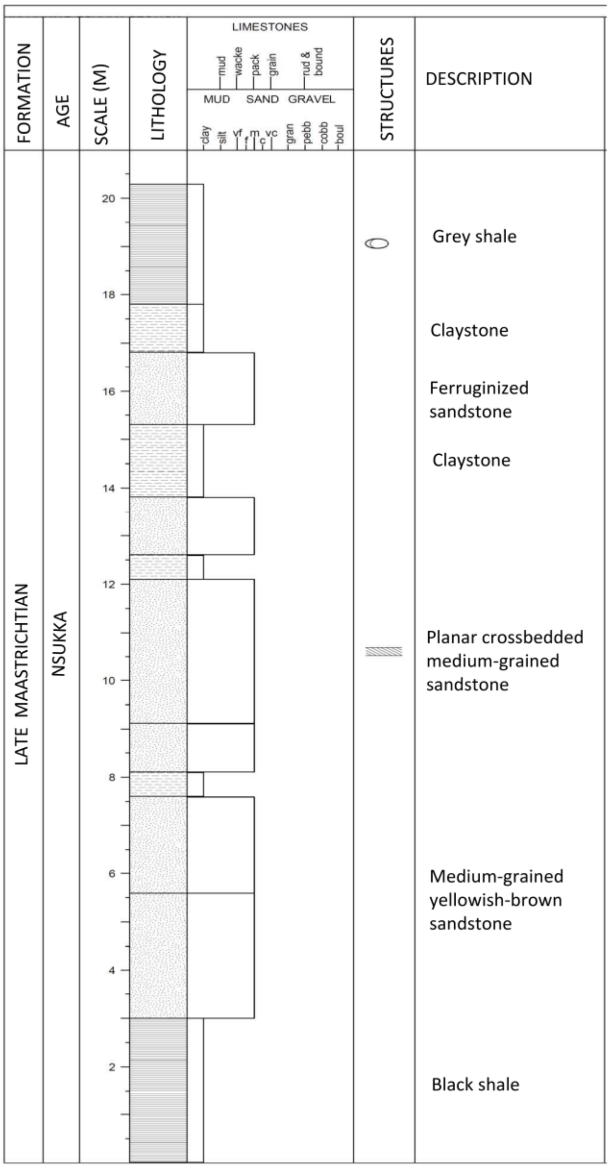
The vertical succession ranges from mud to shaly sand.

Outcrop four
IT IS EXPOSED AT AMABA SECTION (ISUKWATO)
LATITUDE: N 05^0 45’ 25”
LONGITUDE: E007^0 24’ 17”
DISTANCE: 298M ABOVE SEA LEVEL

Fig 4.5: Ferruginous shaly-mudstone at Amaba.

Table 4.2 & 4.3 : lithologs of Rock beds at Ihube and Amaba.





Description of lithofacies

Maxlow (1994) further referred to the term "Facies" as those properties of a rock that can be observed or analyzed which characterize a particular depositional environment. Therefore a facies is a rock unit distinguishable in the field by its geometry, texture, lithology, and sedimentary structures. The description of the lithofacies is simply a collation of these observations to give an interpretation of the environment of deposition and environmental condition existing at the time of deposition.

The description of each lithofacies was based on distinctive lithologic features including **composition, grain size, bedding characteristics and sedimentary structures.** The outcrop locations were subdivided into lithofacies and followed standard facies practices such as that propsed by Mill (1978). They have been described briefly below:

Bioturbated Siltstone and Shale Facies.

This facies consist of friable sandstone, fine-medium grained with interbedded shales with a 0.5m thickness. The facies is found at Ihube.

Interbedded Siltstone and Shale Facies .

This facies is very common in the sections especially in the upper part of the sections. Most of the units of this facies is highly weathered. The colour is greyish black. It has an average thicknes of 2.5m to 3m.

Cross-Bedded Sandstone Facies

Planar cross stratified sandstone facies are developed locally in both lithologic sections described of the study area . Generally, cross beds range between 2.5 and 4cm thick, whereas co-sets may reach up to 1.5m thick. The planar cross-bedded sandstone facies is interpreted as a traction current deposit. The medium scale planar cross bedding resulted from the preservation of the straight crested dunes and sandwaves and transverse bars. (Harms, et al., 1975; Walker and Cant, 1979).

Massive Sandstone Facies

The Massive sandstone facies is yellowish-brown in colour. The thickness range from 3.5m to 4.6m. it is identified in most locations. ,it is fine grained to medium grained and friable in all the units.

Mudstone Facies .

The facies comprises light brown to black mudstone. It is concretioinary. Individual occurrence of this facie reach up to 1m. This facies is in all probability a suspension deposit.

Laminated Shale Facies .

This unit consist of black rippled laminated shales and markes a possible deepening from continental to marine conditions. The facies demonstrated a high fissility in all the units. The thickness of about 2.5m is recorded for the facies.

Result interpretations

Result and Interpretation of Granulometric Analysis

The results of the statistical parameters evaluated are shown in the Table below. Their interpretation was based on Folk, (1974) grain size statistical parameter.

Table 4.4: Computed grain size parameters derived from the probability Curve.

Results of computed grain size parameters and interpretation

Samples N0	Sorting values	Sorting	Skewness value	Skewn Ess	Kurtosis Value	kurtosis	Mean value	Mean size
Ihube	**1.48**	**Poorly sorted**	**0.79**	**Strongly Fine Skewed**	**0.89**	**Platykur tic**	**1.47**	**Medium Sand**
Okigwe junction	**1.51**	**Poorly Sorted**	**0.84**	**Fine Skewed**	**0.93**	**Mesokur tic**	**1.47**	**Medium Sand**

Ikpankwu	**1.41**	**Poorly Sorted**	**o.16**	**Strongly Fine Skewed**	**1.24**	**Leptokurtic**	**1.50**	**Medium Sand**
Umuasua	**1.41**	**Poorly sorted**	**-0.12**	**Coarse Skewed**	**0.89**	**Platykurtic**	**1.52**	**Medium Sand**
Amaba	**1.46**	**Poorly Sorted**	**0.11**	**Fine Skewed**	**0.61**	**Very Platykurtic**	**1.37**	**Medium Sand**

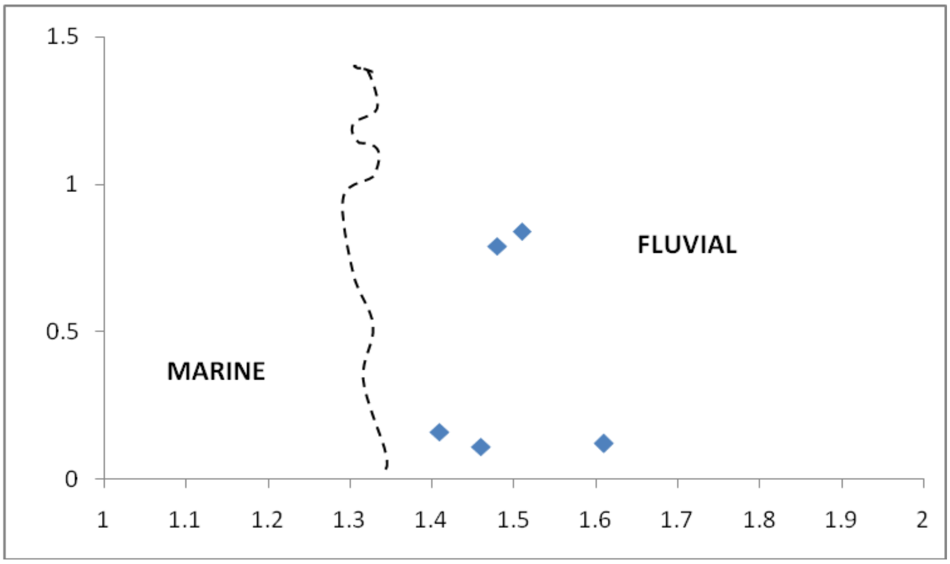


Fig 4.6: Graph of Skewness against Sorting for the Sandstone in the study Area (After Freidman, 1961)

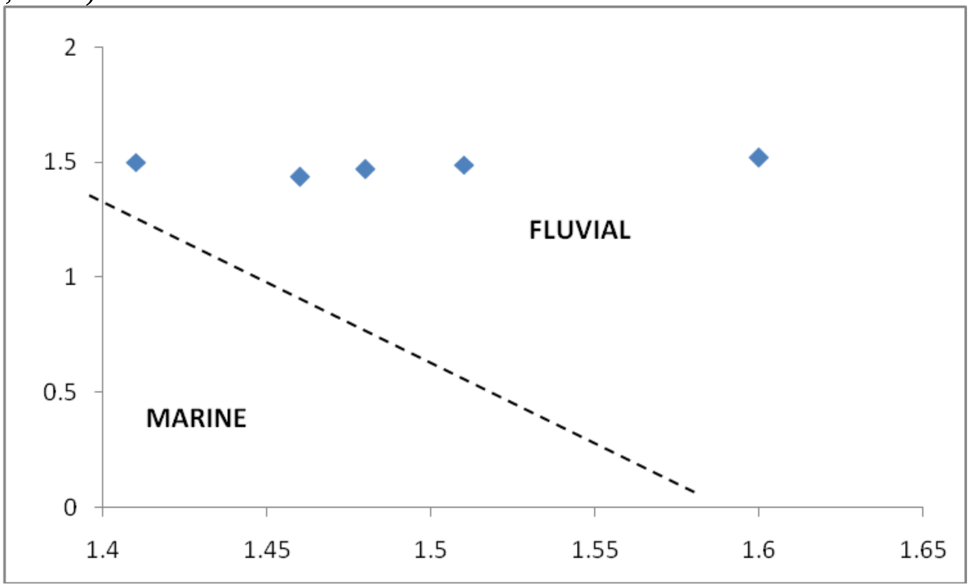


Fig 4.7: Graph of Mean Size against Sorting for the Sandstone in the study Area(After Miola and aiser, 1977)

Results of multivariate computation.

The multivariate results for the sediments of the study area indicate mainly fluvial deposits as shown in Table ;

Table 4.5: Multivariate results of sandstone of Nsukka Formation in the Study area.

SAMPLE	RESULTS	INTERPRETATION
IHUBE	**-16.3689**	**FLUVIAL**
OKIGWE JUNCTION	**-16.8745**	**FLUVIAL**
IKPANKWU	**-12.5599**	**FLUVIAL**
UMUASUA	**-11.2886**	**FLUVIAL**
AMABA	**-12.8884**	**FLUVIAL**

Result and Interpretation of Palynological Analysis

The Result obtained from the palynological analysis were subjected to Standard laboratory techniques of digesting of sediments in hydrofluoric acid only (because they are non-calcareous) was used to process the samples (Traverse, 1988). However Several classification schemes for dispersed organic matter can be found in the literature (e.g., Boulter and Riddick, 1986; Van Bergen et al., 1990; Tyson, 1995; Batten, 1996; Oboh-Ikuenobeet al., 1997).

The samples gotten from Nsukka Formation at Ihube area of Okigwe town are characterized by *Leiotriletesadriennis Laevigatosporitesovatus, Matonisporisequiexinus, Lygodiumsporites*sp *Longapertitesmarginatus, Pediculisporishourquii, Lygodiumsporites*sp, *Pediculisporishourquii, Foveotrlletesmargaritae, Proxapertiteshumbertoide, Spinizonocolpitesbaculatus, and Constructipollenitesineffectus in all locations. This microspore assemblage gave an age the of Late Maastrichtian for the sediments exposed here.*

The Dinoflagelates forms recovered such as Trichodiniumcastanea, Cyclonephelium compactum,

Senegalinium dumium, *Areoligerasenonensis, Spiniferites ramosus,*

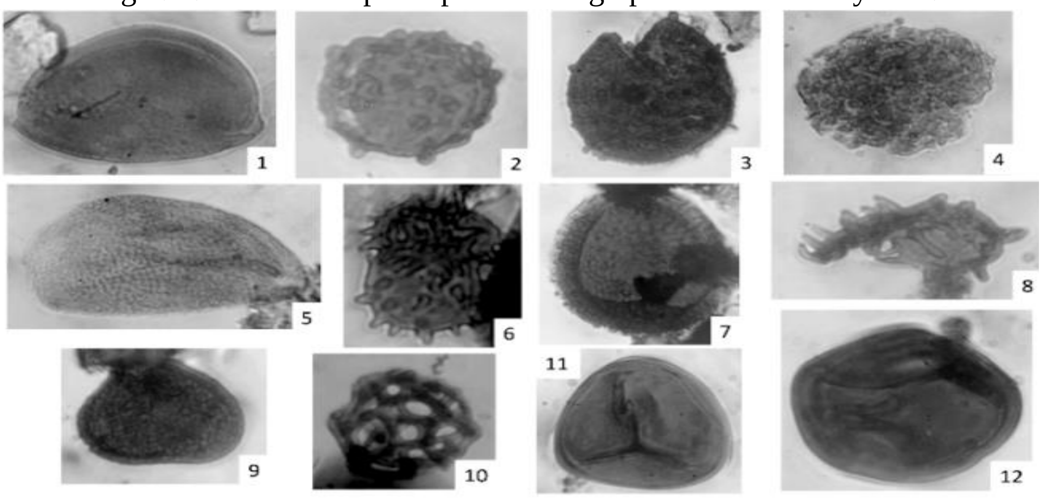
Table 4.6 : Result of Pollen and Sppores recovered from the Study Area.

Sample Numbers Palynomorphs	UM	AM	IHU 1	IHU 9
Spores and Pollen (Terrestrial Species)				
Laevigatosporites major	3	6	2	3
Leiotriletesadriennis	12	10	16	12
Retibrevitricolpitestriangulatus	1	–	–	–
Laevigatosporitesovatus	13	9	14	10
Pediculisporismicrogranulatus	2	3	1	4
Ericipitespachyexinus	–	2	2	1
Syndemicopitestypicus	–	–	3	2
Rugulatisporitescaperatus	7	2	–	–
Gleichiniiditessenonicus	5	1	2	1
Triplanossporitesmicrosinuosus	3	–	–	–
Polyadopollenitessculptus	4	–	1	–
Matonisporisequiexinus	8	5	6	8
Cyathiditesaustralis	3	3	1	1
Longapertitesproxapertitoides	–	1	2	2
Cycadopitesovatus	5	2	–	–
Ariadnaesporitesnigeriensis	–	4	2	1
***Aquilapollenites*sp**	2	–	3	2
Distaverrusporites simplex	2	3	1	–
Cupanieiditesorthoteichus	4	–	1	3
Cingulatisporitesornatus	7	2	1	2
Polypodiaceiosporitesreticulatus	1	3	–	2
Longapertitesmarginatus	24	17	19	35
Mauritiiditescrassibaculatus	6	3	2	1
Liliaciditesnigeriensis	2	1	4	5
Pediculisporishourquii	4	2	3	2
Duplotriporitesariani	1	3	–	4
Echitriporitestrianguliformis	3	2	5	4
Proxapertitesoperculatus	2	3	1	2
Laevigatosporitesdiscordatus	1	3	2	1
Periretisyncolpitemagnosagenatus	–	–	3	5
Pachydermitesdiederixi	3	1	–	2
Syncolporites subtilis	2	3	–	1
Psilatricolporitesoperculatus	3	2	–	5
Monoporitesannulatus	5	4	2	5
Proxapertites cursus	2	1	3	–

Echiperiporitesicacinoides	–	–	0	2
Inaperturopollenites hiatus	–	1	2	–
Longapertitesvaneedenburgi	5	3	6	3
Foveotrlletesmargaritae	5	6	5	3
Buttineaandreevi	2	3	1	–
***Psilamonocopites*sp**	1	–	–	2
Spinizonocolpitesechinatus	3	5	3	3
Proteaciditesdehaani	6	3	2	2
Longapertitesmicrofoveolatus	–	3	2	2
Auriculidites reticularis	2	3	4	–
Retidiporitesmagdalenensis	3	5	1	2
Monocolpitesmarginatus	5	2	4	4
Echiperiporites minor	3	1	3	2
Laevigatosporitesdiscordatus	4	5	2	4
***Lygodiumsporites*sp**	6	3	8	9
Proxapertiteshumbertoide	3	8	3	5
Monocolporopollenitessphaeroidites	–	3	3	–
Constructipollenitesineffectus	5	15	2	4
Spinizonocolpitesbaculatus	10	12	5	7

PLATE 1

Fig 4.8 :Pollen and Spores photomicrographs from the studyArea:

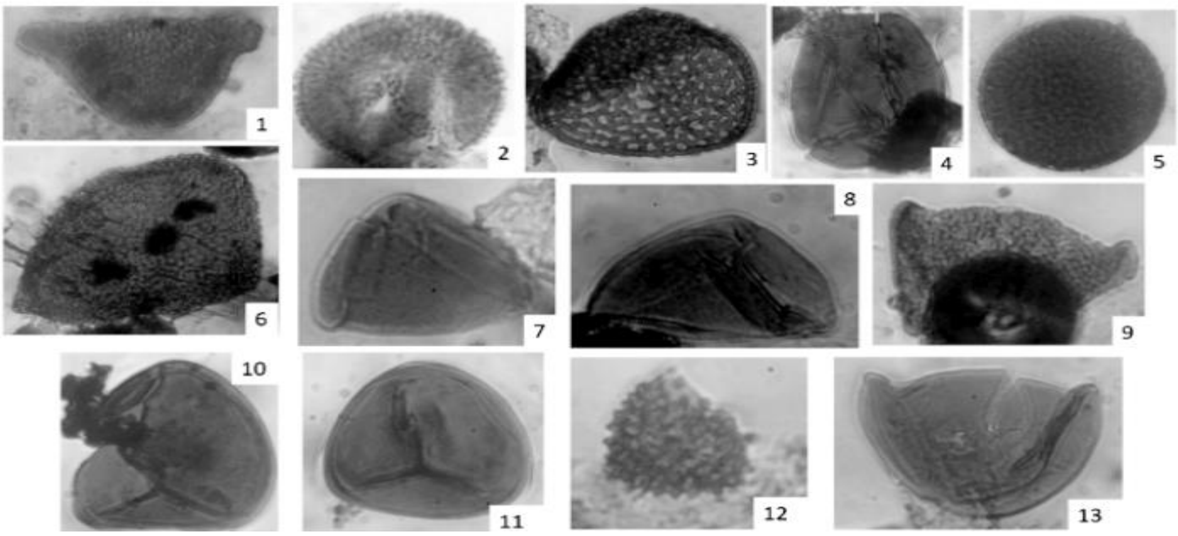


1. *Longapertitesmarginatus*	7.*Cingulatisporitesornatus*
2.*Distaverrusporites simplex*	8.*Spinizonocolpitesbaculatus*

3.*Duplotriporitesariani*	9.*Foveotriletesmargaritae*
4.*Periretisyncolpitemagnosagenatus*	10.*Buttiniaandreevi*
5*Longapertitesvaneedenburgi*	11.*Leiotriletesadriennis*
6.*Spinizonocolpitesechinatus*	12.*Lygodiumsporites sp*

PLATE 2

Fig 4.9: Other Pollen and Spores recovered from the Study Area..



1.Pediculisporismicrogranulatus	7&8.Cupanieiditesorthoteichus
2. Constructipollenitesineffectus	10&11.Leiotriletesadriennis,
3. Proxapertiteshumbertoide	12.Echitriporitestrianguliformis
,4. Polyadopollenitessculptus,	13.Pedi
5.Rugulatisporitescaperatus	
6.Longapertitesproxapertitoides	

For the course of this study, a simplified scheme is adapted to the type of organic components and palynomorph groups present in the sediments. Various types of dispersed organic matter and palynomorph groups were identified including spores and pollen, marine palynomorphs (dinoflagellates), black debris, and amorphous organic matter.

Sample / Numbers / Palynomorphs	UM	AM	IHU1	IHU9
Dinoflagellate cysts (Marine Species)				
Senegalinium laevigatum	2	–	4	2
***Fibrocysta* sp**	–	–	2	3
***Apteodinium* sp**	–	–	4	5
***Trithyrodinium* sp**	–	–	2	1
Cordosphaeridium inordes	–	–	7	6
Areoligera senoniensis	–	–	1	5
Cerodinium obliquipes	–	–	1	2
Operculodinium centrocarpum	1	–	3	1
Dinogymnium acuminatum	2	–	2	–
Cordosphaeridium varians	3	–	9	8
Andalusiella manthei	1	–	3	–
Phelodinium magnificum	–	–	4	2
Cleistosphaeridium diversispinosum	–	–	5	3
Trichodinium castaneum	2	–	15	10
***Andalusiella* sp**	2	–	2	3
Spiniferites ramosus	3	–	5	6
Senegalinium dubium	1	–	4	4
Senegalinium bicavatum	–	–	6	6
Palaeohystrichophora infusoroides	–	–	–	–
Odontochitina porifera	–	–	–	–
Odontochitina operculata.	–	–	–	–
Spiniferites multibrevis		–	6	5
Fibradinium annetorpense	–	–	–	2
***Dinogymnium* sp**	2	–	2	3
***Cyclonephelium* sp**	1	–	8	10
Circulodinium distinctum	–	–	2	–
Cerodinium diebelii	–	–	2	3
Cerodinium striatum	–	–	–	1
Cerodinium leptoderma	–	–	1	2
Andalusiella polymorpha	1	–	3	3
Cyclonephelinium compactum	–	–	3	2
Cyclonephelium deconinckii	–	–	2	1
Palaeocystodinium golzowense	–	–	2	–

Plate 3

Some dinoflagellates cysts photomicrographs from the study:

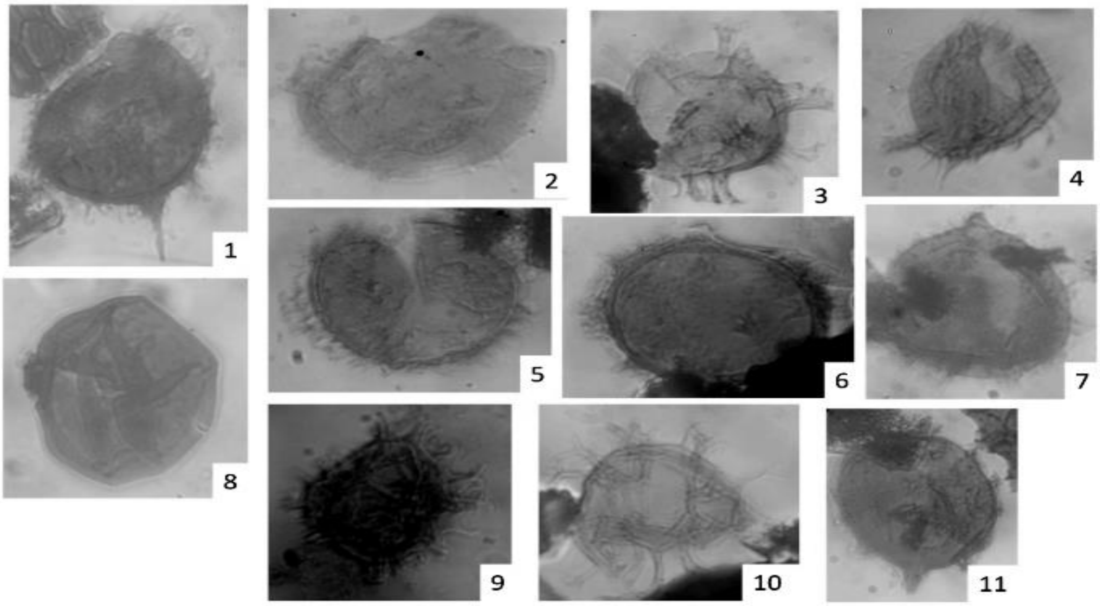


Fig 4.9: Dinoflagellates forms recovered from the study Area.

Table 4.7

1 *Fibrocysta* sp,	8.*Trithyrodinium* sp
2. *Cyclonephelium compactum*	9. *Spiniferites ramosus*
3. *Cordosphaeridiuminodes,*	10.*Spiniferites multibrevis*
4. *Areoligerasenonensis,*	11. *Apteodinium* sp
6. *Cordosphaeridium varians*	
6&7 *Trichodinium castanea*	

DISCUSSION

Lithofacies interpretation forms the primary tool for identifying the depositional conditions under which the sediments were deposited and preserved. Also granulometric studies of the sandstones provided information on the intrinsic properties of sediments and their depositional environment. Further, they help to delve into the nature and energy flux of the multifarious agents transporting the sediments. Sediment texture provides useful information on the mode and extent of transport and environment of deposition of sediments (Mason and Folk, 1958; Friedman, 1961; Sahu, 1964; Visher, 1969).

The texture of sediments has a profound bearing on the physico-chemical processes as well as the biological diversity of the development of the environment (Badarudeen, 1997).

DEPOSITIONAL ENVIRONMENT AND DEPOSITIONAL PROCESS.

The results show the sediments in the study area are fine to medium grained, with an average mean size of 1.48 (medium sized). The size range indicates that the sediments were deposited in a low to medium energy environment with relatively low fluctuation to a high energy depositional environment at some stage (Pettijohn 1965).The standard deviation (dispersion sorting) values range from 1.41– 1.51 which is interpreted as poorly sorted with a calculated average value of 1.212. The studied samples range from very **platykurtic-platykurtic-mesokurtic-leptokurtic** skewed to near symmetricalprobably due to turbulence within a predominantly unidirectional flow (Agumanu 1994).

Various lithofacies can be grouped as architectural elements, which are characterized by a distinctive facies assemblage, internal geometry, external form and vertical profit (Miall, 1988). The recognition of these architectural elements, the inherent characteristics and their relationship, allows for interpretation of the local and regional processes of deposition in the study area. The lithofacies types identified from field studies include;

- Bioturbated Siltstone and shales Facies.(A)
- Interbedded Siltstone and Shale Facies(B)
- Crossbedded Sandstone Facies(C)
- Massive Sandstone Facies(D)
- Laminated Shale Facies(E)
- Mudstone Facies.(F)

Sediments in lithofacies C and A are cross bedded and heavily bioturbated burrows. The presence of these structures indicates tidal environment with high energy (Tucker, 1996). However, the presence of lateral accretion surface within the studied Sandstone sediments suggests fluvial action Reading, (1996) and Tucker (1996). These field observations show that the studied sediments were deposited under a tidal and fluvial channels interaction i.e. littoral environment. The planar cross-bedded sandstone facies is interpreted as a traction current deposited the medium scale planar cross bedding resulted from the preservation of the straight crested dunes and sand waves and transverse bars. (Harms, et al., 1975; Walker and Cant, 1979).

Palynomorphs study of samples in the study area showed that samples are characterized by forms such as The samples gotten from Nsukka Formation at Ihube area of Okigwe town are characterized by *Leiotriletesadriennis, Laevigatosporitesovatus, Matonisporisequiexinus, Lygodiumsporites*sp *Longapertitesmarginatus, Pediculisporishourquii, Lygodiumsporites*sp, *Pediculisporishourquii, Foveotrlletesmargaritae, Proxapertiteshumbertoide, Spinizonocolpitesbaculatus, and Constructipollenitesineffectus in all locations. These microspores and Pollens assemblage gave an Age of the Late- Maastrichtian for the sediments exposed here.*

However, large number of Dinoflagellates forms were recovered such as; *Dinogymnoids indet Trichodiniumcastanea, Cyclonephelium compactum, Areoligerasenonensis* and Senegalinium dumium. The assemblage confirms a late Maastrichtian-Paleocene age for this formation (Salami, 1984 and 1985; Lawal and Moullade, 1986; Shrank, 1987*)*

SUMMARY AND CONCLUSION

The Age, sedimentology and depositional environment, of Nsukka formation sediments exposed at Ihube , Okigwe Southeastern Nigeria has been reconstructed from field relationship, textural and Biostratigraphic studies.

Interpreted datas from field relationship and associated sedimentary structures indicate the sediments were deposited in a fluvial to shallow marine environment.

The results of the grain size analysis shows that the sediments in the study area are fine to medium grained, with an average mean size of 1.2216 (medium sized).the size range which is medium indicates that the sediments found in the study area were deposited in a relatively low to medium energy environment with a low fluctuations to relatively depositional environment at some point of transportation. The standard deviation (dispersion sorting) values range from 1.41– 1.51 which is interpreted as poorly sorted with a calculated average

value of 1.212. The studied samples range from very **platykurtic- platykurtic -mesokurtic-leptokurtic** skewed to near symmetrical probably due to turbulence within a predominantly unidirectional flow., The probability curves for the samples of the studied sediments show that the sandstone units were deposited majorly by suspension, saltation, and traction, this is implies a marine setting with fluvial incursions at certain periods of the depositional history.
The results of bivariate plots for sediments in the study area indicate beach and fluvial deposits, while multivariate results indicate mainly fluvial deposits.
The sedimentary outcrop sections have been divided in six lithofacies based on their textural and field relationship; these include Bioturbated Siltstone and Shale Facies, Interbedded Siltsone and Shale Facies, crossbedded Sandstone Facies, Massive Sandstone Facies, Mudstone Facies and Laminated Shale Facies .
Palynomorphs study of samples in the study area showed that samples are characterized by forms such as The samples gotten from Nsukka Formation at Ihube area of Okigwe town are characterized by *Leiotriletesadriennis, Laevigatosporitesovatus, Matonisporisequiexinus, Lygodiumsporites*sp *Longapertitesmarginatus, Pediculisporishourquii, Lygodiumsporites*sp, *Pediculisporishourquii, Foveotrlletesmargaritae, Proxapertiteshumbertoide, Spinizonocolpitesbaculatus, and Constructipollenitesineffectus in all locations. These microspores and Pollens assemblage gave an Age of the Late- Maastrichtian for the sediments exposed here. While the* large number of Dinoflagellates forms recovered such as; *Dinogymnoids indet Trichodiniumcastanea, Cyclonephelium compactum, Areoligerasenonensis* and Senegalinium dumium. The assemblage confirms a late Maastrichtian-Paleocene age for this formation (Salami, 1984 and 1985; Lawal and Moullade, 1986; Shrank, 1987*).*

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APPENDIX ONE
GRANULOMETRIC ANALYSIS DATA AND DIAGRAMS
SAMPLE ONE (NSUKKA FORMATION)
LOCATION: ALONG IHUBE
WEIGHT OF SAMPLE: 50g
TIME OF SHAKING:10mins

Phi	Weight Retained	%Weight Retained	Cummulative weight %	% Passing
-0.239	6.24	12.48	12.48	87.52
0.971	5.71	11.42	23.90	76.10
0.737	5.82	11.64	35.54	64.46
1.234	5.27	10.54	46.08	53.92
1.736	5.42	10.84	56.92	43.08
2.238	5.50	11.00	67.92	32.08
2.736	6.24	12.48	80.40	19.60
3.736	6.08	12.16	92.56	07.44
Pan	3.72	7.44	100.00	00.00

SAMPLE TWO (NSUKKA FORMATION)
LOCATION: AMABA SECTION
WEIGHT OF SAMPLE: 50g
TIME OF SHAKING:10mins

Phi	Weight Retained	%Weight Retained	Cummulative weight %	% Passing
-0.239	3.85	7.70	07.07	92.30

0.971	4.18	8.36	16.06	83.94
0.737	6.12	12.24	28.30	71.70
1.234	8.44	16.88	45.18	54.82
1.736	8.38	16.76	61.94	38.06
2.238	6.16	12.32	74.26	25.74
2.736	4.74	09.48	83.74	16.26
3.736	4.18	08.36	92.10	07.90
Pan	3.95	07.90	100.00	00.00

SAMPLE THREE (NSUKKA FORMATION)
LOCATION: UMUASUA SECTION
WEIGHT OF SAMPLE: 50g
TIME OF SHAKING:10mins.

Phi	Weight Retained	%Weight Retained	Cummulative weight %	% Passing
-0.239	06.72	13.44	13.44	86.56
0.971	05.74	11.48	24.92	75.08
0.737	05.91	11.82	36.72	63.26
1.234	05.31	10.62	47.36	52.64
1.736	05.49	10.98	58.34	41.66
2.238	05.58	11.16	69.50	30.50
2.736	06.72	13.44	82.94	17.06
3.736	05.40	10.80	93.74	06.26
Pan	03.13	06.26	100.00	00.00

SAMPLE FOUR (NSUKKA FORMATION)
LOCATION: IKPANKWU SECTION
WEIGHT OF SAMPLE: 100g
TIME OF SHAKING:10mins

Phi	Weight Retained	%Weight Retained	Cummulative weight %	% Passing
-0.239	8.10	8.10	8.10	91.90
0.971	8.60	8.60	16.70	83.30
0.737	12.20	12.20	28.90	71.10
1.234	16.30	16.30	45.20	54.80
1.736	16.20	16.20	61.40	38.60
2.238	12.30	12.30	73.70	26.30
2.736	9.40	9.40	83.2	16.90
3.736	8.60	8.60	91.70	8.30
Pan	8.30	8.30	100.00	0.00

SAMPLE FIVE(NSUKKA FORMATION)
LOCATION: OKIGWE JUNCTION

WEIGHT OF SAMPLE: 100g
TIME OF SHAKING:10mins

Phi	Weight Retained	Cumulative %	%Weight Retained	% Passing
-0.239	12.40	12.40	12.40	87.60
0.971	11.30	23.70	11.30	76.30
0.737	12.30	36.00	12.30	64.00
1.234	10.40	46.40	10.40	53.60
1.736	10.80	57.20	10.80	42.80
2.238	11.00	68.20	11.00	31.80
2.736	12.40	80.60	12.40	19.40
3.736	12.10	92.70	12.10	7.30
Pan	7.30	100.00	7.30	0.00