

## LITHOFACIES AND PALEODEPOSITIONAL ENVIRONMENT OF OKPUJE AND ITS ENVIRONS NSUKKA NORTH EAST LOCAL GOVERNMENT OF ENUGU STATE, SOUTH EASTERN NIGERIA

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**ABSTRACT:** This research gives detailed knowledge on the lithic- geology and brief knowledge on trace fossil analysis of the study area. These lithofacies have been organized into six main lithostratigraphic units namely: Unit A, Unit B, Unit C, Unit D, Unit E and Unit F. The lithic fills of the area show an undulating topography with thickness increasing towards the eastern, south eastern and north eastern parts. Six uneestablished lithofacies(Unit) were encountered which includes fine grained friable Sandstone, dark grey Shale, White to pink clay, fine to coarse grained Sandstone, conglomeratic sandstone and heterolithic Sandstone and clay facies coined out from the establish Ajali and Nsukka Formation that underline the area. This formation was dated upper Maastrichtian with the Ajali Sandstone underlying the Nsukka Formation. Sandstone sedimentological analyses b (sieve, grain size analysis) and record of Scoyena and Skoliths ichnofossils indicates a paralic environment (Delta platform and Delta slope realm).

**KEYWORDS:** Depositional environment, Ajali Sandstone, Nsukka Formation and Facies.

### 1 INTRODUCTION

The study area lies between  $6^{\circ}5'$  and  $6^{\circ}55'$  N and longitude  $7^{\circ}15'E$  and  $7^{\circ}20'E$ . It is situated in Nsukka which is located at the north eastern part of Nsukka local government of Enugu state Nigeria as shown in Fig. 1. It is part of the Benue trough basin of Nigeria which runs in a north east direction. Facies classification is one of the basic practices which define geology as a field of study. Initially, identification of rock facies was a common practice only to surface geological mapping. However, the story has changed in recent times as facies identification has become an integral part of the oil exploration/exploitation. An understanding of depositional environment is quite important in appreciating the geology of an area. To put together the geologic history of a region, the depositional environments of its sedimentary rocks must be analyzed. By reconstructing depositional environments geologists are able to reconstruct the climates of the past, life forms of the past, and geography of the past, where the mountains, basins, large rivers, and bays of the ocean were ability to locate energy deposits in the form of coal or oil, each of which originates in a certain type of depositional environment. Presently, a search for hydrocarbon is incomplete without sequence stratigraphic analysis of core samples from appraisal wells and it involves detailed Petrographic and geochemical studies,( Obasi et al, 2013).

#### 1.1 DRIANAGE OF THE STUDY AREA

The area has few surface drainage, it is inferred by some U and V shape valley which may in the past serve as surface drainage. The area encompasses five towns and village. It covers in the northwest Okpuje and Aka-Edem; Ibagwa Ani, Alor-Uno, Edem-Ani and Isi-Uja; in the southeast, Ozi-Edem,Ezi-Ani and Odoru Nsukka and in the southwest Nrobo.

## **1.2 CLIMATE AND VEGETATION**

According to Inyang (1975) the annual record of temperature of Nsukka has a maximum temperature of 27<sup>0</sup>c with minimum of 23.3<sup>0</sup>C occurring from February and July- August respectively. The mean daily maximum temperature is usually more than 27<sup>0</sup>c, while 21<sup>0</sup>c as the mean daily minimum temperature. The relative humidity depends on the type of air mass that prevails: the southwest (Typical maritime) air mass or northeast (Tropical continental) of the ITC- equatorial west lies during high sun and the dry North west trades and sub-tropical anticyclones. However the relative humidity ranges between 35 and 65%. Generally Nsukka lies between the Savannah vegetation type of northern Nigeria and the rain forest belt of the south. The complex trees and grasses which make up the belt have led to the region being referred to as forest- Savannah.

## **2 GEOLOGY OF THE STUDY AREA**

The study area falls within two geologic formations the Nsukka Formation and the Ajali Sandstone:

### **2.1 NSUKKA FORMATION**

The late Campanian-Maastrichtian marine transgression which led to the deposition of Mamu and Ajali Formation proceeded further to lead to the deposition of Nsukka Formation. Nsukka Formation lies conformably on top of Ajali Sandstone as shown in figure 1; the formation was first described by Tattam (1944) as the (Upper Coal Measure). The formation represented a phase of fluvio deltaic sedimentation that began close to the Maastrichtian and continued during the Paleocene. The Nsukka Formation which overlies the Ajali Sandstone consists of coarse to medium-grained sandstone as passes upward into well bedded blue clay, fine grain sandstone and carbonaceous shale with thin bands of limestone (Reyment 1965 and Obi et al, 2001). The intense ferroginisation of well bedded blue clays, carbonaceous shale and thin band of limestone resulted in ironstone which exist in Nsukka Formation (Obi et al, 2001) used sedimentological evidence to suggest that the Nsukka Formation represent a phase of fluvio-deltaic sedimentation that began close to the end of the Maastrichtian and continued during the Paleocene.

### **2.2 AJALI SANDSTONE**

The Ajali Formation overlies the Mamu Formation. The formation was previously known as the false bedded Sandstone, the formation consists of friable poorly sorted sandstone typically white in colour but sometimes iron-stained. A marking banding of coarse and fine layers is displayed. The sand grain and the fragments are sub angular with coarse cement of white clay. Large cross bedding. The Ajali Sandstone is the source of water of artesian borehole and springs at Oji River, Ajali Sandstone is the most aquiferous sandstone in Nigeria after Benin and Imo Formation, (Nwachineke, 2012).

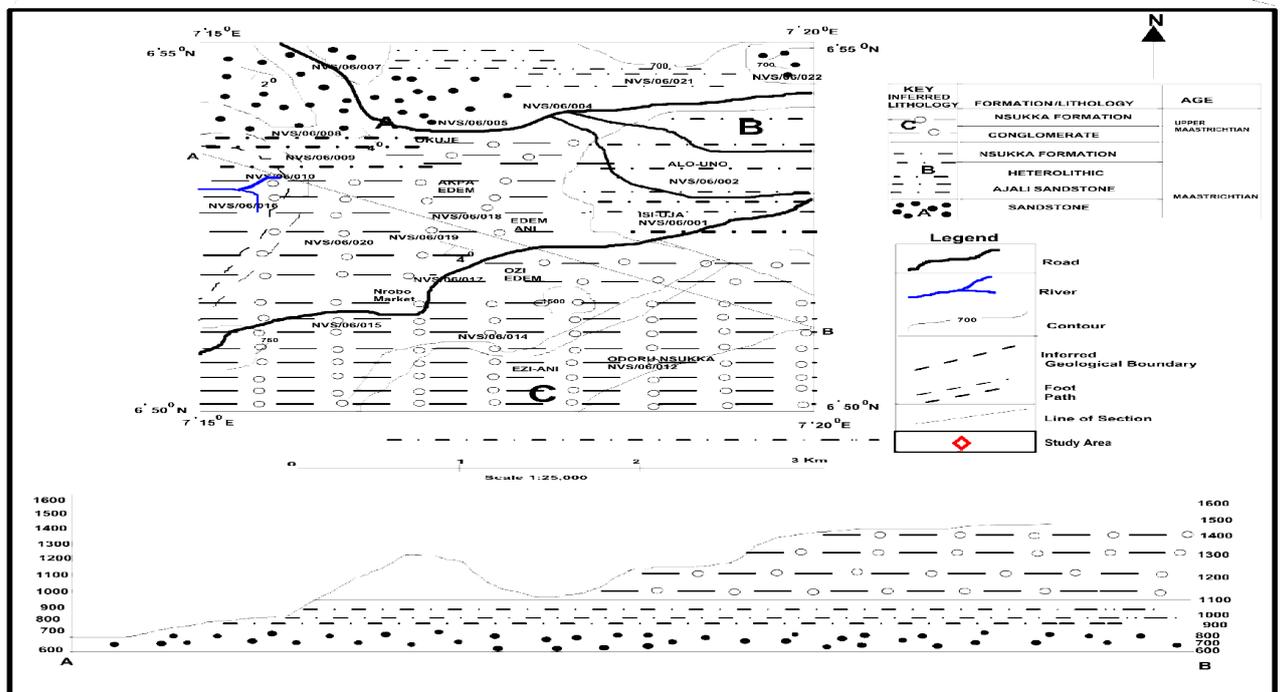


Fig.1 Geology of the Study Area.

### 3 METHODOLOGY

The samples were taken to the laboratory to help ascertain the depositional environment of the sediment in the study area. The samples were subjected to grain size analysis and they are from stations NVS/06/007 (Iyi-Ezer, Okpuje) and NVS/06/016 (Iyi-Iselejuonma in Umuamuna Nrobo Nsukka). The method use is the machine sieved (Electrical) method, the purpose of the sieving is to analyse the sedimentary environment to afford an understanding of the hydrodynamic conditions under which the sediment were deposited. The samples are relatively consolidated and are disaggregated using porcelain mortar and pestle and then dried, the sieving process takes the following steps.

The weight of each sample to be used was weighed in order not to over load the sieves at a 100kg for both the samples are coined and quartered and a suitable fraction examined for the presence of acicular (Kyanite, needles shape) or flacky (Mica) minerals and a note taken of these materials three after quartering. The weighed samples are individually placed at the top of the sieves that are arranged using the root-2 method (1/2-Phi) by Folk (1966) and poorly arranged in order of decreasing mesh size. i.e from base pan to top sieved. These are the apertures sizes, the sieves are tightly covered and

fastened to the sieve shaker which runs for 20 minutes. After shaking for twenty (20) minutes each of the sieve mesh results of sieve analysis were detached and the samples retained on each mesh were measured and recorded accurately against each sieve number.

## **4 RESULT AND DISCUSSION**

### **4.1 DETAIL DESCRIPTION OF EACH UNIT**

For easy description of the lithologies there are six unestablished lithologies in the area:

- Fine grained friable Sandstone facies(Facies A)
- Dark grey Shale facies (Facies B)
- White to pink clay facies (Facies C)
- Fine to coarse grained Sandstone facies (Facies D)
- Conglomeratic Sandstone facies (Facies E)
- Heterolithic Sandstone and clay facies(Facies F)

### **4.2 FINE GRAINED FRIABLE SANDSTONE (UNIT A)**

This unit was found at a station NVS/06/011 (Iyi Ovoo spring at Akpa-Edem). This facies was also encountered at a second NVS/06/007 (Iyi Ezeri Okpuje located at the back of community secondary school, opposite federal livestock farm Okpuje). At station NVS/06/011, the outcrop is 5.3m high. The bottom of the outcrop section consists of 1.5m thick of white friable sandstone. The sandstone is fine to medium grained and are well sorted. Directly on the top of these units is a 0.8m thick light coloured and well laminated siltstone. This unit is directly overlain by a 3m thick parallel bedded and bioturbated, dark grey shale. Generally they strike  $122^{\circ}\text{SE}$  and  $302^{\circ}\text{NW}$  and dip along  $206^{\circ}\text{SW}$  with a dip amount at about  $2^{\circ}$ . These outcrop marks the contact between the Ajali Sandstone and the overlying Nsukka Formation. Here the white friable fine-grained Sandstone represents the Ajali Sandstone. This friable white sandstone facies of Ajali sandstone also outcrops at some other location within the studied area, such as NVS/06/002 (Iyi. Odoru at Alor-Uno), NVS/06/003 (Iyi-Awuna at Ibagwa-Ani), NVS/06/004 a hill at Ibagwa-Ani and at NVS/06/005 (Iyo-Ovogovo at Okpuje. In these areas, the facies has been intensely weathered into red earth.

### **4.3 DARK GREY SHALE (UNIT B)**

This lithofacies belongs to the Nsukka Formation. It outcrops at station NVS/06/011 at Iyi-Ovoo spring in Akpa-Edem as shown in (Fig. 2). The outcrop is about 5.8m high with the base occurrence of white and parallel laminated siltstone. This is followed by about 3m thick dark grey shale. An acid test on this shale shows that it is carbonaceous. It is indurated, bioturbated and fossiliferous. This unit is overlain by very fine-grained, well sorted and yellow sandstone. Overlying the yellow sandstone is about 1m lateritic overburden. This is weathered and dark brown in colour. The contact between the siltstone and the overlying grey shale is scoured. They strike  $302^{\circ}\text{W}$  and  $122^{\circ}\text{SE}$  dips at  $206^{\circ}\text{W}$  and the amount of dip  $2^{\circ}$ .

### **4.4 WHITE AND PINK CLAY (UNIT C)**

The unit lies conformably on the dark grey shales facies. They are encountered at stations NVS/06/006 (Iyi- Okerekere Amujom-Okpuje), NVS/06/022 (Iyi- Ozugum at Ibagwa-Ani), and at NVS/06/021 (Iyi-Odoba at Ibagwa-Ani) of the area as shown in (Fig. 3). The station at Iyi Odoba springs Ibagwa –Ani shows typical section of this facies, the outcrop is about 12.8m thick with a base occurrence of about 0.6m thick of fine grained well sorted sandstone. Overlying this sandstone unit is white and pink coloured clay which is about 11.1m thick. It is well laminated and is intensely bioturbated. With abundant biogenic boring structures of Ophiomorpha and Skoliths. The weathered samples are purple and grey coloured. The more detailed description of this clay facies. This unit is overlain by a 0.2m thick unit of indurated ironstone band. The top occurrence at this section is a 0.6m thick vesicular lateritic overburden of weathered earth.

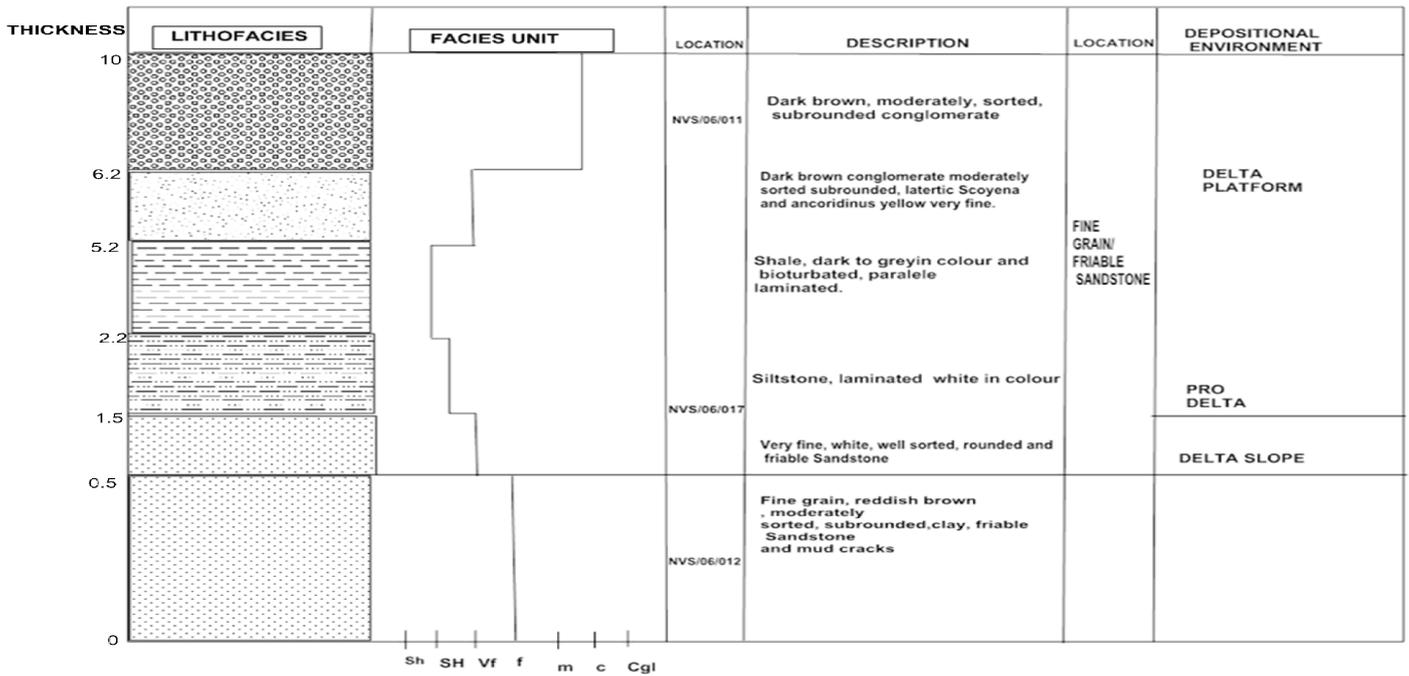


Fig. 2: Lithology and Interpretation of Location NVS/06/011, NVS/06/017 and NVS/06/012. Exposed outcrop

4.5 FINE TO COARSE GRAIN SANDSTONE (UNIT D)

This unit was encountered in Nsukka Formation and it conformably lies on top of the white/pink clay facies. This unit are seen at stations NVS/06/009 (Iyi- Ayata), NVS/06/010 (Mmiri Jesus at Igah-Okpuje), NVS/06/003 (Iyi Awuna at Ibagwa-Ani), as shown in (Fig. 4) NVS/06/020 (Iyi-Okpu at Akpa-Edem), NVS/06/011 (Iyi-Ovoo at Akpa-Edem-Igoro) as shown in (Fig.8), NVS/06/002 (Iyi-Adoro at Alor-Uno) and NVS/06/001 (at Isi Uja). A typical outcrop of these facies is found at location NVS/006/009, NVS/006/010 and NVS/006/011 as shown in (Fig.1 and 2). At location NVS/006/010 the outcrop is about 4.5m thick and consists of three lithological units.

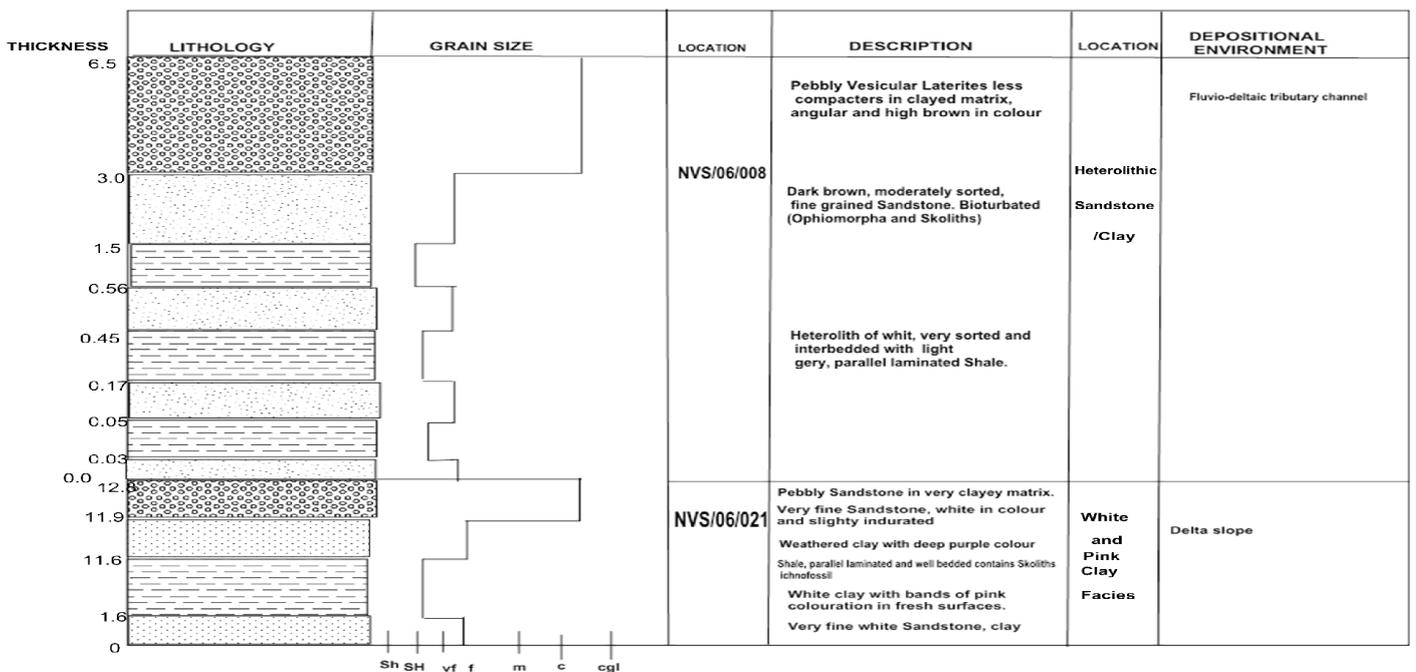


Fig.3: Lithology and Interpretation of Location NVS/06/008 and NVS/06/02. Exposed outcrop

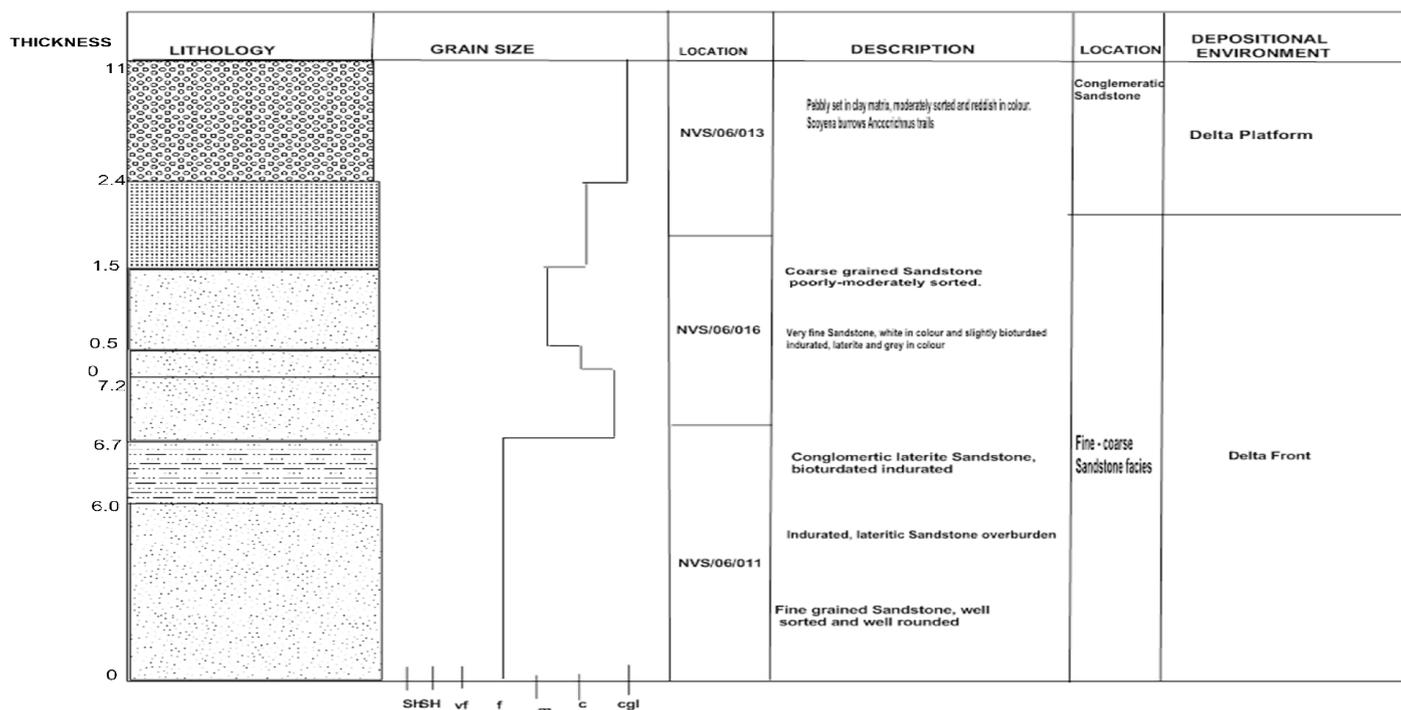


Fig.4: Lithology and Interpretation of Location NVS/06/013, NVS/06/016 and NVS/06/011 exposed outcrop.

Biogenic structure like Ophiomorpha nodosa. This unit serves as the aquifer through which the springs flow. The top-most occurrence of this section consists of an overburden of weathered vesicular lateritic cap. At location NVS/06/003, Iyi Awuna the section is about 7.25m thick a clean and fast rushing spring. This facies consists of a 0.3m thick of indurated sandstone. This unit is overlain by another indurated lateritic sandstone that is light brown to yellow, very fine grained sandstone that is well sorted with a thickness of about 3m thick, fine grained, poorly sorted, angular and very. Fig. The different units of this facies have sharp contact and the beds strikes at 250°SW and 70°NE. It dips at an amount of 2°.

#### 4.6 CONGLOMERATIC SANDSTONE (UNIT E)

The unit was studied at the following stations NVS/06/012( Iyi-Ohe at Odoru Nsukka located opposite St. Cyprain Special Science School), NVS/06/013 (Iyi-Adoka at Ezi-Ani Nsikka), NVS/06/014 (Iyi-Nwankwu at Ezi-Ani), NVS/06/016( Iyi-Isiejuonma at Umuamuna Nrobo Nsukka), NVS/06/015 as shown in Fig.7. At Ajanogbo hill in Umudieto Nrobo Nsukka) and NVS/06//017 (Iyi-Oheghie at Ozi-Edem). This unit lies conformably on top of the fine coarse sandstone facies. A good exposure of this was encountered at location NVS/06/014 and NVS/06/016 of the study area Fig.5. The facies consists of about 6.9m of pebbly, sharp sandstone in clay matrix. Immediately on top is 0.9m thick, laminated and dark grey shale. Overlying the shale is about 1m thick kaolimitic clay, with well preserved plant impression and bioturdated structures. The clay is locally dugged by tournelling at Ajanogbo hll in Umudieto Nrobo Nsukka location NVS/06/015 and the bedding plane of the sandy shale clay units is asymmetrically rippled. Overlying the clay bed is vesicular lateritic overburden of about 5m thick. At station NVS/06/014 this unit grades into conglomeratic sandstone of about 1.2m thick.

The sandstone is moderately sorted, indurate and coarse grained at Iyi Adoka in Ezi-Ani, the sedimentary structures of this facies are well observed. The bioturbation from Scoyena and Ancorichnus ichnofossils are present. Also found are shallow trails of fossils. The Scoyena ichnofossils has a depth and diameters ranges of 1-3cm and 1-2cm respectively with bed thickness of about 7m. At other stations, this unit has been laterized into a vesicular laterite that caped the Nsukka Formation. The beds of this facies have a sharp contact.

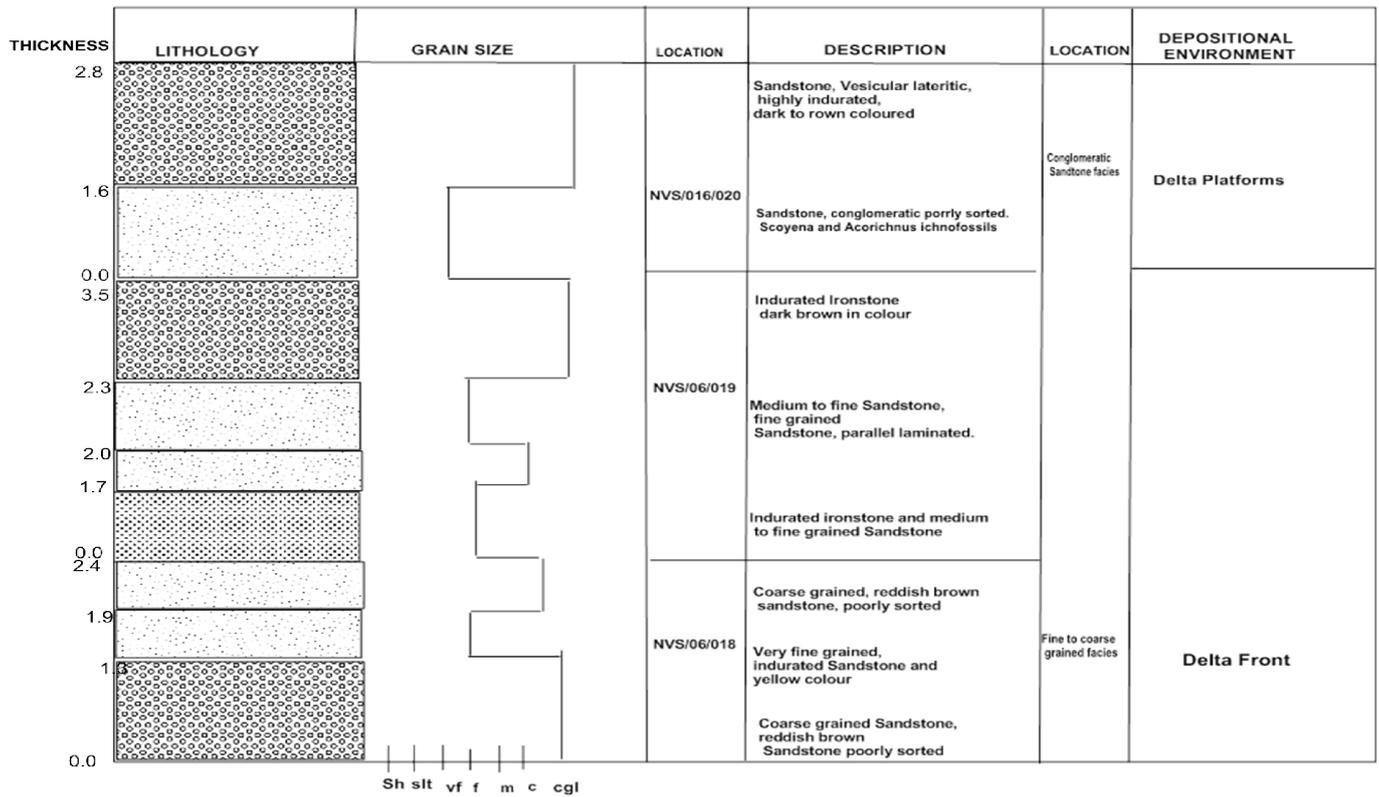


Fig.5: Lithology and Interpretation of Location NVS/06/020, NVS/06/019 and NVS/06/018, exposed outcrop.

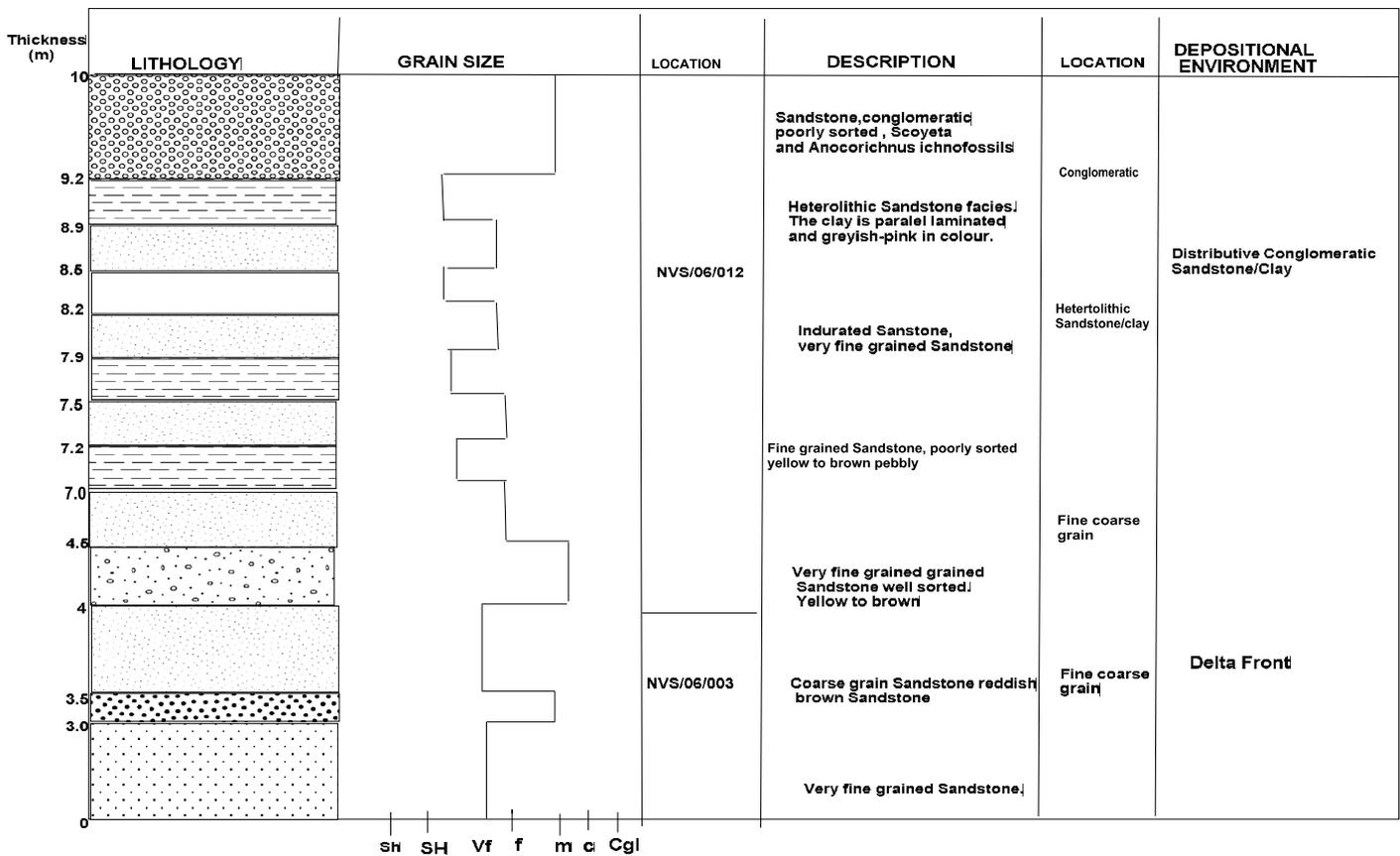
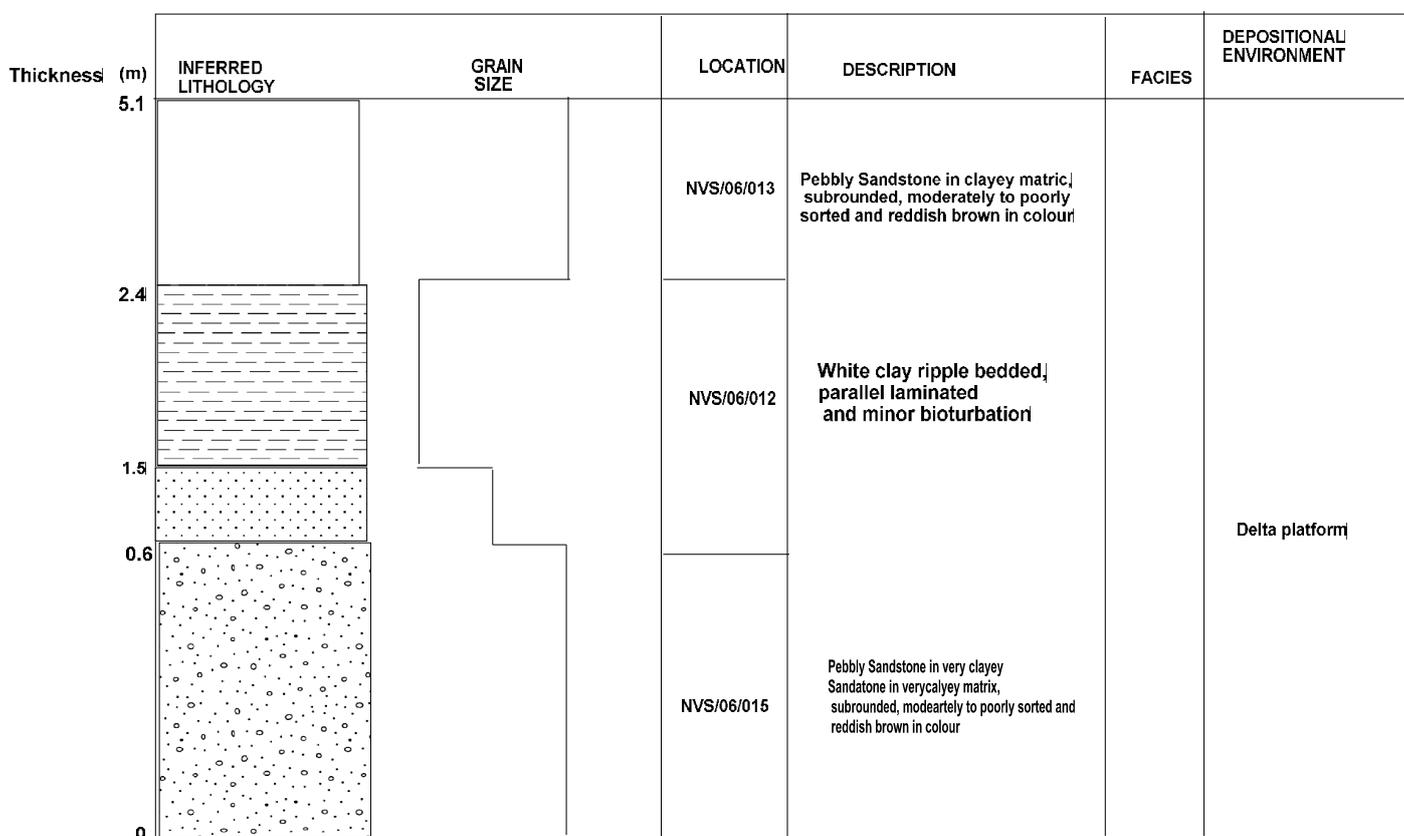


Fig.6: Lithology and Interpretation of Location NVS/06/012 and NVS/06/003, exposed outcrop.

At location NVS/06/012 Iyi-Ohe in Odoru Nsukka-Opoist Cyprain Special School, as shown in (Fig.5) there is stagnant dirty water surrounded by Agbani Odoru, Eburu Mmiri and Barrack town in Nsukka. The lithofacies are the same, the area of this water body measure about 40,000m. The bed strike at 2120SW and 320NE and dips at 296°NW an amount of about 8°.

**4.7 HETEROLITHIC SANDSTONE AND CLAY (UNIT F)**

This unit lies conformably on the conglomeratic sandstone facies and is the topmost of Nsukka Formation in the studied area Fig. This unit was observed at stations NVS/06/012 (Iyi-Ohe Odoru. Nsukka opposite St, Cyprain Special Science), as shown in (Fig.5). NVS/06/008 (Iyikalayi at Uwani-Akwu Okpuje) and NVS/06/009 (Iyi-Ayata by DIFRRI at Okpuje-Ani). At locations NVS/06/008 and NVS/06/009 dark grey coloured clay was found interbedded with medium grained that is white coloured. Their respective thickness is 0.2m and 0.8m respectively. The clay/shale is thickly laminated with two laminae of 0.01m of very fine-grained white sandstone. They are parallel laminated with an asymmetrically shaped laminae plane. At location NVS/06/012, as shown in (Fig.6) the facies grades into rapid succession of a heterolithic facies being made up of a succession of siltstone and clay. The siltstone group is about 0.3m thick while the clay is about 0.4m.



**Fig.7: Lithology and Interpretation of Location NVS/06/013, NVS/06/012 and NVS/06/015, exposed outcrop.**

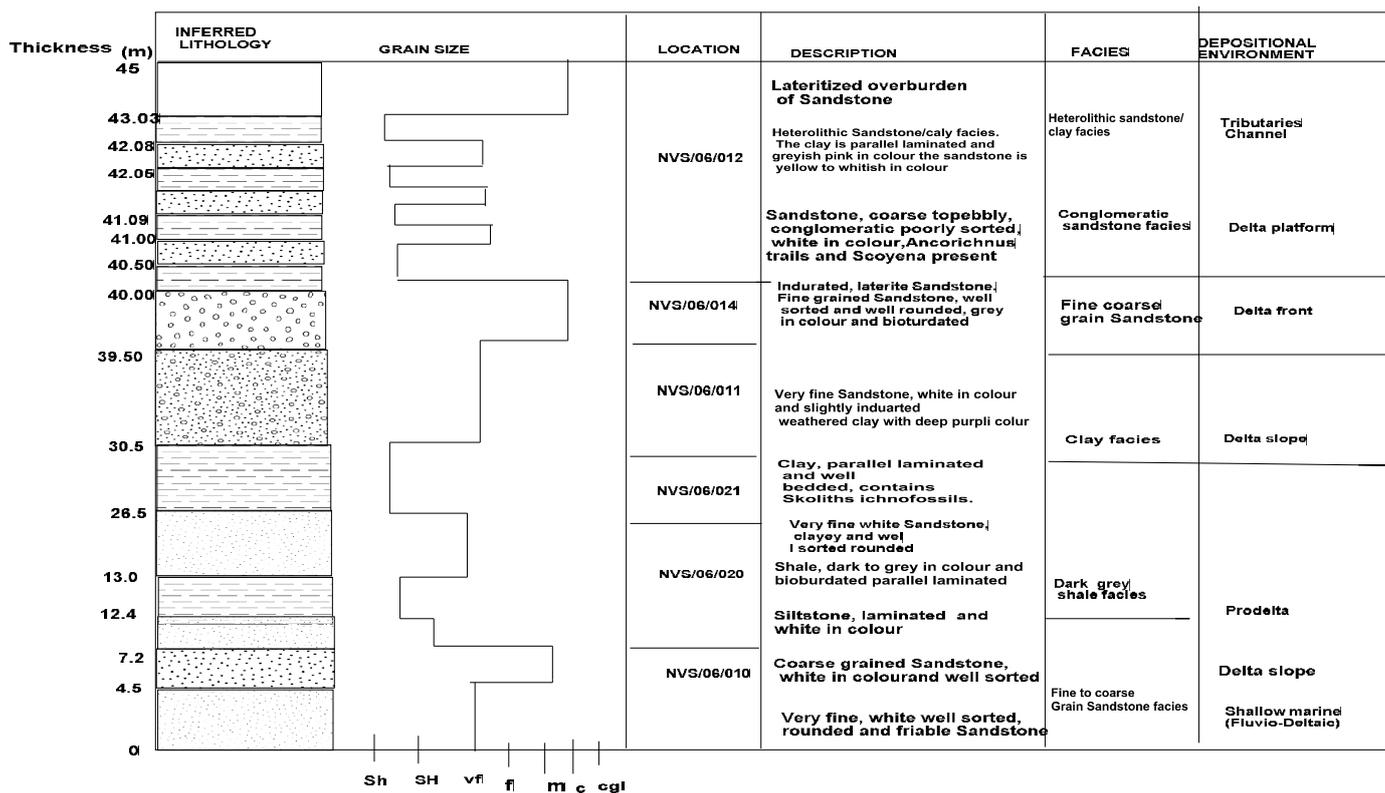


Fig.8. Generalized Lithosection for the Six Unit Encountered in the Two Formation in the Study Area Showing their Depositional Environment

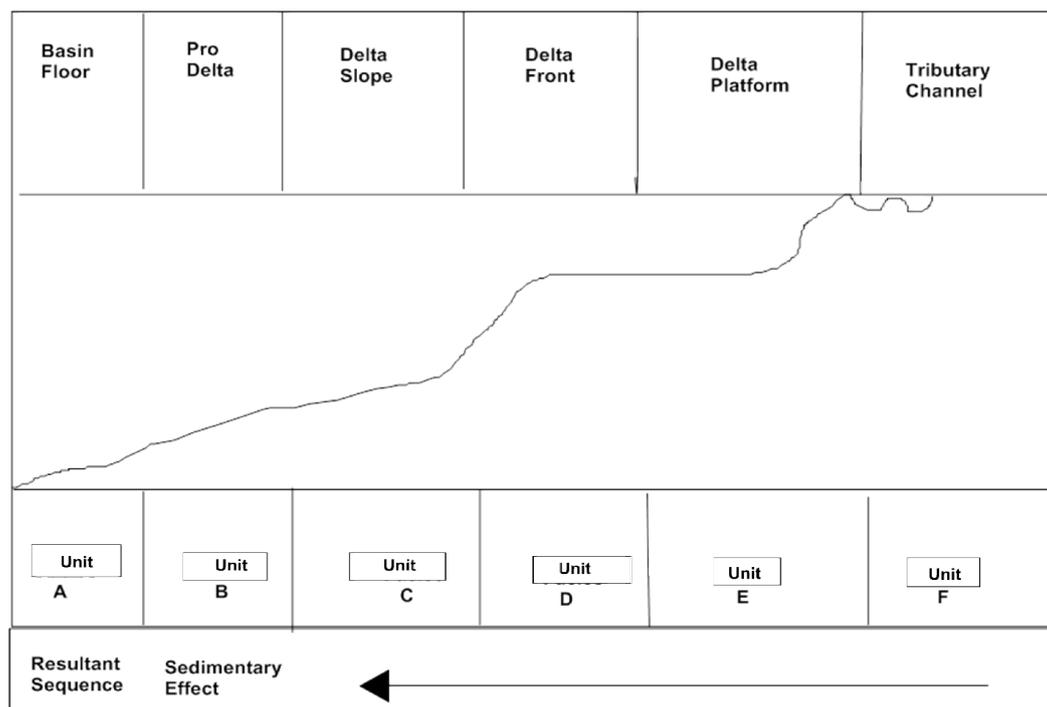


Fig. 9. Showing Relationship between Facies and Environment of Ajali and Nsukka Formation.

## 5 CONCLUSION

The study area which has six lithofacies was recognized as shown in (Fig.8). This includes fine-grained friable sandstone (A), dark grey shale unit (B) white and pink clay unit (C), fine to coarse grained sandstone unit (E) and the heterolithic sandstone unit (F). Two formations were encountered in the area studied: Ajali Sandstone and the Nsukka Formation. The fine-grained friable sandstone unit belong to Ajali Sandstone while the rest five other unit belongs to Nsukka Formation. From each of the units analysis result indicates that the top of Ajali Formation encountered were fluvio-deltaic in origin, while the Nsukka Formation was deposited in fluvio- deltaic environment but essentially pro-deltaic tributary channel. The result from the sieve analysis extrapolates that Nsukka Formation was deposited in parallic environment in a predominantly euxinic condition which accounts for the red earth colouration of the lithologies. In addition, indication by the presence of *Scoyena* and *Skoliths*. Ichnofossils. From the trace fossil analysis shows a deltaic environment ranging from delta platform to delta slope realm respectively.

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