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Lithostratigraphy of the Maastrictian Nsukka Formation in the Anambra Basin, S.E Nigeria.

U.M. Uzoegbu[1*], U. A. Uchebo[2], and I. Okafor[3]

1. *Senior Lecturer, Geology Programme, Abubakar Tafawa Balewa University, PMB 0248, Bauchi, Nigeria.*
2. *Assistant Lecturer Geology Programme, Abubakar Tafawa Balewa University, PMB 0248, Bauchi, Nigeria.*
3. *Lecturer 1, Petroleum Trust and Development Fund, Chair, Department of Geology and Mining, University of Jos, PMB 2084, Jos, Nigeria.*

Abstract: *A detailed lithostratigraphic study of the Campanian-Maastrichtian formations (Early basal Campanian to Maastrichtian) from a borehole and wells in the Anambra Basin has been undertaken. The lithofacies of the Nsukka Formation comprises shales, sandy clay and sands. The formation was encountered at several wells in the Anambra Basin. The Elf Nigeria Ltd well numbers 447/1/AAR-1, 7/4/AO-1 and 447/6/NM-1 penetrated the entire Campanian-Maastrichtian sequences of the formations. A lectostratotype has been proposed from the lithological differences between the Mamu and Nsukka Formations for the proper definition of the stratigraphic unit. This is to satisfy the code of accepted stratigraphic practice which states that stratotype should be proposed for established formations. It will also help to reduce the general assumption on similarities in the stratigraphic nomenclature of some lithofacies in the Mamu and Nsukka Formations.*

I. Introduction

The Anambra Basin became the site of major deposition following the Santonian folding in the southeastern Nigeria (Fig. 1). Compressional uplift of the Lower Benue Trough succession (Albian to Coniacian) along a NE – SW axis was accompanied by tectonic inversion and downwarping of the Anambra platform. Estimates of total sediments thickness in the Anambra Basin from gravity measurements range from 1000 – 4500 m (Ladipo et al., 1992), out of which between 3000 – 3500 m were deposited during the late Cretaceous (Upper Campanian to Maastrichtian).

The aims of this study are to provide a detailed description of the Nsukka Formation and to propose a type section for its elucidation. No type section was designated when the unit was established rather been generalized as similar to the Mamu Formation. A type section is the best means of defining a stratigraphic unit (Hedberg, 1976).

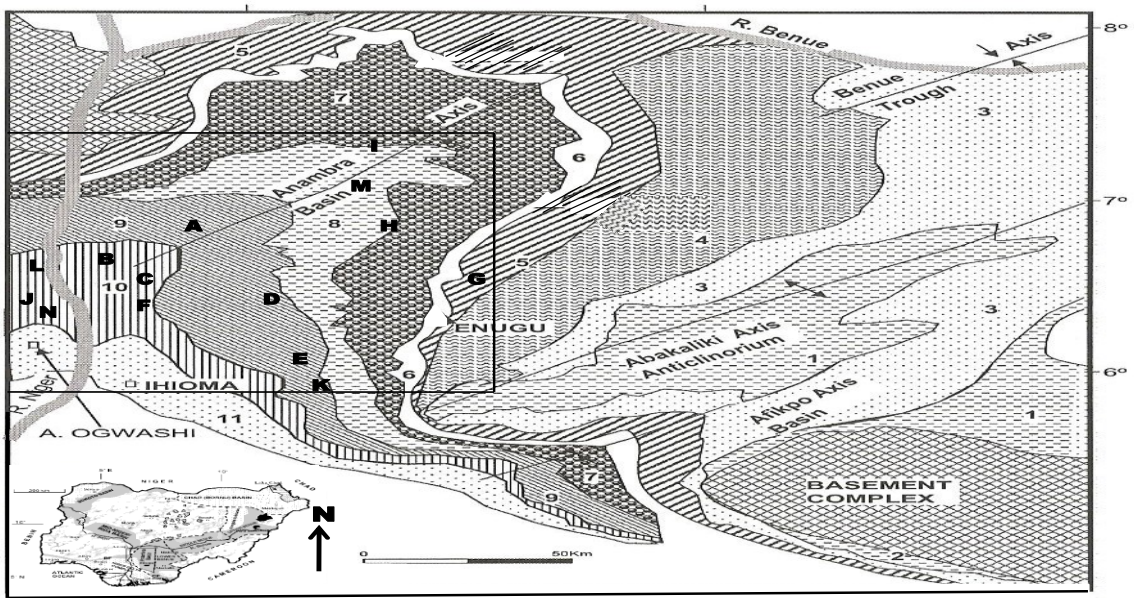

Fig. 1: Generalised geological map of the SE Nigeria (boxed area of inset A-N) showing the location of the drilled wells. Numbers indicate Cretaceous and Tertiary formations shown as follows; **1.** Asu River Group; **2.** Odikpani Formation; **3.** Eze-Aku Shale; **4.** Awgu Shale; **5.** Enugu/Nkporo Shale; **6.** Mamu Formation; **7.** Ajali Sandstone; **8.** Nsukka Formation; **9.** Imo Shale; **10.** Ameki Formation and **11.** Ogwashi-Asaba Formation (modified from Akande et al., 2007)

Stratigraphy

At least five major transgressive episodes have been recorded from the stratigraphic successions of the Anambra Basin from the late Cretaceous to Eocene times (Fig. 2). This was correlatable to the global eustatic sea level chart. These changes in relative to sea level controlled the distribution of sedimentary facies within the basin. The sedimentary fills of the trough are highly variable, ranging from deep to shallow marine shales and carbonates, turbidites, shoreline deltas, as well as continental fluvial sands.

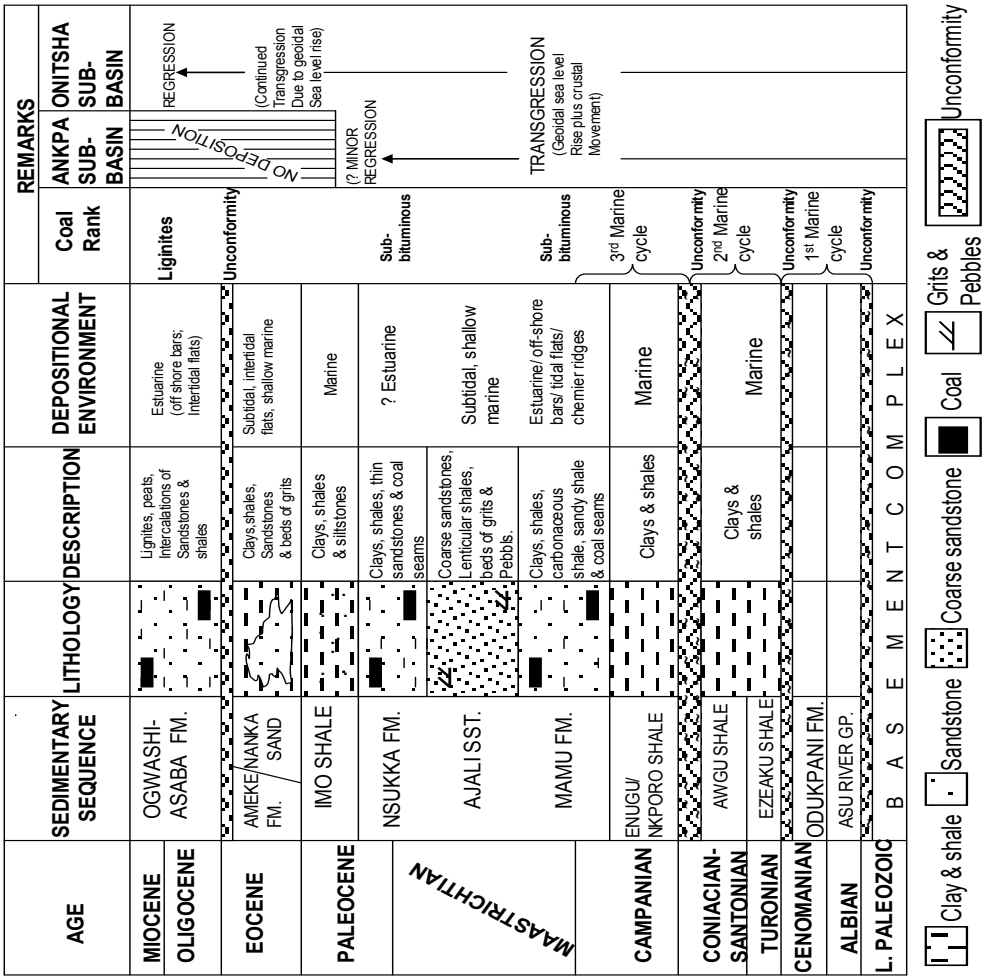

Fig. 2: The stratigraphy of the Anambra Basin southeastern Nigeria (modified after Ladipo, 1988 and Akande et al., 1992).

II. Lithostratigraphy

Table 1 present the fourteen wells drilled in the Anambra Basin by Elf Nigeria Ltd to enhance proper description of the lithologies and in Fig. 1 are the locations of these wells (A-N).

The Nkporo Shale

The basal facies of the late Cretaceous sedimentary cycle in the Anambra Basin is the Nkporo Shale which indicates a late Campanian age (Fig. 2). In general this formation is exposed at Leru 72 km Enugu – Port Harcourt Express way and has been described as a coarsening upward deltaic sequence of shales and interbedded sands and shales (Ladipo et al, 1992). Locally, gypsum occurs as laminae within the sediments but is non-commercial. The interpretation is supported by the vertical association of distributary channel sands where exposed (basal Mamu Formation), and the lateral equivalents of lower flood plain carbonaceous shales (Enugu Formation) towards the central parts of the basin (Fig. 3).

Table 1: List of the wells located in the map area, with permission from Elf Nigeria Ltd.

Wells	Code
A	447/1/AAR-1
B	447/2/OAR-1
C	447/3/OO-1
D	7/4/AO-1
E	7/5/IM-1
F	447/6/NM-1
G	446/7/IU-1
H	444/8/AU-1
I	444/9/H-1
J	448/10/AA-1
K	446/11/AK-2
L	448/12/AD-1
M	441/13/AE-1
N	447/14/H-1

*See Figure 1 for locations. All wells are operated by Elf Nigeria Ltd.

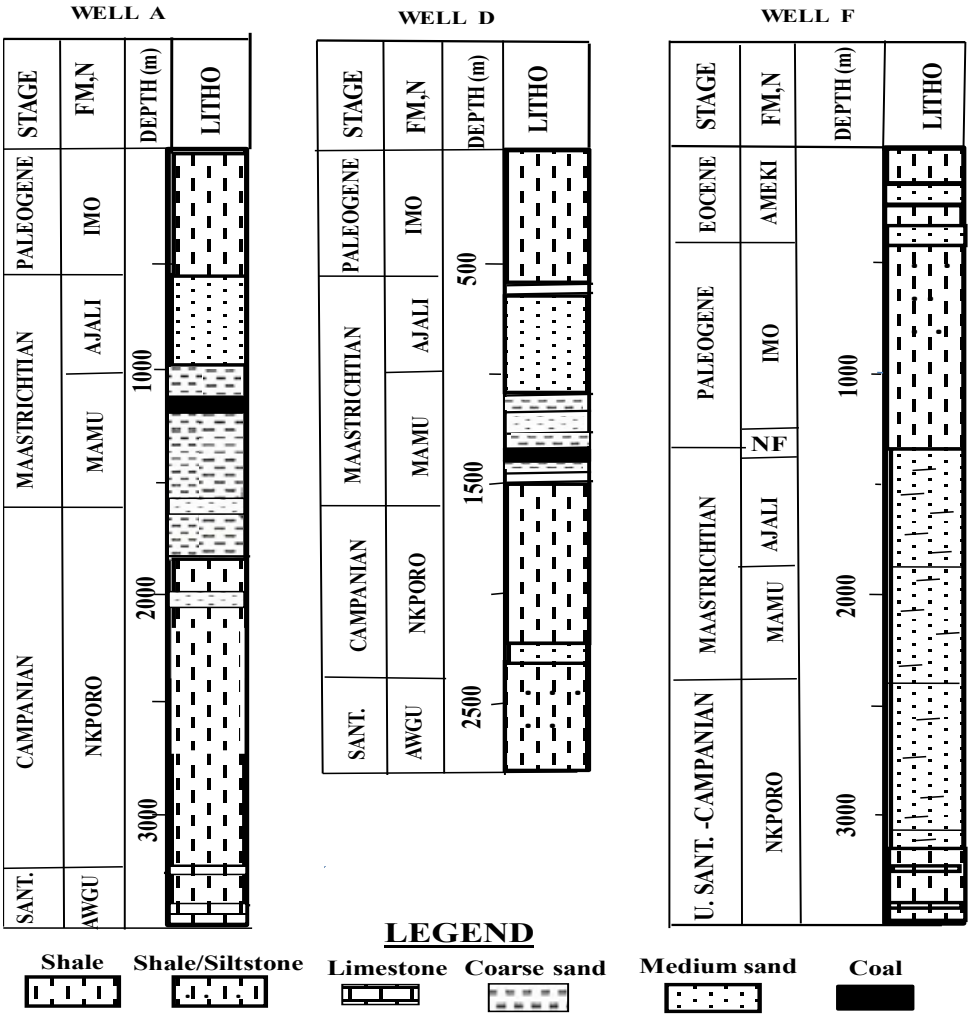

Fig. 3: Lithologic profile of wells drilled in the Anambra Basin by Elf Nigeria Ltd. These wells are (A) 447/1/AAR-1, (D) 7/4/AO-1and (F) 447/6/NM-1.

The Enugu Shale

The Enugu Shale are found north of Awgu and exposed at Milikin Hills at Enugu, thus restricting the facies to the central and northern parts of the basin. Lithology mainly of carbonaceous shales and coals within the upper half deposited in lower flood plain and swampy environments (Ladipo et al., 1992). Siderite and pyrite are common early diagenetic minerals associated with these sediments (Fig. 3).

Owelli Sandstones

This sandstone is the major sand member of the Enugu Shale Formation and forms an elongate shoestring sandbody elongated to the NE, defining a member belt of a fluvial/distributary channel system. Sedimentary structures of the channel sand exposed at Ihe junction, for example, demonstrate possible tidal processes and, in conjunction with a few gastropod shells recovered; suggest marine incursions into these (distributary) channel systems.

Mamu Formation (Lower Coal Measures)

The Mamu Formation succeeds the Upper Campanian lateral facies associations (Fig. 2). The age ranges from Lower to Middle Maastrichtian from south to north, and is accompanied by both vertical and lateral facies changes (Ladipo et al., 1992). The thickness of the formation varies across the basin, ranging from 100 m to over 1000 m (Fig. 3). The lithologic associations include shales and sandstones, with some limestones in the south and coal seams in the central to the upper parts of the basin.

Typical depositional environments include distributary/eustuarine channels, barrier foot, swamp and tidal flats.

Ajali Sandstons (False bedded Sandstones)

The Ajali Sandstones consists of mineralogically supermature, medium to coarse grained, moderately sorted quartz arenites (Fig. 2), about 300 m thick extending across the entire basins as a sheetlike sandbody, and into the Middle Niger Basin. The formation is slightly diachronous, ranging from Middle to late Maastrichtian from south to north. The sediments are unconsolidated and kaolinite matrix constitutes less than 5% of the total rock volume. The clays also occur as thin and laterally extensive beds (< 1 m usually) which intercalated with the sands and act in places as the only permeability barrier in the sequence. Recent analyses of SEM micrographs of the grains show they have good sphericities and roundness due to several episodes of reworking in successive mega-tectonic phases.

Cross bedding is the dominant sedimentary structure of the formation. It is associated with reactivation surfaces, mud drapes, tidal bundles, backflow ripple channels cut and fills, lateral accretion surfaces, as well as *Skolithos* and *Ophiomorpha* ichnogenera (Ladipo et al., 1992). These structures characterized the formation over the entire basin, and suggest tidal origin within a shallow marine environment. Paleocurrent trends across the basin suggest a depositional environment similar to the southern part of the North Sea, which is characterized by helicoidal tidal currents and dominated by large-scale sand waves (Dike, 1976).

Nsukka Formation (Upper Coal Measures)

The Nsukka Formation (Upper Coal Measures) conformably overlies the Ajali Sandstone Formation and occurs from the north of Awka to the upper Ankpa sub-basin. The lithology is mainly interbedded shales, siltstones, sands and thin coal seams (Fig. 2), which have become lateritized in many places where they characteristically form resistant capping on mesas and buttes. The formation is diachronous, spanning upper Maastrichtian into Danian. Depositional environment has been suggested to be similar in many ways to the Mamu Formation (Lower Coal Measures) i.e transitional/shoreline, mud flat and swamps, deposited during a largely regressive phase.

The Imo Shale

The Imo Shale developed as thick bluish to greyish clays and marine shales with a maximum thickness of about 500 m. It appears to thin out west of the River Niger towards Araraomi and Gbekebo, with thickness of 200 m and 180 m respectively (Reyment, 1965). East of the River Niger, within the formation, however, lenses of sands occur.

STRATOTYPES

Tattam (1944), du Preez (1947), Simpson (1954), Hazell (1958), de Swart and Casey (1961), Reyment (1964) and Allix (1987) did not provide a proper classified type section for the Nsukka Formation throughout their entire investigations, They only made used of outcrop samples no detailed deep drilled borehole lithology has been investigated to properly designate the type section of this formation. The formation has always been generalized as having similar but not the same to the Mamu Formation. This gives room for abrupt conclusion in the interpretation of the lithofacies of the unit. A unit stratotype or boundary stratotype provides the most stable and unequivocal standard definition for a stratigraphic unit. The sand-shale was encountered at Akpugo Eze is

now proposed as a lectostratotype (Fig. 4). A lectostratotype is a rock section selected later to serve as the type section of a formation in the absence of an adequately designated original stratotype (Hedberg, 1976).

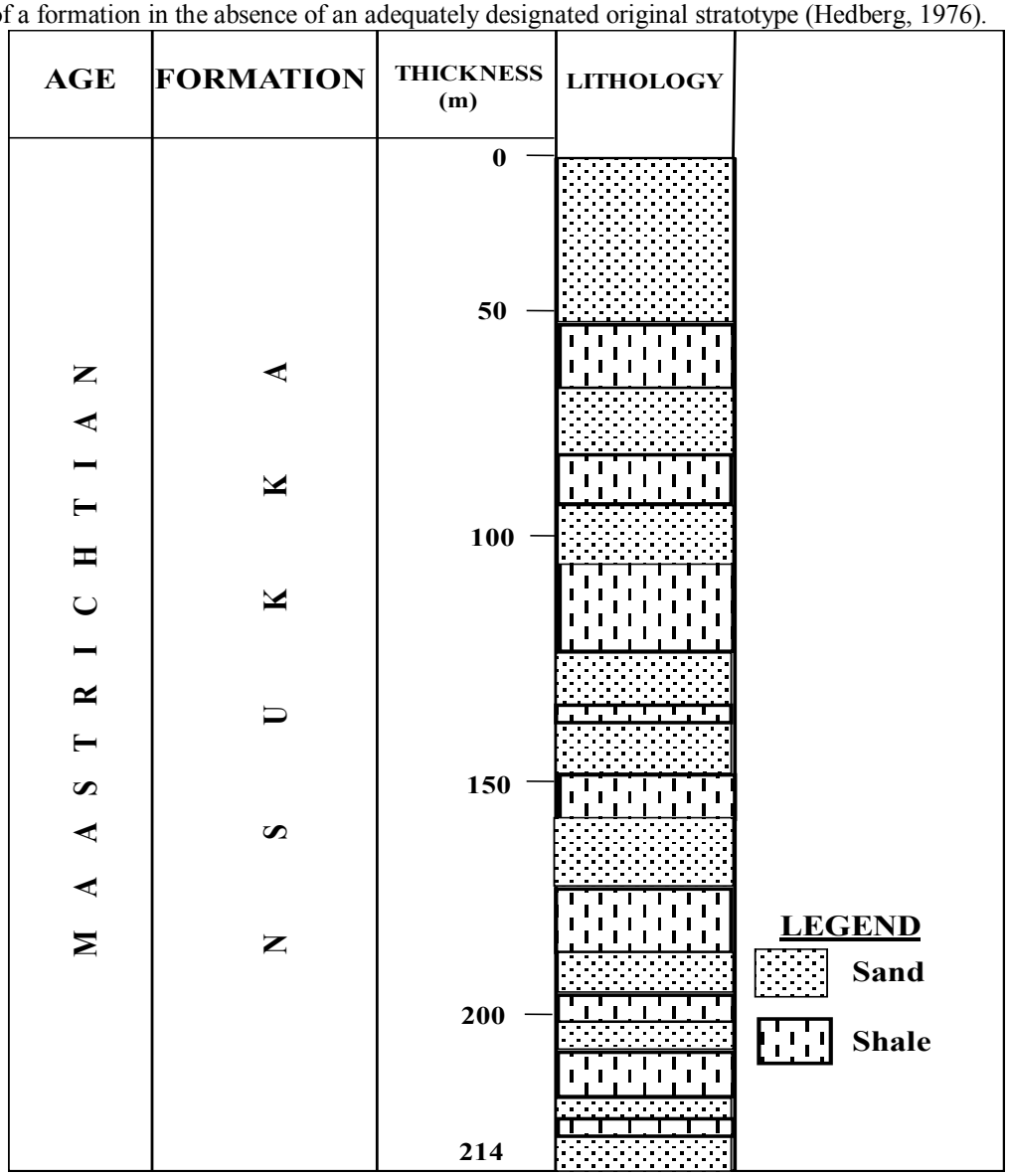

Fig. 4: Lithologic profile of the Nsukka Formation at Akpugo Eze (after Federal Department of Water Resources, Enugu).

Lectostratotype for the Nsukka Formation

Location - Akpugo Eze, Enugu near Oji River.
Thickness - 214 m (After Federal Department of Water Resources, Enugu)

The section encountered at Akpugo Eze village at Enugu near Oji River is proposed as a lectostratotype for the Nsukka Formation (Fig. 4).

0	-	9.1 m	Lateritic sand
9.1	-	15.9 m	Medium – coarse brownish sand
15.9	-	27.4 m	Brownish red sandy clay
27.4	-	33.5 m	Blackish shales
33.5	-	38.1 m	Coarse pebbly blackish sand
38.1	-	45.7 m	Hard blackish shales
45.7	-	54.9 m	Brownish white sand
54.9	-	59.4 m	Shale greyish black
59.4	-	64.0 m	Sand blackish coarse grained
64.0	-	79.9 m	Shale blackish
79.9	-	87.5 m	Sand coarse
87.5	-	99.1 m	Shale blackish, organic soft

99.1	-	117.3 m	Sandy clay, greenish black
117.3	-	125 m	Shales, soft blackish grey
125	-	129.5 m	Sand medium – coarse blackish
129.5	-	140.2 m	Shales, soft blackish grey
140.2	-	186.0 m	Sand, blackish, medium – coarse
186.0	-	191.1 m	Shales, soft blackish grey
191.1	-	214.0 m	Sand, blackish, medium – coarse

In the lithology of fourteen wells drilled in the Anambra Basin by Elf Nigeria Ltd (Fig. 3), the Nsukka Formation was absent or rarely represented. Using these wells for other applications by Unomah and Ekweozor (1993) also failed to made mention of this vital formation.

III. Discussion

The type section described above is similar in lithology to upper part of the 50 m thick sequence described for the Nsukka Formation at Oji River by Offodile (2002). The Akpugo Eze section has thicker shale beds. The lower part of the section is comprised of shales, sandy clay, medium to coarse blackish sands and brownish red sandy clay, blackish shales, medium to coarse brownish sands and lateritic sand at the top. This part of the sequence (50 m) is considered in this study to be a part of the Ajali Formation which underlies the Nsukka Formation. The upper part of the Ajali Formation composed of coarse sandstones with thin lenticular shales, beds of grit and pebbly gravel (Ladipo et al., 1992). This upper section is considered to be part of the Nsukka Formation. The abrupt contact between the Nsukka and the Ajali Formations in the section is drawn at the top of thin lenticular shales, beds of grit and pebbly gravel at 50 m because the Nsukka Formation does not contain beds of grit and pebbly gravel. The Awgu section is composed of coarse pebbly blackish sand (Offodile, 2002) and at Ezimo it composed of shale, lateritic sand and thin coal seams (Uzoegbu, 2010) and is part of Nsukka Formation. The Nsukka Formation is different from the overlying Imo Shale which consists of intercalations of bluish to greyish clays and deep bluish marine shales (Ladipo et al., 1992; Offodile, 2002). It occurs, as highlands at Ebenebe and Ugwuoba in Enugu and Anambra states (Ladipo et al., 1992). The compromising views of some workers on the lithostratigraphical subdivision of the Akpugo Eze, Awgu, Ezimo, Elf Nigeria Ltd wells (447/1/AAR-1, 7/4/AO-1, 447/6/NM-1) Figure 3 and Federal Department of Water Resources, Enugu on the formation are due to the non-compliance with the standard for the definition of the Ajali, Nsukka and Imo formations as provided by early workers like Tattam (1944), du Preeze (1947), Simpson (1954) and du Swart and Casey (1961). The question is why in all the wells drilled by Elf Nigeria Ltd in the Anambra Basin the Nsukka Formation was not mentioned? Again, in Unomah and Ekweozor (1993) this same formation was not noticed while using these wells in their applications. It's absent, was it because the formation was not encountered in those wells? Or is it still the same similarity in abrupt conclusion with the Mamu Formation that caused it's absent in those well's lithologies? Well, in every similarities there are always contrasting views. The Mamu Formation has intercalations of limestone lithologies which were not obviously noticeable in the lithological units of the Nsukka Formation.

The lectostratotype proposed in this paper provides a standard for the definition and recognition of the Nsukka Formation. The establishment of the type section satisfies the rules of stratigraphic practice (Hedberg, 1976). According to this rule, a specified sequence of rock strata provide the most stable and unequivocal standard for the definition of a unit stratotype. The lectostratotype does not include upper and lower boundaries of the formation which are however, well illustrated by Federal Department of Water Resources, Enugu (Figure 4). In this borehole, the upper and lower are abrupt are drawn at about 64 m and 220 m respectively. This reflects changes in the depositional regimes at the beginning and closes of its depositional history and may indicate minor breaks in sedimentation. With the propose stratotype the concept and definition of the formation is better elucidated.

The Nsukka Formation is correlatable with the lower part of Kerri-Kerri Formation in the Upper Benue Trough and the Patti Formation in the mid-Niger Basin. On the basis of the proposed lectostratotype the formation is better defined and should no longer be mixed or have abrupt conclusion of being the same with Mamu Formation.

IV. Conclusion

The Nsukka Formation comprises mainly interbedded shales, siltstones, sands and thin coal seams. No limestone present. For more precise definition of the formation, a lectostratotype has been proposed.

Acknowledgements

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