Scientia Africana, Vol. 14 (No.1), June 2015. Pp 55-74
 ISSN 1118 – 1931

LITHOLOGY AND ECONOMIC POTENTIAL RESOURCE OF IGUMALE-NSUKKA AREA, SE NIGERIA.

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Received: 11-12-14
Accepted: 09-04-15

ABSTRACT

The Maastrichtian Mamu and Nsukka Formations in the Anambra Basin (SE Nigeria) consist of a cyclic succession of coals, carbonaceous shales, silty shales and siltstones interpreted as deltaic deposits. The studied area is located in the northern part of Nsukka within the Anambra Basin southeastern Nigeria. The aim of this investigation is to examine the litholologic and economic aspect of some rocks in this area. Four main stratigraphic units belonging to the Enugu Shale, the Lower and Upper Mamu Formation and the Ajali Sandstone were identified. The Enugu Shale is the oldest unit which forms the base of the sequence and could be subdivided into subunits; carbonaceous shale, grey shale and sandy shale. The carbonaceous shale consists of dark, soft bluish shales-thinly laminated. The grey comprises laminated shales alternating with sandstones and the sandy shale consists of alternating shale, fine sandstones and siltstones. The Mamu Formation succeeded the Enugu Shale and two members of this formation; Lower and Upper Mamu Formation are identified. The Lower Mamu Formation is made up of three subunits, carbonaceous shale, grey shale, and sandy shale. The Upper Mamu unit consists of friable fine white sandstones. The Ajali Sandstone overlain the Upper Mamu Formation and consists of whitish to pinkish red, poorly consolidated medium grained sandstones. It is well cross-bedded and contains plant impression, and burrow-fills as ichno-fossils. The sandstones are used in the manufacturing of glass while laterites are used for various construction purposes such as roads, buildings and bridges. The clays are for pottery, glazed tiles, in ceramics industry. The coal has a future prospect for industries, such as iron and steel industry as cooking coal, cement industries and raw materials for chemical industries and also use locally for cooking. The alternation of shales and sandstones in the Enugu Shales, Mamu Formation and Ajali Sandstones provide a good petroleum system.

Key Words: Lithofacies, sandstone, shale, mineralogy, depositional environment potential resource.

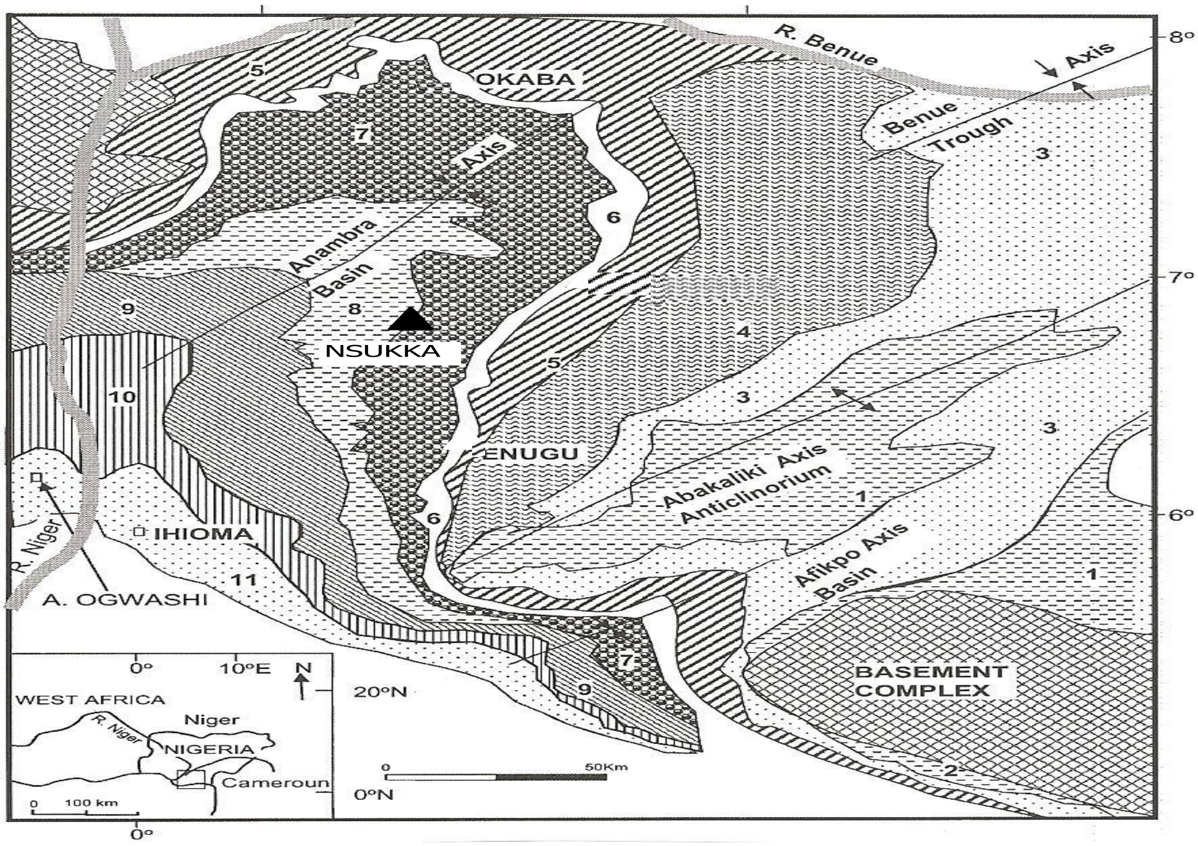
INTRODUCTION

The studied area is bounded by longitudes 7°30´E and 7°38´E and latitudes 6°45´N and 6°51´N. It is lies northwest of Nsukka. The area which covers 40.5km^2 lies within the Anambra Basin and includes the following town, Ehalumona, Mbu, Imilike-Agu, Ogboduaba, and a part of Opi-Agu and

Ezimo (Fig. 1). The area is accessible by roads and footpaths (Fig. 1). The main access routes are the Eha-Alumonah-Mbu-Ikemu trunk C road, the Obollo-afor-Ogboduaba-Mbu-Enugu new road and Eha-Alumona-Agu –Umabor-Opi road.

Many areas of Southern Nigeria including the studied area were first investigated by Shell D'Arcy during their early stages of oil prospecting in Nigeria from 1938-1957 (Dike, 1976). Simpson (1954) studied the Nigerian coal fields and the general geology of parts of Onitsha, Owerri and Benue provinces and observed that the occurrence of Nigerian coal seams were mainly within the Mamu Formation. De Swardt and Cassey (1963) observed that Nigerian coal is sub-bituminous. Reyment (1965) on the basis of abundant index fossils (pelecypods, ammonites and foraminifera) dated the Eze-aku Shales (Lower Turonian, the Nkporo shales (Campanian) which are lateral equivalent to Enugu shales while the Mamu, Ajali and Nsukka Formations are Maastrichtian (Fig. 2).

Short and Stauble (1967) noted that there were three main sedimentary cycles in the southern Nigerian sedimentary basins. The first (Albian to Santonian) was restricted to Benue Trough. The second (Campanian-Eocene) cycle filled the Anambra Basin (to which the studied area belongs) and the Afikpo syncline, and third initiated the formation of the modern Niger Delta. They also recognized that there was uplift during the Paleocene-Eocene, which resulted in the erosion of the rejuvenated Abakaliki anticlinorium, the Anambra Basin and Afikpo syncline.



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Murat (1972) noted that the sedimentary basin of Southern Nigeria was controlled by three major tectonic phases. Burke *et al*. (1970) recognized that sediments of the second cycle were derived from the folded Abakaliki anticlinorium. Nwachukwu (1972) noted that a slight tectonic movement probably took place during the Cenomanian in Benue Trough. Uzuakpunwa (1974) in his discussion on the tectonic implication of the Abakaliki pyroclastic, suggested a pre-Albian movement along the NE-SW trending fault system resulting in the formation of rift like Benue Trough.
Hoque (1976) found out that the sediments of the first sedimentary cycle are feldspar. He also noted that those of the second cycle (found mainly within the Anambra Basin which includes the studied area) were devoid of feldspar. Uzoegbu *et al*. (2013a) more recently proposed a stratotype for the Nsukka Formation because of similarity between the Mamu and Nsukka Formations. This paper deals with examination of the lithologic and economic aspect of some rocks in the studied area.

Regional Stratigraphic Setting

Sub-bituminous coals are restricted to the Maastrichtian Mamu and Nsukka Formations which crop out in long narrow ridges in the NE–SW trending Anambra Basin (Fig.1). The Mamu and Nsukka Formations consist of alternating sandstones, sandy shales and mudstones with interbedded coal seams. The Formation is underlain by the Campanian Enugu/Nkporo Shales (lateral equivalents), and overlain by the Ajali Sandstone (Middle Maastrichtian) and Nsukka Formation (Upper Maastrichtian to Danian) (Fig. 2). Five sedimentary units are recognized in the Mamu Formation in the Enugu area, where the thickest exposed section (approximately 80 m) occurs (Simpson, 1954; Reyment, 1965). From the base, the units consist of (i) a basal shale or sandy shale, (ii) sandstones with occasional shale beds, (iii) carbonaceous shales, (iv) coals and (v) sandy shales. The Nsukka Formation has well exposed section at Iyinzu in Ezimo area with thickness of about 55 m. The succession is paralic as demonstrated by the alternating marine and continental facies, and is considered to represent part of the "third marine cycle" in southern Nigeria (Short and Stauble, 1967; Hogue, 1977; Agagu, 1978). Sediments of the third marine cycle were mainly deposited in Campanian – Maastrichtian times in the Anambra and Afikpo Basins (Fig. 2). These two post-Santonian basins were formed as successors to the Benue Trough, where deposition of the first and second marine depositional cycles took place in Albian – Santonian times (Fig. 2). The third-cycle sediments were deposited during the initial growth of the proto-Niger Delta in the Late Cretaceous (Short and Stauble, 1967). An Early Paleocene transgression led to the termination of the proto-Niger Delta and the deposition of Imo Shale, which was succeeded by the regressive phases of the Ameki and Ogwashi Asaba Formations.

MATERIALS AND METHODS

Four stratigraphic units belonging to the Enugu Shale, the Mamu Formation and the Ajali Sandstone were mapped. These stratigraphic units are the Enugu Shale, Lower Mamu shale, the Upper Mamu shale and the Ajali Sandstones (Fig. 1). The Enugu Shale and the Lower Mamu Formation could be subdivided into sub-units (Table 1).

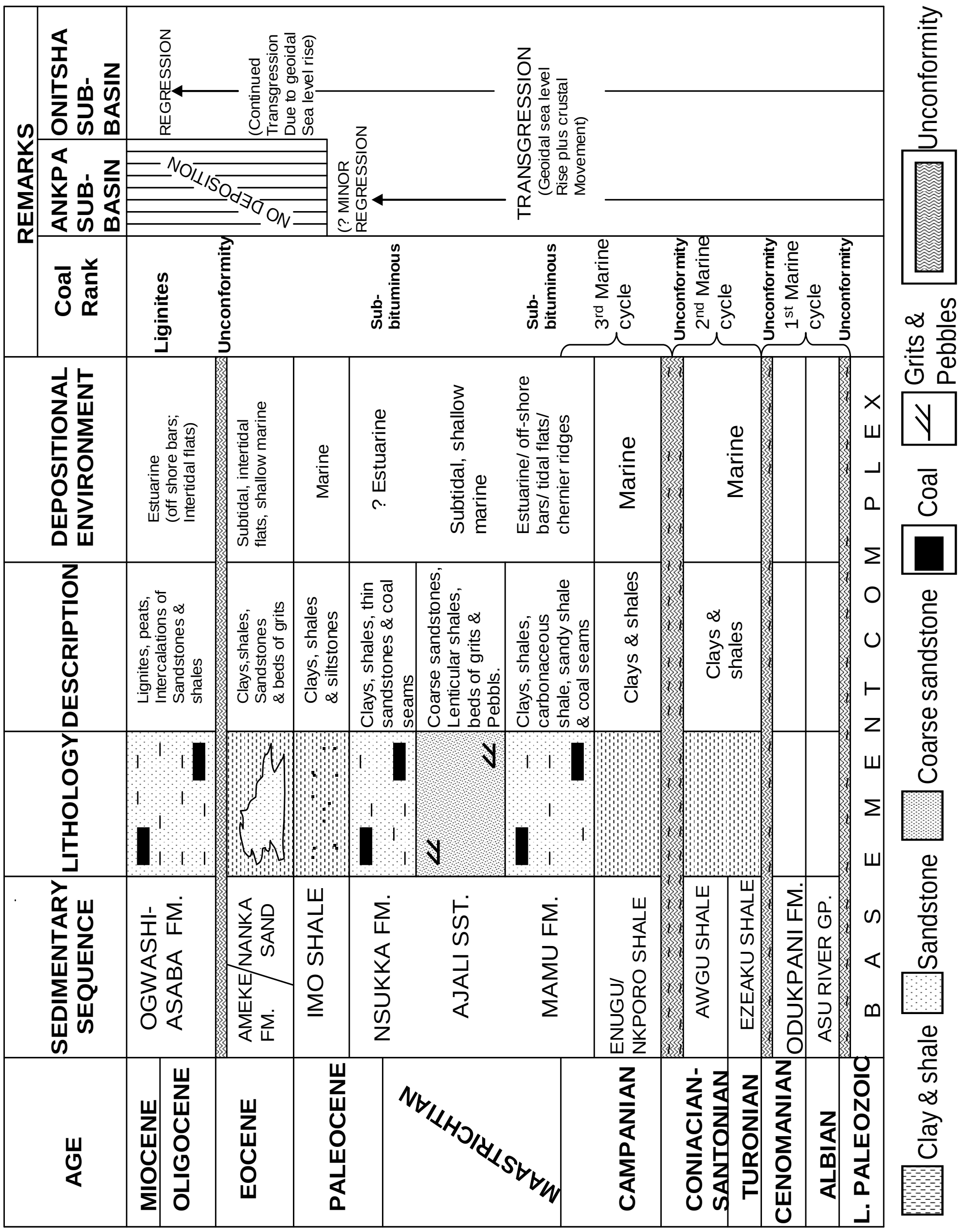

Fig. 2: The stratigraphy of the Anambra Basin southeastern Nigeria (modified after Ladipo, 1988 and Akande et al., 1992).

A detailed geological survey of mapping, measuring and studying in details the litholgic units, rock types and topography of the area were carried out. The measurement of sections was done simultaneously with sampling. Six outcrop sections were studied and sampled. Some features that were of particular interest were noted. Seven samples were selected for sieve analysis.

The samples were disaggregated into individual grains by the use of ceramic pestle and mortar, and about 126.0gm of each sample were then soaked in hydrogen peroxide for 12 hour. Wet sieving was

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carried out using 63- μ m mesh sieve to remove the clay/mud fraction. Each was then oven dried for 12 hours to remove moisture content and sieved using standard sieve opening of 3.35mm, 2.36 mm, 1.18mm 850 μ m, 425 μ m, *300 μ m*, *212 μ m*, 106 μ m, *63 μ m* and pan. The mechanical sieve shaker was switched on for 15 minutes, after which the segregated grains retained in each sieve were collected and weighed and then used for grain size statistical analysis. The analysis of grain size distribution was carried out for Ajali Sandstone, using Folk and Ward (1957) formulas as shown below.

i. Median (md) = $\phi 50$ (50 percentile)

ii. Mean (mz) = $\dfrac{\phi 16 + \phi 50 \phi 84}{3}$

iii. Skewness (ski) = $\dfrac{\phi 16 + \phi 84 - 2\phi 50}{2(\phi 84 - \phi 16)} + \dfrac{\phi 5 + \phi 95 - 2\phi 50}{2(\phi 95 - \phi 5)}$

iv. Standard Deviation (δi) = $\dfrac{\phi 84 - \phi 16}{4} + \dfrac{\phi 95 - \phi 5}{6.6}$

v. Kurtosis (KG) = $\dfrac{\phi 95 - \phi 5}{2.44(\phi 75 - \phi 25)}$

Lithostatigraphic Sections were measured from base to top. Interesting features were noted and photographed. Beds thickness, grain size, colour, estimated sorting were all noted.

Table 1: Lithostratigraphic succession established in the studied area (modified from De Swardt and Casey, 1963).

Age	Formation	Member	Thickness (m)	Descriptions
Upper Maastrichtian	Ajali Sandstone	Ajali Sandstone	400	Medium to coarse grained, poorly consolidated, friable with whitish mudstone bands at various horizons. The sandstone is typically cross-bedded.
Lower Maastrichtian	Mamu Formation	Upper Mamu Formation	100	Medium to fine grained, Friable white sandstone.
		Lower Mamu Formation	200	Alternation of grey shales, and sandy shale which are thinly laminated and occasionally carbonaceous shale with coal seams at various horizons in rhythemic manner.
Campano - Maastrichtian	Enugu Shale		150	Soft dark grey to bluish carbonaceous shales. Nodular concretions are present in these shales and the shales are thinly laminated with mudstones.

RESULTS AND DISCUSSION

Lithological Units

The Enugu Shale with an approximate thickness of 150 m exposed at Imilike Agu as a type section. Simpson (1954) and Reyment (1965) described the Enugu Shale from its area in Asata and Obweeti stream valley within Enugu area. The Enugu Shale which underlies the plain east of the Enugu escarpment in the mapped area covers about 40% of the area. It consists of predominantly soft, dark grey blue carbonaceous shales and sandy shale which alternate with siltstones and occasional bands of mudstones intercalation.

Enugu Shale: The studied area the lithologic unit of the Enugu Shale can be subdivided into three main subunits as (a) Sandy shale, (b) Grey shale and (c) Carbonaceous shale.

Carbonaceous Shale

An exposure of this subunit is recognized along the channel of the Vava stream at Imilike-Agu. It comprises of dark soft carbonaceous shales which are thinly laminated (Fig. 3). The shales are dark blue with nodular concretions and potholes at the base with intercalation of clay which alternate with siltstone (Akhirevbulu and Ogunbajo, 2011; Uzoegbu, 2014). At the top it is weathered to ferruginized sandstone (Fig. 4). Along Opi new road which about 3km outside the studied area a beautiful exposure of this subunit was recognized.

Grey Shale

The type sections of this subunit in the studied area were recognized along the channels of Ofianzu and Isiogene-Onu streams at Mbu and at Eha-ndiagu along the channels of Omeme and Iyi-akwa streams. The grey shales alternate with mudstones and fine sandstones. The grey shale is commonly found overlying the carbonaceous shale in the most of the outcrops studied, and also has nodular concretions. This shale gradually graded into sandy shale upwards and in some places it is weathered to reddish brown coarse sandstone or ferruginized sandstone and the top of which is capped with laterites (Fig. 4E).

The grey shales are characteristically fissile and split into thin flexible flakes of various sizes. The colours of dark carbonaceous shale and grey shale are due to the quantity of organic matter or oxidation state of iron in the rock (Pettijohn, 1975; Ojo and Akande, 2009, Valkarelo and Bhattacharya, 2009; Uchebo, 2010; Obaje et al., 2011; Omali et al., 2011; Uzoegbu et al., 2013a; Uzoegbu, 2014).

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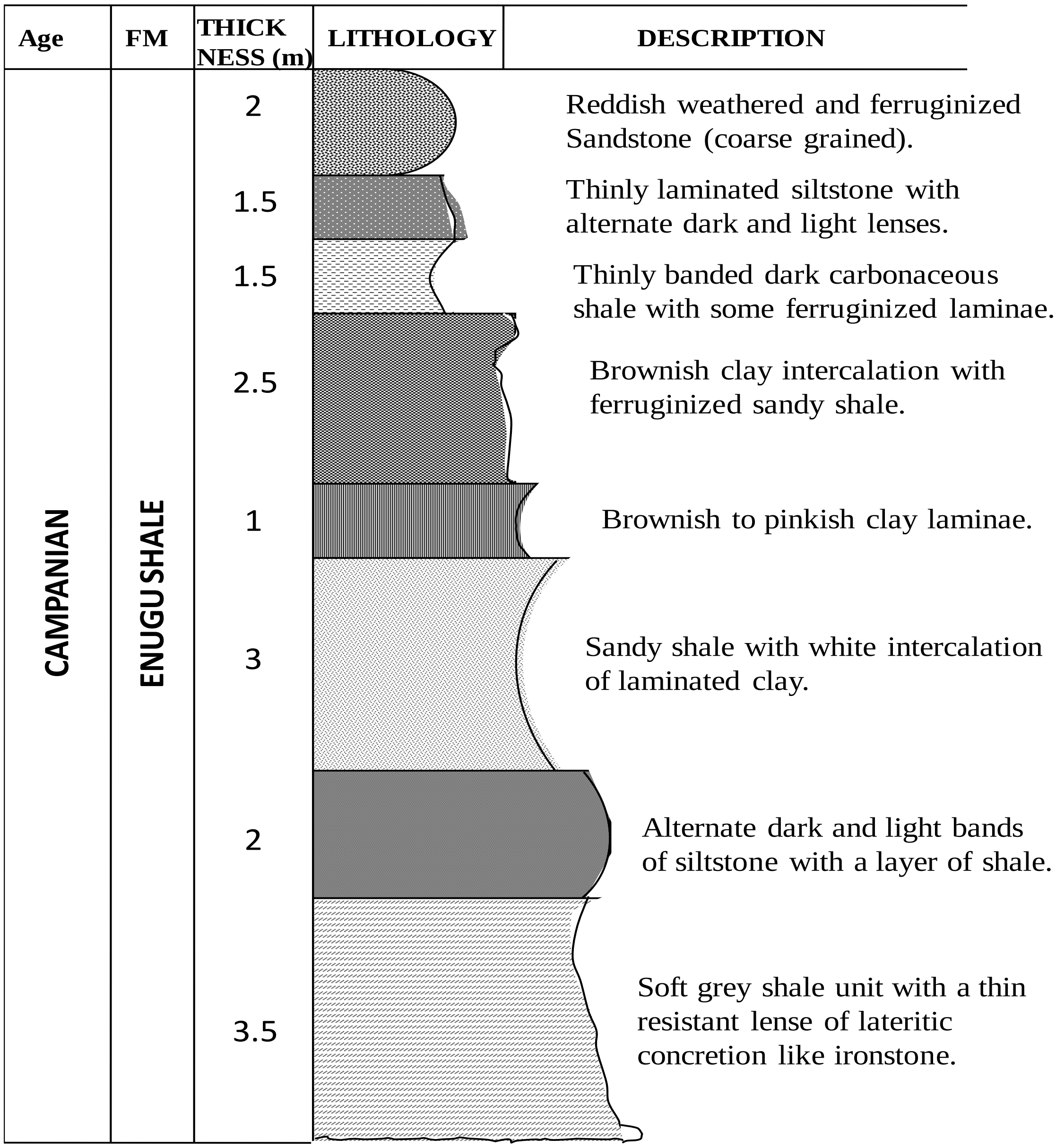

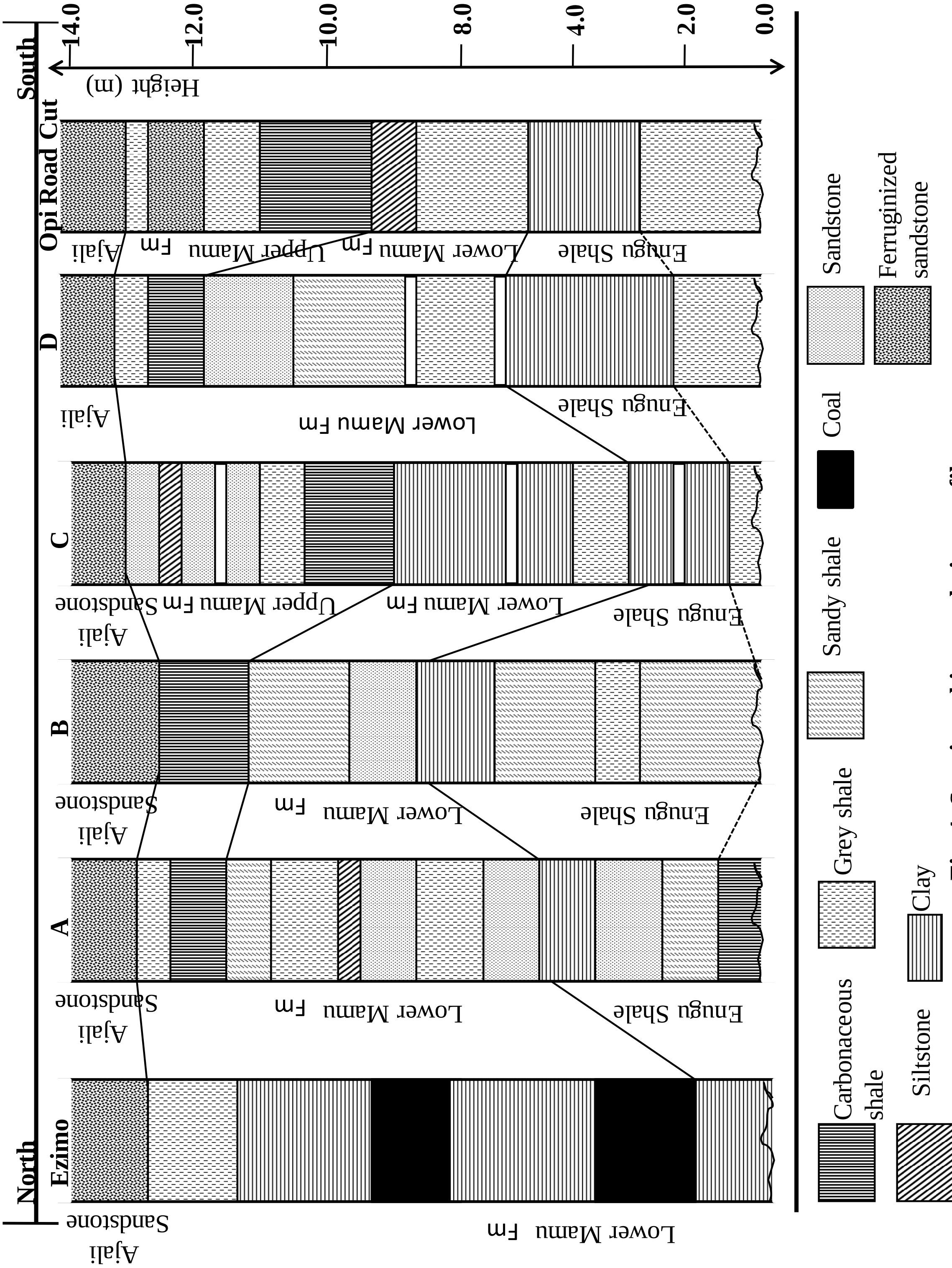

Fig. 4: Stratigraphic correlation profiles.

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Sandy shale

The sandy shale forms the upper part of the grey shale in the studied area and consists of alternating thinly laminated shales, very fine sandstones which are whitish to brownish in colour with thin bands of clay intercalations (Fig. 5). The top of this sandy shale is reddish brown and is capped with laterites. Varve structures are common to the sandy shales. Beautiful exposures of this subunit are recognized along the new road cut at Mbu, Ogboduaba and along the channel of Ofianzu stream. The sandy shale contains plant debris and bioturbation structures in some places.

Environment of Deposition

The occurrence of plant remains, concretions, shale casts, varve structures, thin lamination and freshwater associated with these subunits of the Enugu Shale suggests deposition under shallow marine conditions. The gradation from carbonaceous shale to fine and siltstone also suggests open or shallow marine environment.

Lower Mamu Formation: The lower Mamu Formation covers about 30% of the studied area and three subunits of this formation are recognized; Carbonaceous shale, Grey shale and Sandy shale (Fig. 5).

Carbonaceous shale

This subunit has very exposed outcrops at the sources of Igbogbo stream, Iyi-Agu Orba and along channel Iyi-Vava at Anyazulu Umabor. The shale is dark thinly laminated with occasional thin bands of clay intercalations towards the upper part (Akhirevbulu and Ogunbajo, 2011; Uzoegbu, 2014). Each lamination is about 2cm. Varve structures and concretions are found in some of places. The shale is commonly found in very deep valley of the streams at the lower slope of Enugu escarpment. In some places this subunit delineates the contact between the Ajali and Lower Mamu Formations.

Grey shale and sandy shale

The grey shale consists of thinly laminated dark grey shale alternating with mudstone, and fine sandstone and gradually graded into sandy shale at upper part. The grey sandy shale is highly fissible and contains plant impressions and bioturbation structures. The sandy shale at the upper part of the grey shale alternates with fine sandstone and siltstone and occasionally poorly laminated in some places. The sandy shale is highly weathered to reddish brown and the sandstone is ferruginized. The upper part is commonly capped with laterites. In the studied area the grey sandy shale has excellent exposures at Omeme stream and Ugene stream.

Coal Seam

At Ezimo, about 2km from the north of the studied area a traverse was taken and along the channel of Iyi-nzu stream two coal seams are recognized. The coal seams alternate with grey shale. The coal seams exposed are 1.5 m thick each along the river channels and waterfalls developed from these coal seams. The coal is generally black, friable and brittle and the hardness is about 2.5. It has a splintery fracture system.

The proximate analyses of the Ezimo coal by De Swardt and Casey (1963) shows moisture (10-13.6%), volatile matter (39-49%), fixed carbon (59-78%), calorific value (10,000-13,000B Tn u/1b) and sulphur (0.5-%). This analyses show that the Ezimo coal has almost the same quality as that of Enugu coal and therefore is of sub-bituminous class. This supported by the report of Uzoegbu (2010), Uzoegbu et al. (2013a, b), Uzoegbu and Ostertag- Henning (2014) and Uzoegbu (2014). The Opi new road cut consists of three subunits; carbonaceous shale, grey shale and sandy shale without coal seams as recognized in the studied area.

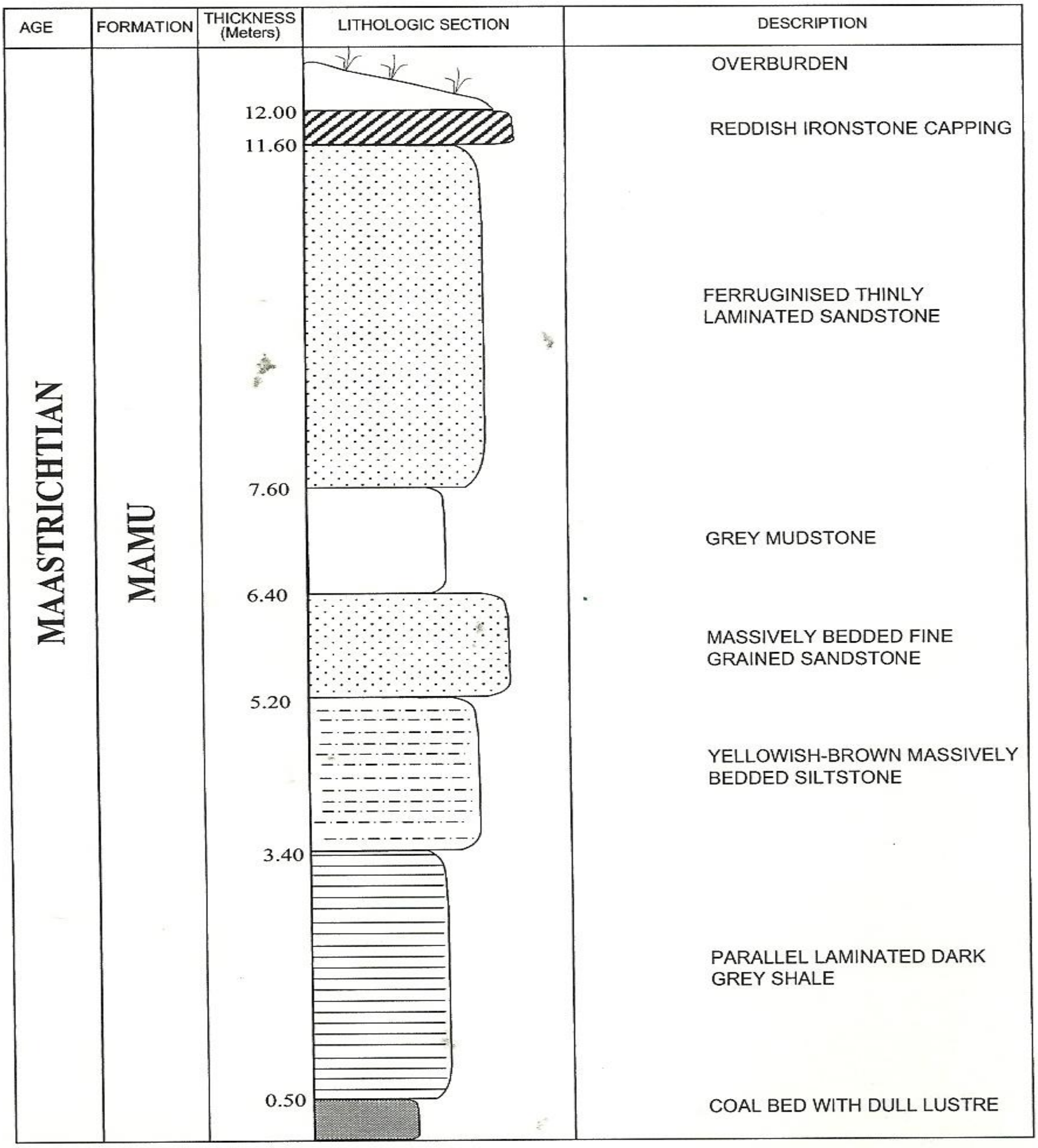

Fig. 5: Lithologic profile of Lower Mamu Formation.

The occurrence of coal seams at Ezimo and the absence of these in the Lower Mamu Formation in the studied area and along Opi new road cut are evidence that Ezimo coal seams are stratigraphically lower than the studied area and Opi new road cut (Fig. 4).

Environment of Deposition

The abundance of carbonaceous shale in the studied area and coal seam at Ezimo, all in the Lower Mamu Formation suggests non-marine or swamp deposits. The regressive phase in the second sedimentary fill up of Anambra Basin is marked by the

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development of paralic sequence of Mamu Formation which is overlain by continental sequence of the Ajali Sandstones (Reyment, 1965; Murat, 1970).

Upper Mamu Member

The upper Mamu Formation covers about 10% of the studied area and made of one unit. In the studied area this unit is not well exposed but it has an excellent outcrop along Opi road cut (Fig. 4). In this unit the main rock type is whitish to grey sandstone. The sandstone is very fine grained, friable and thinly laminated with thin bands of mudstone intercalation. Each lamination is about 1cm thick. Towards the base the lamination increases in thickness for about 3cm and the sandstones became coarser. These grades upwards to medium and fine grained. This shows fining upward sequence (Ojo and Akande, 2009, Valkarelo and Bhattacharya, 2009; Uchebo, 2010; Obaje et al., 2011; Omali et al., 2011; Uzoegbu et al., 2013a). This unit is highly burrowed and bioturbation structures which are evidence of ichnofossils were found.

Sieve analysis of the sandstone shows that it is negatively skewed; leptokurtic in grain size distribution and with mean size between 2.50-3.40 ø (Table 2) and the histogram plot show a unimodal distribution (Fig. 6).

Ajali Sandstone

Simpson (1954), Reyment (1965), Adeleye (1975) described the Ajali Sandstone from its type areas along Ajali river and Nkpologu in Nsukka area. It occupies about 15% of the studied area and is found on the western margin of the area. This is the youngest Formation and it overlies the Mamu Formation. It has very exposed outcrops at Ugwu-Ikwube in the studied area and along Opi road cut. At Ugwu-Ikwube this outcrop has a well developed fascinating cave system. The sandstone is characteristically friable, poorly consolidated, white to pinkish colour, iron stained with thin bands of white mudstones. At Ugwu-Ikwube the sandstone is typically cross-bedded on small scale (Fig. 7). The grains grade from medium to fine grain upwards and the beddings are massive at the base and thinly laminated upwards.

Table 2: Seive analysis for white sandstone of Upper Mamu Formation.

Phi (ø)	Wt. Retained on Seive	Corrected wt.	Cumulative wt.	Cumulative wt. %	Weight (%)
0.0-5.0	0.6	0.6	0.6	1.1	1.1
0.5-1.0	2.4	2.4	3.0	5.6	4.5
1.0-1.5	3.2	3.2	6.2	11.5	5.3
1.5-2.0	2.9	2.9	9.1	16.8	5.9
2.0-2.5	4.0	4.0	13.2	24.2	7.4
2.5-3.0	8.3	8.4	21.6	39.7	15.5
3.0-3.5	19.8	20.1	41.7	76.7	37.0
3.5-4.0	12.5	12.7	154.3	100.0	23.3
Seive loss	0.7				
Total wt.	53.7				

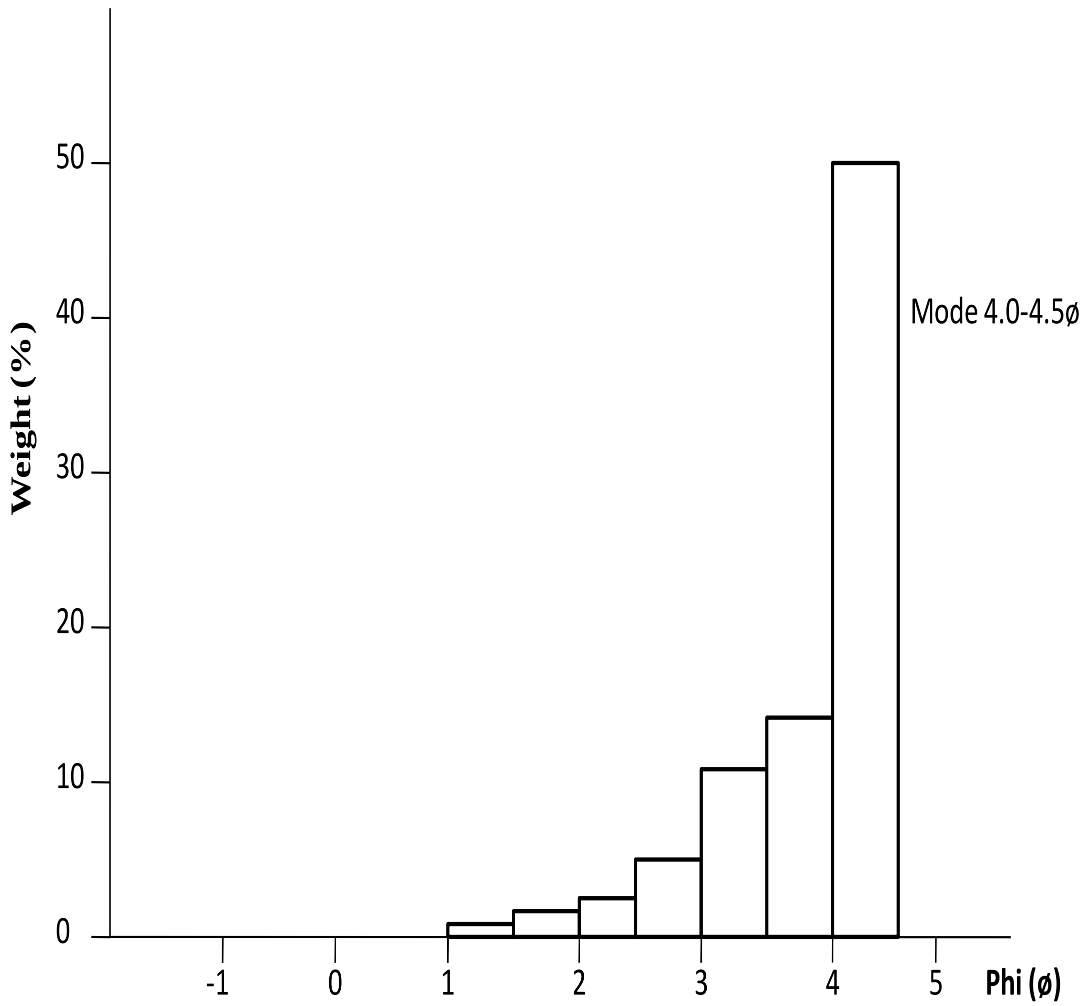

Fig. 6: Histogram plot for white sandstone of Upper Mamu Formation.

Sieve analysis of the sandstone shows that it is well sorted and skewness is positive and ranges from nearly symmetrical to leptokurtic grain size distribution (Table 3). Histogram plots show bimodal distribution between 1.0-1.50 ø (Fig. 8). The mechanical analysis of coarse sandstone shows that the sandstone is poorly sorted, negatively skewed leptokurtic and slightly bimodal.

The grains are equant to subequant and are predominantly subangular to subrounded (Table 4). Many large polycrystalline quartz grains have been found to break along individual grain boundaries, indicating a textural inversion (Hoque and Ezepue, 1977). They therefore concluded that significant portion of the finer sand and silt fraction could come from fragmentation of large polycrystalline quartz in a dynamic environment.

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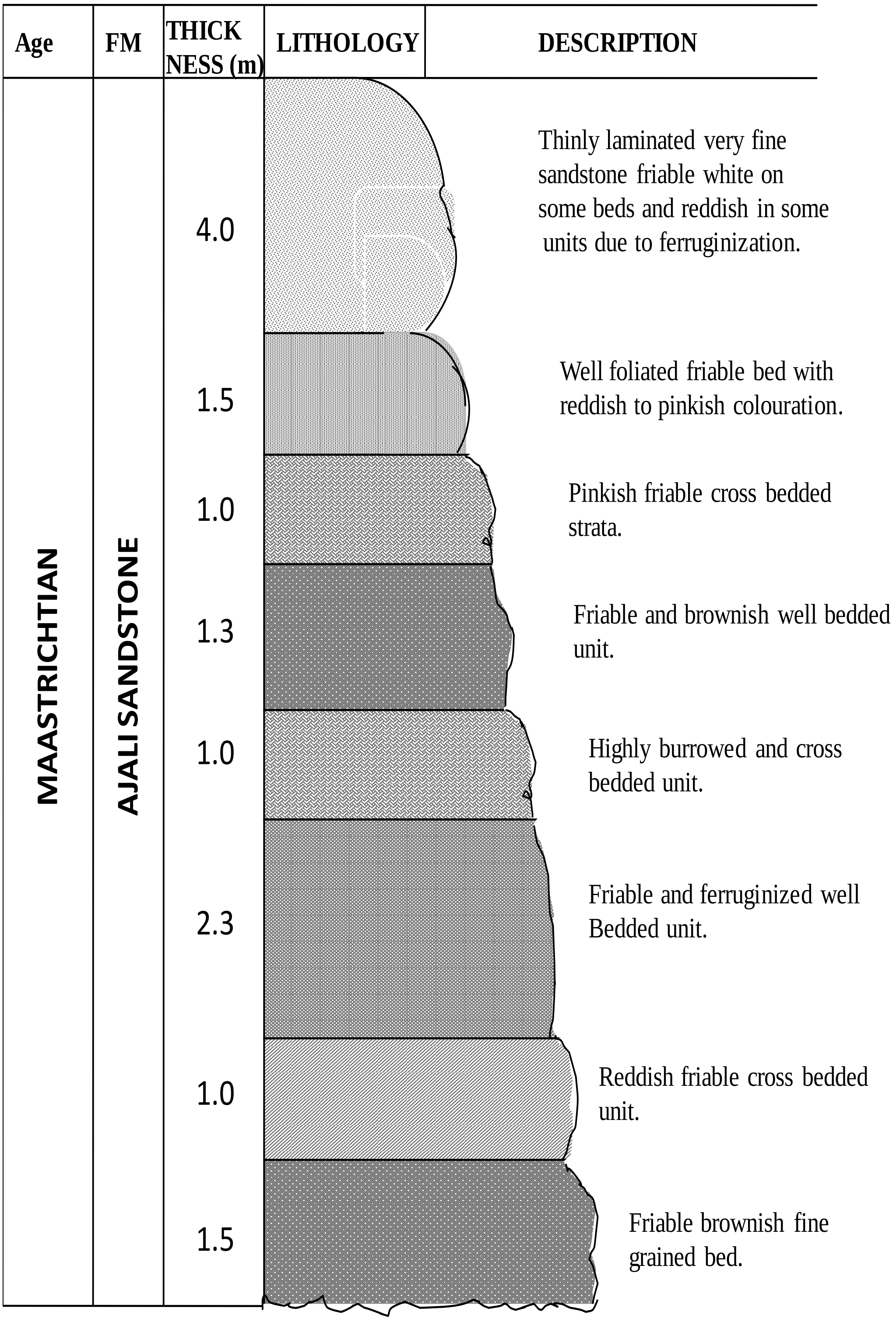

Fig. 7: Lithologic profile of Ajali Sandstone.

Table 3: Seive analysis for white sandstone of Upper Mamu Formation.

Phi (ø)	Wt. Retained on Seive	Corrected wt.	Cumulative wt.	Cumulative wt. %	Weight (%)
> 2.0					
-2.0-1.5	0.6	0.6	0.6	1.0	1.0
-1.5-1.0	0.5	0.5	1.1	2.0	1.0
-1.0-0.5	2.2	2.2	3.3	5.9	3.9
-0.5-0.0	3.8	3.8	7.1	12.8	6.9
0.0-0.5	6.4	6.5	13.6	24.4	11.6
0.5-1.0	9.8	9.9	23.5	42.1	17.7
1.0-1.5	14.2	14.3	37.7	67.6	25.5
1.5-2.0	8.8	8.9	46.6	83.6	15.9
2.0-2.5	4.7	4.7	51.3	92.0	8.4
2.5-3.0	1.9	1.9	53.2	95.3	3.4
3.0-3.5	1.2	1.2	54.4	97.4	2.1
3.5-4.0	1.7	0.7	55.1	98.7	1.3
4.0-4.5	0.7	0.7	55.8	100.0	1.3
> 4.5					
Seive loss	0.41				
Total wt.	55.4				

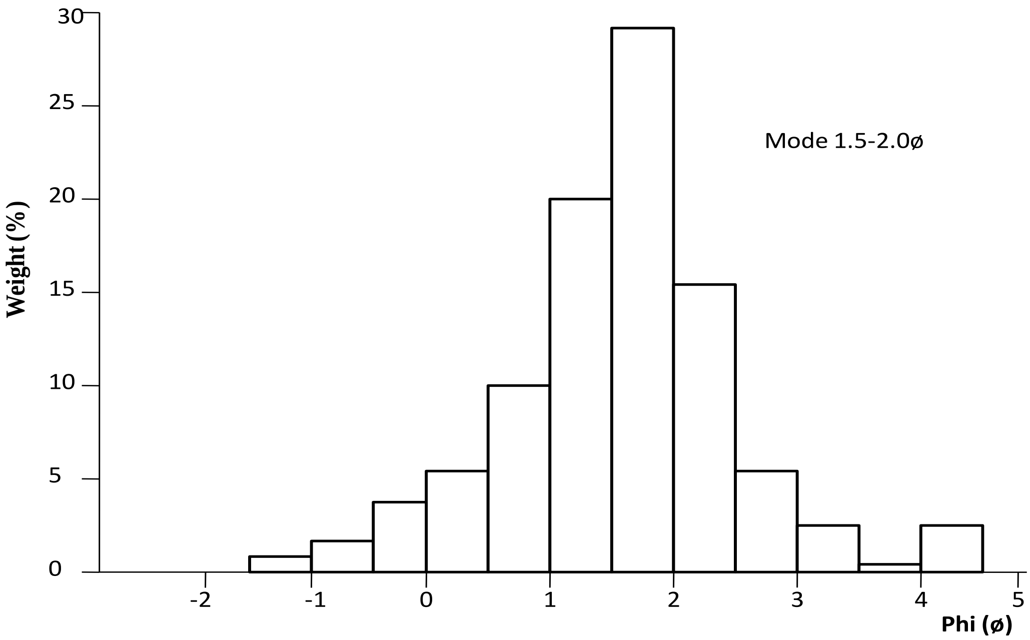

Fig. 8: Histogram plot for Ajali Sandstone.

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Table 4: Thin section textural study of the Ajali Sandstone.

N0.	Mineral Grain	L (mm)	W (mm)	W/L Sphericiy	Roundness	Exticition	Structure	Grain To Grain Contact		
								Line	Point	Concave-Convex
1	Quartz	0.23	0.11	0.48	SR	Straight	M	-	2	-
2	″	0.31	0.12	0.38	SA	″	M	-	3	-
3	″	0.25	0.10	0.40	SR	″	M	-	1	-
4	″	0.23	0.14	0.61	SA	″	M	1	-	-
5	″	0.18	0.10	0.56	SA	″	M	1	-	-
6	″	0.14	0.11	0.79	SR	″	M	-	-	2
7	″	0.23	0.12	0.52	SR	Wavy	P(2)	1	-	-
8	″	0.14	0.10	0.71	SR	Straight			1	-
9	″	0.25	0.10	0.40	SR	″	M	-	1	-
10	″	0.23	0.12	0.52	SA	″	M	1	1	-
11	″	0.25	0.11	0.44	SR	″	M	1	-	1
12	″	0.18	0.09	0.50	A	″	M	-	1	-
13	″	0.25	0.10	0.40	SR	″	M	-	-	1
14	″	0.12	0.10	0.83	SR	″	M	-	2	-
15	″	0.14	0.09	0.64	SR	″	M	-	-	-
16	″	0.20	0.08	0.40	SR	″	M	-	3	-
17	″	0.23	0.14	0.61	SR	″	M	-	-	1
18	″	0.23	0.12	0.52	SA	″	M	-	1	-
19	″	0.10	0.09	0.90	SR	″	M	-	-	-
20	″	0.12	0.10	0.83	SR	Wavy	M	-	-	1
21	″	0.14	0.10	0.71	SR	Straight	P(2)	-	2	-
22	″	0.10	0.09	0.90	SR	″	M	-	1	1
23	″	0.18	0.12	0.67	SR	″	M	1	1	-
24	″	0.35	0.18	0.51	SR	″	M	-	2	-
25	″	0.08	0.04	0.50	SR	″	M	-	-	2
26	″	0.18	0.10	0.56	SR	″	M	2	1	-
17	″	0.10	0.08	0.80	SA	″	M	-	3	-
28	″	0.35	0.10	0.30	SR	″	M	-	2	-
29	″	0.12	0.11	0.92	R	″	M	-	1	-
30	″	0.25	0.20	0.80	SR		M	-	2	-
	∑	5.86	3.26	18.1						
	Mean	0.20	0.11	0.60						

Note: A=Angular; SA=Subangular; SR= Subrounded; R= Rounded; M= Monocrystalline; P(2)=Polycrystalline (with two crystals).

Environment of Deposition

In the studied area Ajali is characterized by presence of fine to medium grained sandstone, small scale cross-beds, leaf impressions, burrow-fills and absence of calcareous and carbonaceous matters. These suggest a continental environment or fluviatile environment. Grove (1951), Reyment (1965) suggest that Ajali was deposited in a continental environment. Hoque and Ezepue (1977) gave a detailed account of petrology of Ajali sandstones and confirmed the earlier views as regards its depositional environment viz continental (fluvio-deltaic).

Stratigraphic Correlation

There are six sections across the entire studied area that exhibit characteristic lithologic variations within each lithologic unit. Ajali Sandstone is medium to fine grained and typical crossbedded. The Lower Mamu Formation is characterized by subunits sandy shale grey and carbonaceous shales with sandstones mudstones bands and Upper Mamu Formation consists of white sandstone. Finally, the Enugu Shale at base is distinguished by three subunits soft dark and bluish carbonaceous shale, grey shale and sandy alternating with siltstones upwards (Fig. 4A). The B profile also shows similar lithologic variations within each of the four lithologic units correlatable with A, C and D profiles.

For more detailed correlation of the lithologic units in the studied area, two more traverse were taken along Ezimo-Agu road passing through Iyi-nzu stream channel which shows an excellent exposure of Mamu Formation with coal seams. The other traverse was taken along Opi new road cut at the southern part of the studied area and this has exposures of all the four lithologic units in the area. These four lithologic units are exposed sequentially from Ajali Sandstone on top, Upper Mamu Formation white sandstones, Lower Mamu Formation, and finally to Enugu Shales at the base (Fig. 4E) along Opi new road cut (Vakarelov and Bhattacharya, 2009).

Economic Geology

Sandstones

Sandstones and gravels which are washed out from the Ajali sandstones and Mamu Formation are used extensively for building purposes. They are used locally for making blocks, concrete and in block industries at Nsukka near the studied area. The sandstones are easily quarried because of their loose grains and along the stream channels the alluvial sandstones and gravels are sieved by the natives. The sandstones of the studied area are quartz arenites (up to 95% quartz) and can be suitable for manufacture of glass.

Laterites

The Enugu Shales and in some places the Mamu Formation have been lateritized. The laterites are used commonly for various construction purposes such as roads, buildings and bridges in the studied area. The Enugu shales are highly lateritized and these are now being quarried at Mbu for the construction of Obollo-Afor-Mbu-Enugu new road.

Clay and Shales

The plastic clays such as chlorite, illite and montmorillonite and grey shale are used locally for pottery and for painting houses by the natives at Mbu, Eha-ndiagu and Opi-agu. Ogbukagu (1974) found that clays in the Mamu Formation have low drying, firing shrinkage, low porosity and fine fluorescent colours. Therefore these clays

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can be used for pottery, glazed tiles, in ceramics industry.

Coal

There is a potential reserve of coal along the channel of Iyi-nzu at Ezimo which has not been mined. This coal grades between groups A and B of sub-bituminous class as that of Enugu coal (De Swadrt and Casey, 1963). The coal has a future prospect for industries, such as iron and steel industry as cooking coal, cement industries and raw materials for chemical industries. The coal is used locally for cooking.

Hydrocarbon Prospect

The studied area has necessary potentialities for the accumulation of petroleum. The alternation of shales and sandstones in the Enugu Shales and Mamu Formation due to transgression and regression episodes could have produced natural reservoir rocks, cap rocks and good stratigraphic traps essential for economic accumulation of oil. The carbonaceous shale could serve as source rock because it is rich in organic matter while porous and permeable sandstone could serve as reservoir rocks.

The studied area which is within Anambra Basin is made up of three major formations; the Enugu Shale, the Mamu Formation and the Ajali Sandstone. These Formations were deposited during the second sedimentary cycle and their ages range from Upper Campano-Maastrichtian.

The Campano-Maastrichtian Enugu Shales are made up of three subunits; soft dark bluish carbonaceous shale, grey shale and sandy shale. The Mamu Formation which overlies the Enugu Shale is made up of two members; the lower and the Upper Mamu Formation. The Lower Mamu Formation comprises of three subunits; the carbonaceous shale, grey shale and sandy shale. The Upper Mamu Formation is made of one unit which is fine grained friable white sandstones.

The Ajali Sandstone, the youngest of three Formations, overlies the Mamu Formation in the studied area. It consists of poorly consolidated, friable medium grained sandstones and pinkish to reddish colour and some ironstained with thin white bands of mudstones and shale at various intervals. It is typically cross-bedded on large scale, highly burrowed and contains plant impressions as ichnofossils.

The studied area seems to have high economic potentiality for hydrocarbon accumulation. Lateritic shales, sandstones, clays and coal are of economic importance in the studied area and used for many purposes.

Gratitude is expressed to Prof. E.F.C. Dike and Prof. N.G. Obaje for having patiently supervised my M.Sc. and Ph.D work. Abubakar Tafawa Balewa University, Bauchi is gratefully acknowledged for using the Geology and Civil Engineering Laboratories for the analyses of some of my samples.

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