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Biostratigraphy of a Section along Port Harcourt to Enugu Express Way, Exposed at Agbogugu, Anambra Basin, Nigeria

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ABSTRACT

The biostratigraphy of stratigraphic sections exposed at Agbogugu along the Port Harcourt – Enugu Expressway was studied and some key evaluations were reached. The stratigraphic section (The Enugu Shale) is one of the Campanian – Maastrichtian successions of the Anambra Basin, Southeastern Nigeria. It is located at latitude $6^{0}15^{1}N$ and longitude $7^{0}21^{1}E$ of Greenwich Meridian. The lithologic units of the succession are basically shales with ironstone intercalation showing a likely marine depositional environment. The method of study involved the collection of sample to evaluate the final subsequent laboratory analysis of collected sample to evaluate final observable features. A total of nine (9) samples were collected from this outcrop. From the laboratory analysis carried out, a lithological description of all samples collected depth by depth was made with 2.0m HCI to check the presence or absence of calcareous forms. A sand/shale ratio plot was made from the wet sieve analysis and an approximate percent of sand and shale were interpreted. The result shows more shales than sand in the sediment showing a marine origin of deposition. Also from micropaleontological analysis made, 6 diverse forms of benthic arenaceous foraminifera assemblages were recovered. They are; Ammobacultiesamabensis, Haphragmoides saheliense, Siroplectammina hausorum textularia gilbedina, Ammobaculities sp and Haplophragmoldes sp. They are the benthic and their ages span from campanian to maastrichtian which coincides with the marine incursion in the Anambra Basin. These forms suggest a coastal swamp, tidal flat to estuarine, delta front to inner neritic environments of deposition.

Keywords: Biostratigraphy, Foraminifera, Benthic, Marine, Agbogugu.

INTRODUCTION

This project work was based on the Biostratigraphy of the Enugu Shale exposed at Agbogugu,Anambra Basin, Nigeria. The Enugu shale is one of the Campanian-Maastrichtian sedimentary successions of the Anambra basin. The Basin came into existence during the Santonian Orogeny. Prior to the Orogeny, it was a protobasin covered by thin veneer of older sediments. (Reyment,1965).

The Basin had several transgressive and regressive events which led to the continual deposition of sediment in it. (Whiteman, 1982).

The studied outcrop is a succession of shales and intercalation concretionary ironstones showing a marine phase of deposition. The outcrop is exposed at Agbogugu along the port Harcourt-Enugu expressway in between Enugu and

Okigwe. The study is aimed at determining age of sediments and their possible depositional environments using fossils as index.

Aims and objectives of study

The aim and objectives of this study is to understand and document the fossil assemblages that are characteristic of the study area, have an understanding of the lithostratigraphic framework of the study area, understand the correct sedimentary boundaries using its fossil assemblages and use the fossil assemblages and the stratigraphy of the outcrop to deduce the age and possible paleoenvironments of deposition.

Location and accessibility of study area

The study area is located in Anambra Basin; Agbogugu is in between Enugu and Okigwe along the Port Harcourt – Enugu Expressway at latitude 6^0 15^1N and longitude $7^0$$21^1$E of Greenwich Meridian (figure 1).

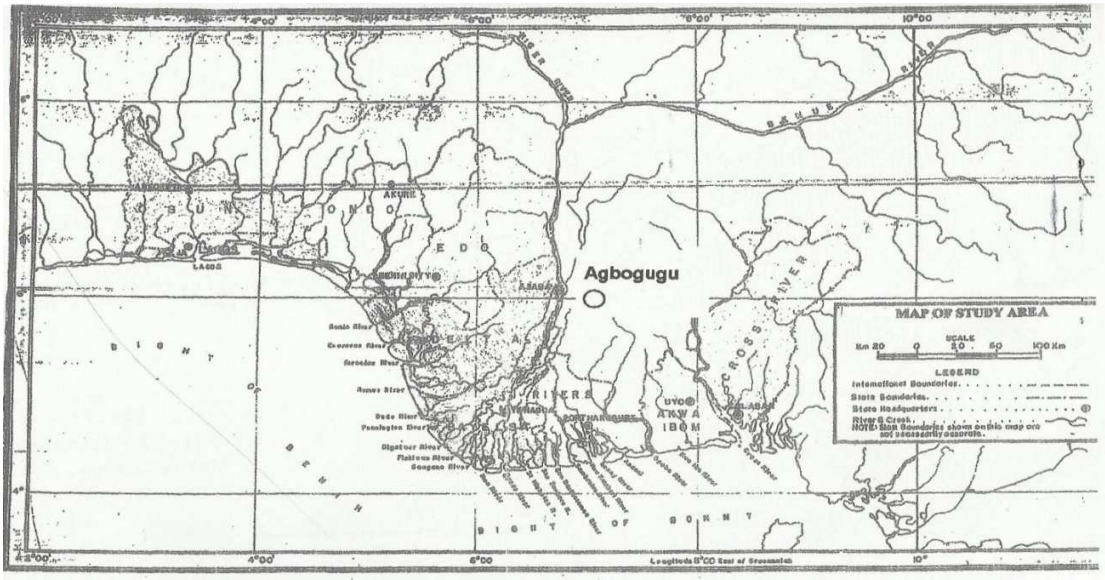

Figure 1: Map of the study Area

The studied outcrop is a sedimentary succession of the Enugu shale made up of shales and interbeds of ferruginized mudstone (ironstone). It is easily accessible by road, located along road cuts of the Port Harcourt- Enugu Expressway.

Stratigraphy of anambra basin

The stratigraphy and lithostratigraphic studies of Anambra Basin have being well established through many publications. Also, much has been known of the biostratigraphy of Anambra Basin from past works. From a review of the paleogeographic history of Nigeria from Albian times, the stratigrraphy and paleogeography of the Anambra Basin was reviewed as follows:

The Campanian began with a short marine transgression followed by a regression.(Kogbe ,1974). In the Anambra Basin, Southeastern Nigeria, the Nkporo shale and its lateral equivalents, the Enugu shales and Owelli sandstone constitute the basal beds. These were overlain by the paralic sequence of Mamu formation followed the continental Ajali formation and a return to a partially paralic Nsuka formation (Maastrichtian) which is now believed to be partly Paleocene. (Ladipo et al, 2001).

Nkporo Formation: The Nkporo shale is the basal sedimentary unit that was deposited following the Santonian folding and inversion in Southeastern Nigeria and indicates a late Campanian age, based on the presence of Afrobolivina afra (Reyment, 1965).

The formation is generally poorly exposed but has been described as coarsening upward deltaic sequence of shale and interbed of sands and shale with occasional thin beds of limestone (Kogbe, 1974;Reyment 1965;Whiteman 1982;Ladipo 1992).

The Nkporo shale has lateral equivalents as Enugu shale and Owelli sandstone which occurs towards the central parts of the basin. These inner-basin Nkporo group has been interpreted as lowstand pro-delta to Delta front sequence, deposited at the shelf edge which was probably located at Onitsha high and bear Lokpanta (Zaborski, 1983).

The enugu shale: The Enugu shale is restricted to the central and northern parts of the Anambra Basin and consists of carbonaceous grey black shales and coals with interbeds of very fine sandstone/siltstone deposited in lower flood plain and swampy environment. The bedding planes are poorly defined with early diagenetic minerals such as pyrite and siderites. The sediments have a poorly developed foreshore and shoreface with extensive coastal swamps (Kogbe, 1970; Whiteman 1982; Ladipo 1992).

The Enugu shale was assigned campanian to Lower Maastrichtian, based on diagenetic species of palynomorphs such as Cingulatisporites ornatus and Tricolpites tienebaensis. (Reyment 1965; Whiteman 1982)

THE OWELLI SANDSTONE: The Owelli sandstone regarded as a facies of the Nkporo groups is a lateral equivalent of Enugu shale (Whiteman, 1982). It is an elongate shoestring sandbody to the northwest defining a meander belt of fluvial channel system and a fluviatile point bar. The Enugu and Owelli sandstone were deposited in open marine shelf and alternatively storm and tide dominated. The Owelli sandstone is typically massive, hard and often ferruginous in some places and friable, it may be prominently cross bedded, medium-coarse grained with pebbles, sometimes aligned at the base of the cross beds. Silt layer are occasionally present. It may attain 450-600m thickness south of Udi and intervenes conformably between Enugu shale and Awgu shale. The Owelli sandstone is a coarser deltaic facies of the Nkporo group laid down during the late Campanian transgression phase (Whiteman, 1982). Few Gastropod shells and pelecypods have been recovered suggesting a marine incursion into channel systems (Reyment 1965; Whiteman 1982).

MAMU FORMATION: The Mamu formation overlies the Enugu shale conformably and contains sandstone, shale mudstone, sandy-shale with coal seams in various horizons (Reyment, 1995). The sediment pile varies across the basin and ranges from 75m to over 1000m (Reyment, 1965; Ladipo, 1992). The possible environments of deposition are estuarine floodplain, Swamp and tidal flat flood plain. It is excellently exposed along the Enugu-Onitsha Road at the Miliken Hill and the outskirts of Enugu (Kogbe, 1974). The age of this formation is put at lower-middle maastrichtian and has a significant thickness variation from about 100m in the south to as much as 100m in the central and northern part of the basin (Ladipo et al, 2001).

AJALI SANDSTONE: The Ajali sandstone overlies the Mamu formation and has a diachronous age from South to North (Middle-upper Maastrichtian) and exhibits significant thickness variation from less than 300m to over 1000m in the centre of the basin (Ladipo et al, 2001). Depositional characteristics are uniform for most parts of the basin, made up with textually mature sand facies i.e. mature quartz arenite intercalated with Kaolinite beds. Dominant sedimentary structures are cross bedding associated with reactivation surfaces, mud drapes, tidal bundles, backflow ripples, channel cut and fills and lateral accretion surface (Ladipo et, 1992). Ichnofossils found include Skolithos and Ophiomorpha which are parts of the characteristic structures of the formation across the entire basin and suggest tidal shallow marine depositional environment (Ladipo, et al, 1992).

NSUKKA FORMATION: The Nsukka formation succeeds the Ajali sandstone conformably but is discontinuous across the basin possible due to erosion. The lithologies comprise of shales, silts and claystones deposited in a transitional/Swamp environment. Thin beds of limestone occurs towards the top and contains Oyster shells which suggest an upper cretaceous age (Kogbe, 1974), while Reyment (1965) gives the age of the formation as Maastrichtian with the presence of sphenodiscus studeri as well as casts of pelecypods and gastropods.

MATERIALS AND METHODS

The study involves collection of samples from outcrop in the field, were then analyzed in the laboratory to describe the lithologic characteristics and paleontological assemblages to obtain necessary data or results for interpretation.

SAMPLE COLLECTION: Samples were collected in an outcrop of Enugu shale exposed at Agbogugu, Anambra Basin, Nigeria. The studied outcrop is a succession of shales and interbeds of ironstones, on top of the succession is a weathered rock (laterite) of about 4.9m thick. A total of 9 samples were collected, samples were not just collected from the surface but by digging deep with a shovel in order to collect fresh samples. Only shale samples were collected and collection was made randomly in increasing depth. The collected samples were then put into a nylon polyethene bag with label to avoid contaminants and for ease of identification.

LABORTORAY ANALYSIS

LITHOLIGICAL DESCRIPTION: This involves description of the lithologic aspect of the samples collected to check the presences of calcareous forms. The exercise is basically done using 2.0m concentration of HCI to check for effervescence. Effervescence indicates the presence of calcareous forms while the reverse is absence of calcareous forms. In line with this, the proper depth by depth description of all samples collected was made. It involves type of rock, facies type, colour, presence and absence of calcareous forms, bioturbation and other observable features. This result is then used to erect a graphic log of the outcrop with description of the possible observational features alongside.

BIOSTRATIGRAPHIC PREPARATION METHOD: Samples for each depth were pulverized and 10g weighed into enamel container. The samples were mixed with waater and treated with 2g Sodium bicarbonate (Na_2CO_3) and brought to boil at about 200◦C for some minutes.. Samples were turned into plastic containers and allowed to cool. Cooled samples were washed using a set of sieves Set of sieves 90, 75 & 53µm respectively in a jet of water. Residues from each sieve was collected and dried.. The dried samples were examined using paleontological microscope at varying magnifications and the fossils were picked and morphological examinations were then carried out on species with aid nomenclature. Species were also counted and recorded.

RESULTS

Lithostratigraphy: A total of nine (9) samples were collected from the studied outcrop. The dip of the beds ranges from 2^0-4^0 having strike direction of 40^0NW and 220^0SE. the lithologic units are shales with interbeds of ironstones and weathered rock (laterite). There were no clear bedding planes recognized and the total thickness of the outcrop is about 12m. Lithostratigraphy is the subdivision and correlation of sequence strata by means of rock type. It is not as reliable as biostratigraphy, as rocks continue laterally to great distances but can be used in the absence of fossils.
Lithostratigraphic units as seen from the outcrop consist of dark grey coloured shales with concretionary interbeds of ironstones of calcareous forms although sample 7 at about 5.7m depth from base show little effervescence. From wet sieve examination the sequence shows more of authigenic mineral grains such as pyrite, quartz and mica. The shales are very fissile and very fine from the wet sieve analysis. The lithologic facies of almost all sampled depth is the same showing the characteristic features of the Enugu formation. The summarized lithologic characterization is shown on the graphic log of the study outcrop (figure 2).

The various percentages of the lost and retained weight of each sieve according to sample depth were recorded as shown in table 1 and plotted on the sand/shale ratio log in figure 3.

Table 1: Percentages of sand and shale from sieve analysis

Sample	Total weight	Weight retained (sand)	% retained (sand)	Weight lost (shale)	% lost (shale)
Sample 1	10g	3.2g	32	6.8g	68
Sample 2	10g	4.5g	45	5.5g	55
Sample 3	10g	1.4g	14	8.6g	86
Sample 4	10g	1.4g	14	8.6g	86
Sample 5	10g	2.3g	23	7.7g	77
Sample 6	10g	1.8g	18	8.2g	82
Sample 7	10g	2.7g	27	7.3g	73
Sample 8	10g	2.3g	23	7.7g	77
Sample 9	10g	2.2g	22	7.8g	78

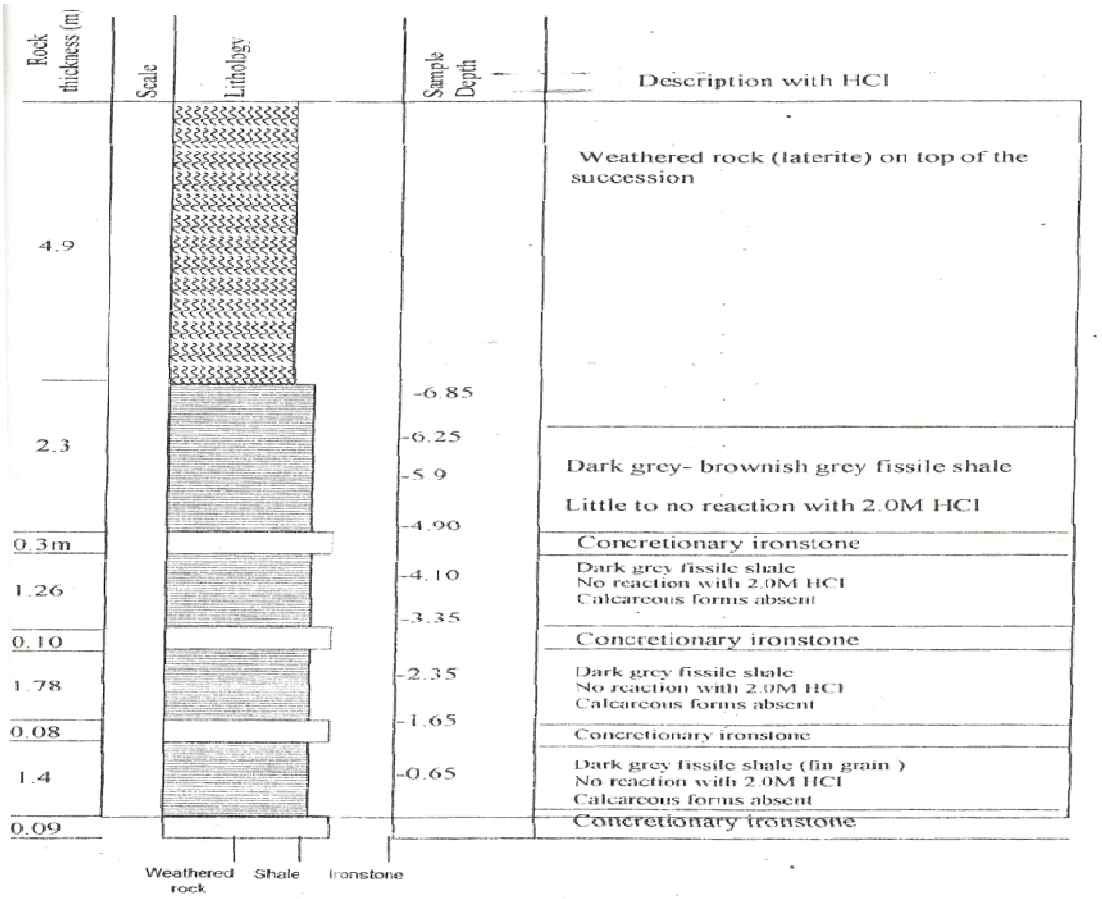

Figure 2: Graphic log of the studied outcrop

BIOSTRATIGRAPHY

Biostratigraphy is the characterization/subdivision of rock strata and correlation using fossils. The biostratigraphy of the studied outcrop is therefore based on the fossil assemblages (forminifera) recovered from the laboratory analysis.

MICROPALEONTOLOGY: The encountered fossils as shown on plate 1 below are Ammobaculites amabensis, Haplophragmoides saheliense, Spiroplectammina hausorum, Textularia gilbedina, Ammobaculites sp and Haplophragmoides sp. The fossils as encountered in each sample and their numerical count in each sample are given in Tables 2.

A distribution chart showing the distribution of the fossils against their depth of occurrence is made alongside with a graphic log of the studied outcrop. The six (6) fossil species that were encountered are all benthic, making all the total assemblage of benthic forminifera to be (six), 100% of all discovered forms. The distribution chart plotted from the discovered forms against their depth of occurrence using suitable scale as shown on figure 4.

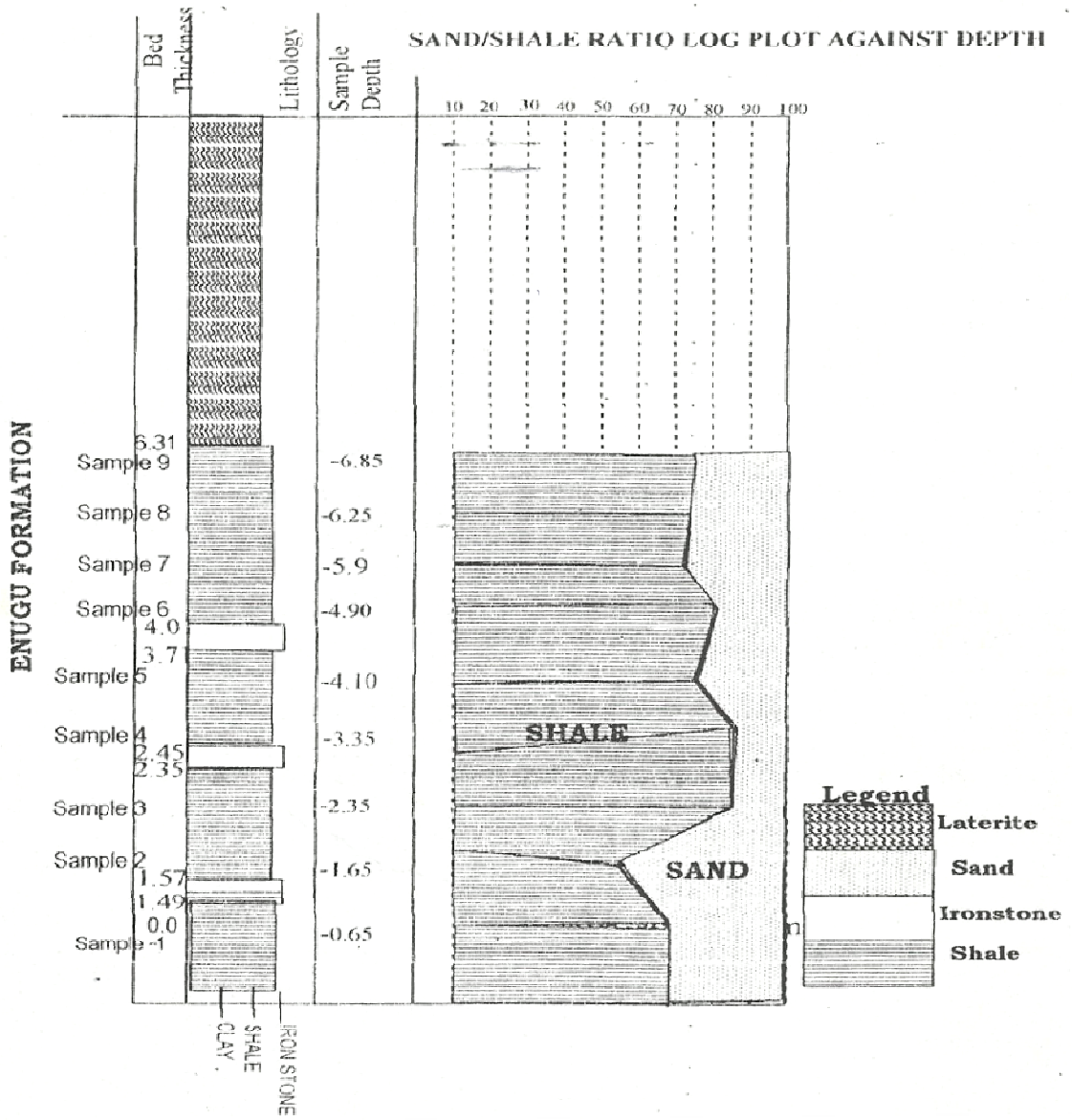

Figure 3: Sand/shale ratio log against depth of the outcrop

Table 2: Foraminifera in each sample and their numerical count

Sample	Fauna	Numerical count
Sample 1	Ammobaculites amabensis	1
Sample 2	Haplophragmoides saheliense	3
Sample 3	Barren	-
Sample 4	Textularia gilbedina	11
	Spiroplectammina hausorum	2
Sample 5	Textularia gilbedina	25
	Spiroplectammina hausorum	3
Sample 6	Barren	-
Sample 7	Ammobaculites sp	3
	Haplophragmoides saheliense	12
	Haplophragmoides sp	1
Sample 8	Barren	-
Sample 9	Barren	-

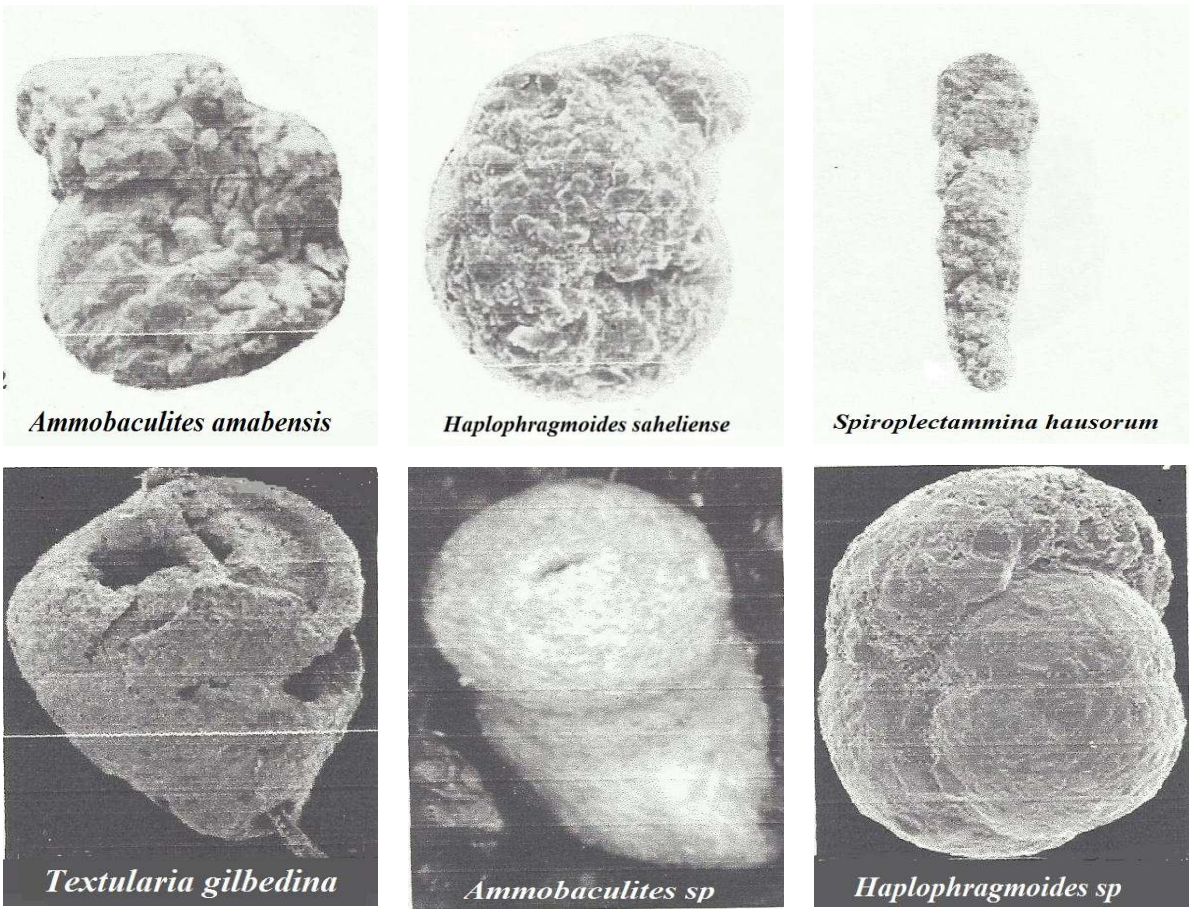

Plate 1: Photographs of the foraminifera as identified under the microscope

The above foraminifera distribution chart gives an insight of necessary evaluations on the paleobathymetry of the studied outcrop. Total population abundance and diversity for each sample collected was calculated and presented in table 3.

Table 3: Foraminifera Abundance and Distribution Table

Sample	Fauna Abundance	Fauna Diversity	Age
1	1	1	Campanian- Maastrichtian
2	3	1	Campanian- Maastrichtian
3	0	0	-
4	13	2	Campanian- Maastrichtian
5	28	2	Campanian- Maastrichtian
6	0	0	-
7	16	3	Campanian- Maastrichtian
8	0	0	-
9	0	0	-
Total	61	6	-

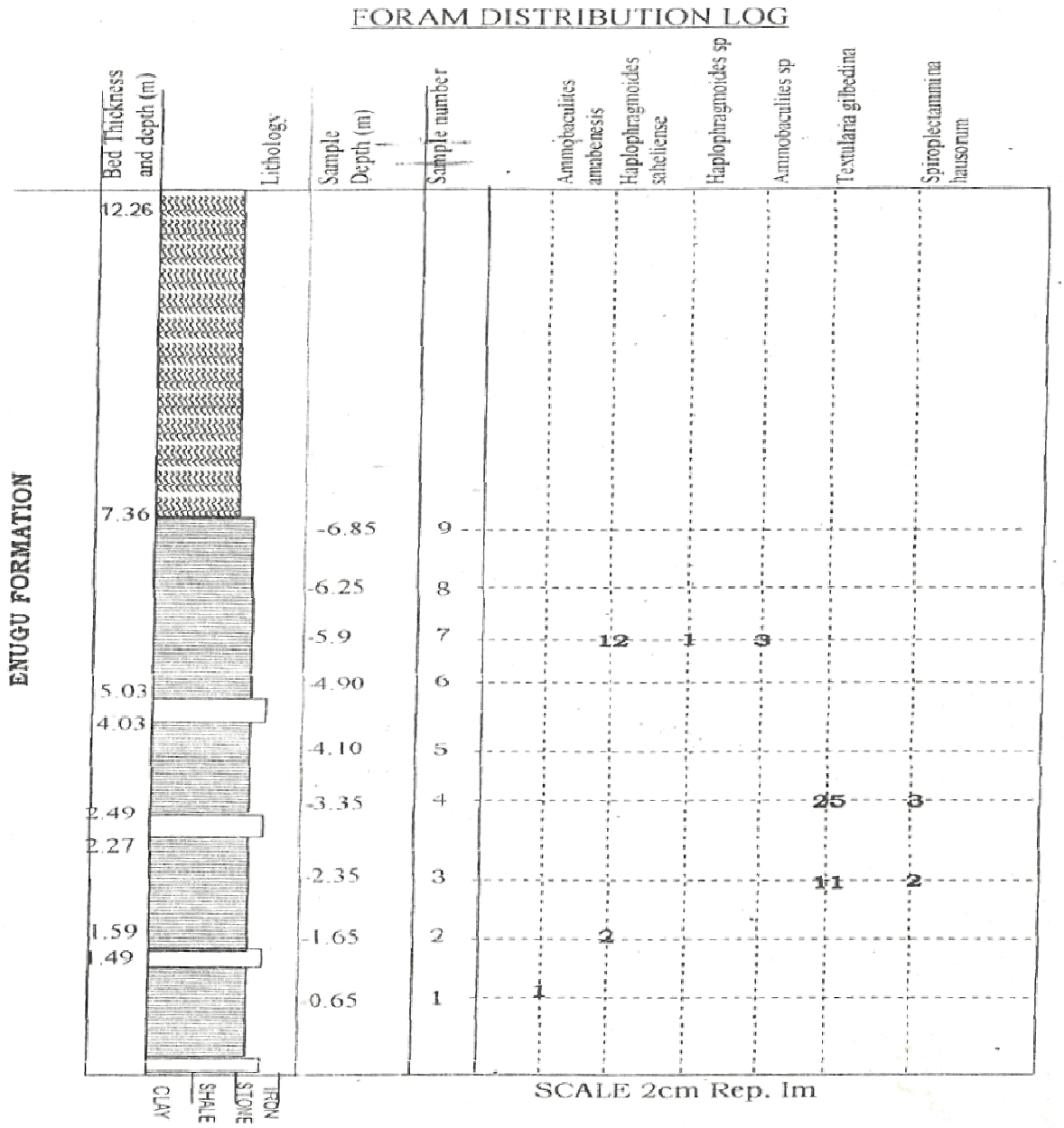

Figure 4: Foraminifera distribution chart

DISCUSSION

From the lithologic and biofacies analysis carried out, the following inference and interpretations were reached.

LITHOSTRATIGRAPHY: From the combinational results of the graphic log and sand/shale ratio-plot, the studied outcrop is a marine deposition. The presence of authigenic minerals such as pyrite, mica and quartz suggest possible of authigenic possible environment of deposition to be likely near shore or shoreface. This suggest continental shelf at shallow marine environments. The high value of the shale to sand in the sand/shale ratio plot suggests inner neritic and delta front environments of depositions. The lower part of the graphic log combined with the sand/shale ratio plot suggest the existence of a paralic condition, Ladipo et al (2001).

*MICROPALEONTOLOGY***:** The biofacies encountered here also suggest marine environment of deposition. The forms recovered all the benthic arenaceous forms, the presence of Amobaculities and Haplophragmoides sp suggest delta front – tidal flat environment of deposits. The presence of Texturlaria gilbedina suggests estuarine – shoreface environment Petters, (1979). The presence of Haplophragmoides sp and Spiroplectamina hausorum which are indices of campanian and maastrichtian age respectively suggest an age span from maastrichtian – campanian.

From the fossil abundance and diversity plot, the possible environment of deposited is also likely to fall into the shallow marine environment or tidal dominated environment because of the low diversity and abundance of fossils.

CONCLUSION

Six benthic arenaceous foraminifera assemblages have been established for the Campanian-Masstrichtian Enugu formation studied in this work. The age of the forms are established by existing published references of age index foraminifera assemblages. The Spiroplecctammina hausorun is an index of Masstrichtian and Haplophragmoides saheliense is an index of Campanian-maastrichtian age (Petters 1982). The six forms found have a total population count of 61 forams in six different forms. They are all arenaceous and benthic in occurrence and age graded campanian-maastriachtian. From the study, all samples were collected from shale and the inferences made suggest a marine deposition. The benthic arenaceous forms found, which are diagnostic of tidal dominated to shallow marine environments. The possible environments are tidal flat and coastal plain-deltafront environment. The paleoenviornment of deposition is likely an inner neritic-shoreface environments.

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