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Granomeric Analysis of Mamu Formation and Enugu Shale around Ozalla and Its Environs; Evidence from Field Study

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Abstract: *The study area lies within the Anambra Basin which geologically made up of Enugu Shale and Mamu Formation. This study aimed at determining the geology and depositional environments of these Formations through field relationship and grain size distribution as well as morphometric studies. The field data shows Enugu Shale as fissile, light grey with extraformational clast which graded into Mamu Formation which is made up of alternating sequence of shale, siltstone, mudstone, coal and sand, it shows a fluctuating environment. The granulometric study of sand member of Mamu Formation shows characteristic very well sorted, fine to medium grains which were deposited in relatively turbulent well aerated marine environment probably above wave base. The bivariate and the multivariate results reveal Aeolian/shallow marine deposit. The fissility of Enugu Shale suggests that it was deposited in low energy environment, distal to proximal lagoon environment and the presence of extraformatonal clast indicates fluvial incursion. However, it can be concluded that Mamu Formation was deposited in fluctuating environment ranging from an oxygenated shallow marine to acidic swampy environment. Hence is paralic Formation.*
Keywords; *Mamu Formation, Enugu shale, Kurtosis, Skewness and Benue trough*

I. Introduction

The stratigraphic units are part of the sediments deposited in the Anambra Basin of south Eastern Nigeria, according to (Kogbe, 1976) and (Nwajide, 1972). The study area is bounded by latitude 6^0 15’ 0”N to 6^0 20’ 0”N and longitude 7^0 25” 0”E to 7^0 30’ 0”E (fig.1.0). Towns located in the area included Umuatubuoma in Enugu South Local Government Area, Ozalla in Nkanu West Local Government Area in Enugu and Akabge Ugwu Udi Local Government Area, all in Enugu state Nigeria. Accessibility in the area is made easy by major road, minor roads, main roads, and foot path as shown in figure 2.0. The major roads runs from Agbani to Udi, while the main road is the new Port Harcourt–Enugu express way that runs from Ozalla to Umuatubuoma. The minor road runs from Aminbo and Udi forming a Y- junction at Ituku near University of Nigeria Teaching Hospital Ituku- Ozalla. Foot paths are scattered all over the study area. Enugu shale and Mamu Formation are part of the sediments deposited in the Anambra Basin of southeastern Nigeria.

The sedimentation of the south eastern Nigeria as described by (Kogbe 1976), began in the Albian and continued up to the Santonian. Murat (1972) studied the tectonic evolution of the southern part of the Benue Trough with reference to the Anambra Basin. Short and Stauble (1976), suggested that three depositional cycles occurred in the sedimentary basins of southeastern Nigeria with regards to the tectonic activities of the region. The first cycle was confined to the Benue Trough; the second cycle filled the Anambra Basin and Afikpo syncline, whereas the third cycle formed the tectonic separation of the Niger Delta. The Anambra Basin evolved following the subsidence of a platform in the southern Benue Trough, concurrent with the lateral translocation of the depocenter during the Santonian thermotectonic event that folded and elevated the Abakaliki region (Reyment, 1965 and Murrat, 1972) It is a Cretaceous sedimentary domain partly sandwiched between the southern Benue Trough below the Niger Delta. Hogue, (1976) suggested that the granite complex of Cameroon Basement Complex must have accounted for a large part of the sand depositional cycle which is distinguish by quartz arenite which is the sandstone type in the study area. The Enugu shale consists of shale and occasional sandstone. Bands of impure coal are also common. Reyment (1965) described it as included in the Asata-Nkporo shale known as Nkporo Shale. Reyment (1965) renamed the lower coal measures of (Simpson 1954) the Mamu Formation using same lihologic description. The Formation consists of shale with coal seams, and sand. Mamu Formation is Maestrichtian in age the coal seams vary in thickness from a few inches to twelve feet.

The main goal of the study is to have a better understanding of the geology of the study area, stratigraphic information and concisely interpret the depositional environment which will be very vital in basin analysis.

II. Method Of Study

The methods employed in this research include; Desk studies, Reconnaissance survey, detailed geologic survey, Laboratory and statistical analysis. The original topographic map of the area was blown and digitalized to aid easy locations. The preliminary survey of the study area was done by traversing the area and noting possible access roads and outcrops of interest for proper field study. The detailed geologic mapping of the study area was carried out during the month of October 2013, using a field base map of scale 1:50,000. The study was based on variations in the lithology, rock types, structures and other geologic features. Outcrop study was carried out around erosion sites and road cuts. The research concentrates on the textures of grain, colour, matrix characteristic, degree of weathering, and sedimentary structures. The study of the outcrops was carried out by taking the coordinates of the location on the GPS. Each bed is measured for thickness and properties such as colour, grain size, sorting and roundness. The altitudes of the beds were measured if a good surface is found, and also geologic structures were recorded. Samples were also collected and labeled accordingly from the studied outcrops and were taken to the laboratory for analysis. Equipment used in the field work include; clinometers, compass, geologic hammer, measuring tapes, camera, field notebook, and sample bags, GPS, as well as magnifying lens. Six samples were collected from the study area and were sieved according to the technique of Friedman (1979). The nest of sieve was arranged with the coarsest at the top and the finest pan at the bottom. The disaggregated and weighed samples of the sand were each poured into the uppermost part of the sieve and shaken for 15 minutes. The data obtained were used in plotting the cumulative probability curves and histogram in order to determine the grain size parameters of the sand. The parameters include; mean (Mz), median, mode, Skewness(Sk), Kurtosis(KG), and graphic standard deviation (□).The linear discrimination functions (Y1, Y2, Y3) of Sahu (1964) and the bivariate plots of skewness against standard deviation (Friedman, 1961), and mean diameter against standard deviation (Moiola and Weiser, 1979) were used for environmental discrimination. Two types of graphic presentation of grain size data used are Histogram and Cumulative probability curve although few of these curves are shown in this research.

Fig.1.0: Map of Enugu showing the location of the study area (Kogbe 1976)

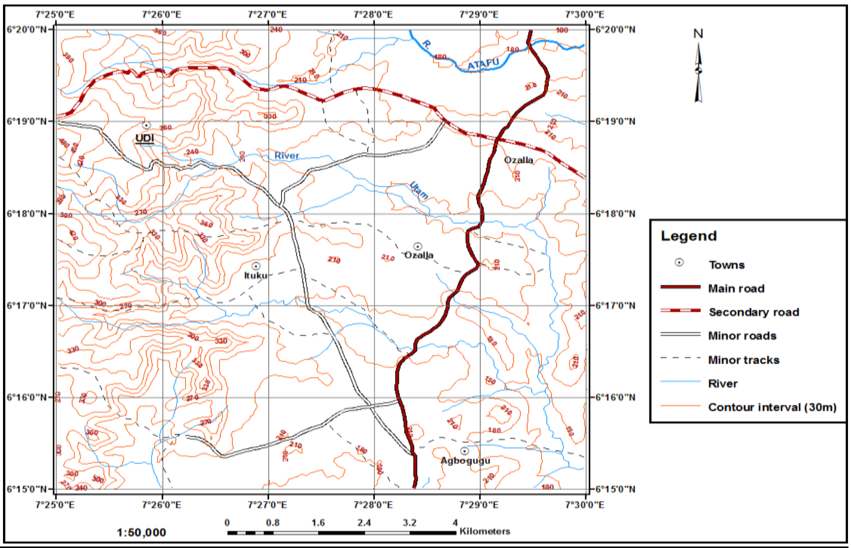

Fig 2.0: Topographyic map of the study area.

III. Result And Analysis

Interpretation of depositional environment and environmental discriminations were carried out using various statistical measures obtained from grain size analysis data as shown in table 1.0 and 2.0. Cumulative probability curve**s** show the distribution of the grain size of the samples obtained in the study area as shown in figure 4, and figure 6-8. The curves show the modal distribution of the analyzed samples through histogram plots as shown in figure 3.0 and figure 5.0.

From the curve, the statistical analysis as proposed by Folk and Ward (1957) were obtained for interpretation of the depositional environment. The plots show unimodal variation which signifies that a particular size fraction in the distribution is better sorted than others in each of the plots and thus suggests some variation in the energy of the current that deposited the sediments. The modal class of the distributions falls within fine to coarse grain, indicating that the sediments were deposited in low energy environment with high energy dominating at intervals. The statistical parameters of grain size distribution have been a major parameter in delineating the influence of depositional processes (Folk, 1966). The univariate results show that the Sand member of Mamu Formation is medium to fine grain, and mostly coarse skewed, with an average value of -0.7 (very well sorted) sand and average kurtosis is 1.24 (leptokurtic) (Tables 3.0 & 4.0).

The medium to fine grain sand of the Mamu Formation indicates that the sediments were deposited in a mixed energy environment; however, the abundance of fine sand indicates lower energy current dominated the deposition of the sediments. The very well sorted sand member of Mamu Formation is an evidence of quiet environment with low energy of deposition. Kurtosis plots platykurtic to very leptokurtic which suggest that Mamu Formation was sourced from more than one sourc**e.** The variations in the energy and fluidity factors seem to have excellent correlation with different processes and environment of deposition (Sahu, 1964). The linear discrimination functions of Sahu (1964) for finding the relation between variances exhibited by parameters were used to discriminate the environment.

(a) For the discrimination between Aeolian processes and littoral (intertidal) environments, the discriminate function used is given below:

$Y1 = -3.5688\ MZ + 3.7016\ \delta 1^2 - 2.0766\ SK1 + 3.1135\ KG$

Table 1.0: Grain size analysis data for sand sample 1

Sieve size (mm)	Phi value Ø	Weight retained(g)	%weight retained	Cum. Weight retained	%passing
1.18	-0.25	1.26	0.63	1.14	98.86
0.60	0.75	2.64	1.32	2.46	97.54
0.30	1.75	3.61	1.81	4.27	95.73
0.15	2.75	130.95	65.48	69.75	30.30
0.075	3.74	53.81	26.905	96.66	3.34
0.063	4.00	4.00	2.00	98.66	1.34

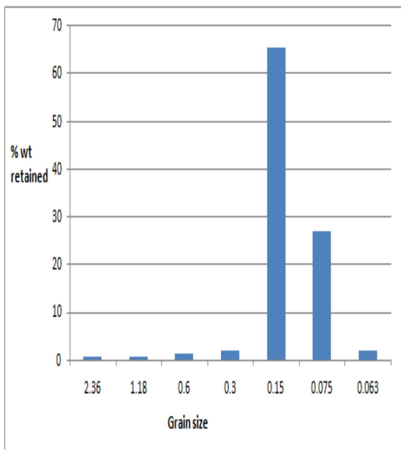

Fig. 3.0 Histogram chart of sample 1

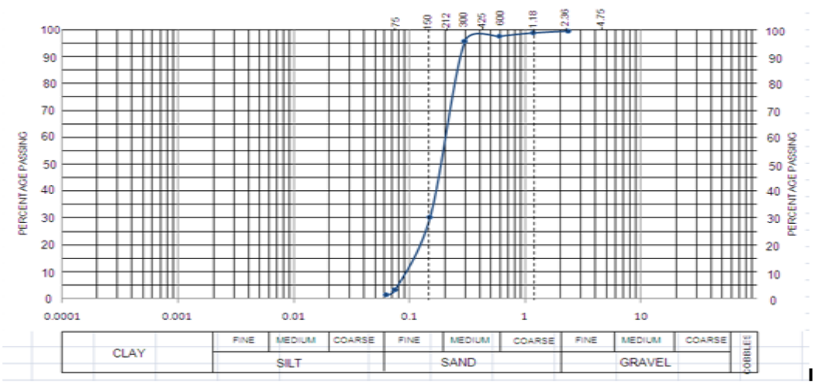

Fig.4.0 Probability curve for sample 1

Table 2.0: Grain size analysis data for sand sample 2

Sieve size (mm)	Phi value Ø	Weight retained(g)	% weight retained	Cum. Weight retained	% passing
2.36	-1.25	0.77	0.39	0.39	99.61
1.18	-0.25	2.24	1.12	1.51	98.50
0.60	0.75	2.81	1.41	2.92	97.08
0.30	1.75	2.55	1.28	4.20	95.80
0.15	2.75	107.95	53.98	58.18	41.82
0.075	3.74	80.85	40.00	98.18	1.82
0.063	4.00	2.32	1.16	99.34	0.66

Total sample used 200g

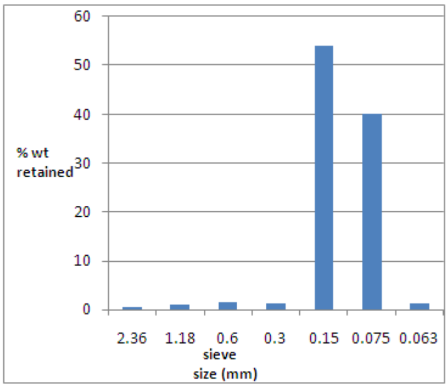

Fig. 5.0: Histogram chart of sample 2

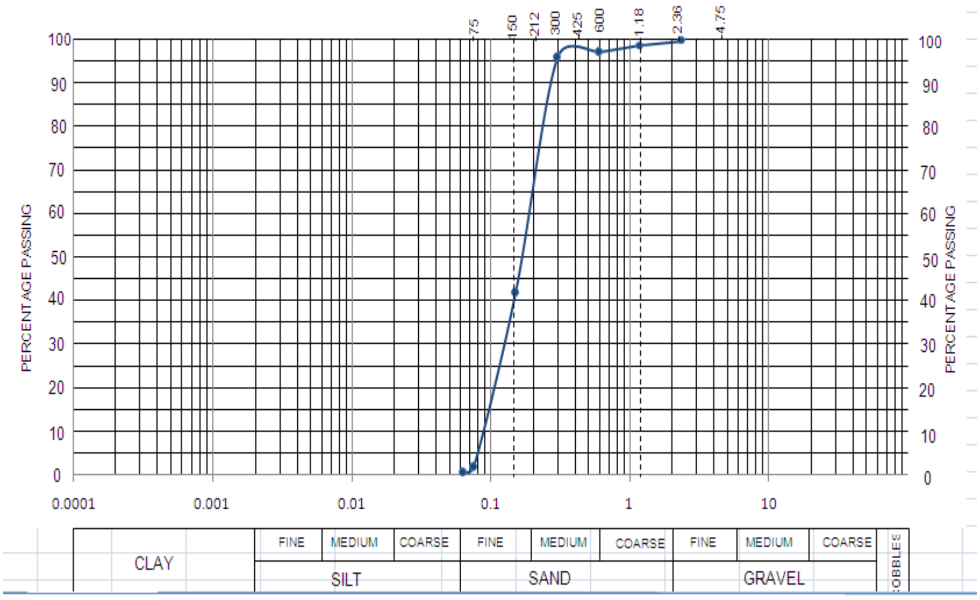

Fig. 6.0: Probability curve for sample 2

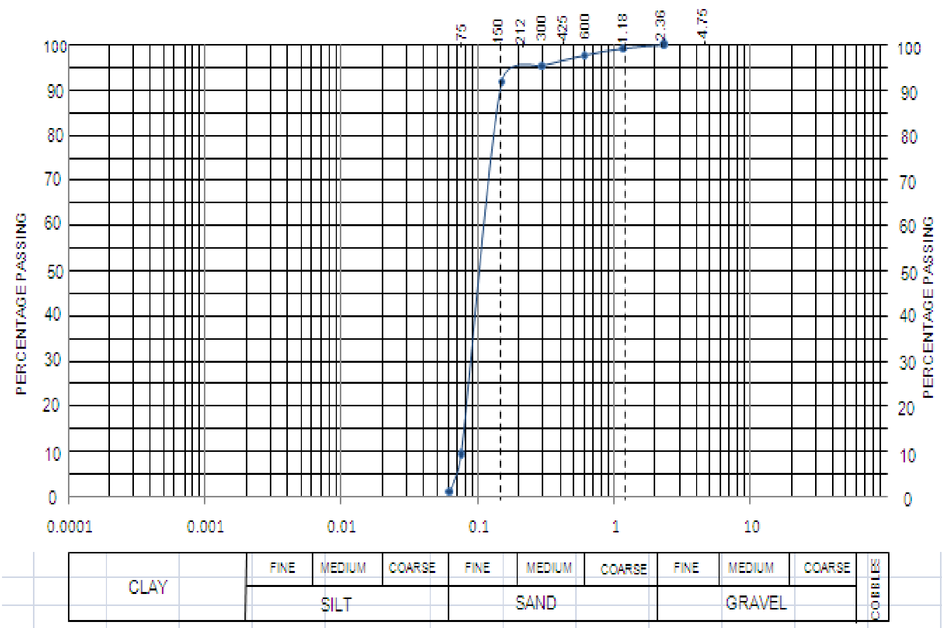

Fig. 7.0 Probability curve for sample 3

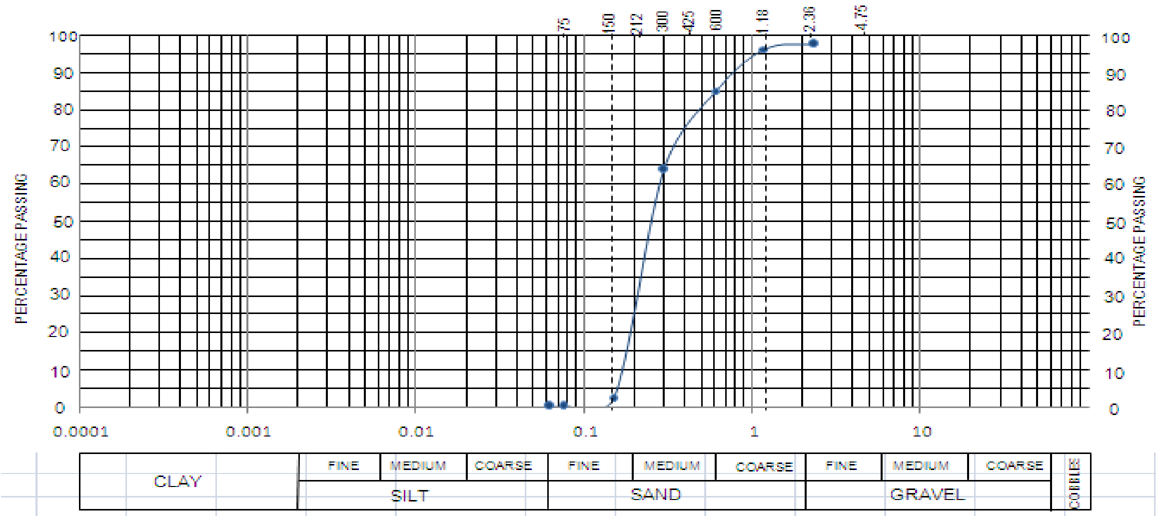

Fig.8.0: Probability curve for sample 4

Table 3.0. Computed grain size parameter drive from probability curves

Sample No	Sorting	values	Skewness (SK)	values	Kurtosis (KG)	values	Mean(Mz)	Values
Sp1	Very well sorted	-0.54	Coarse skewed	-0.1	Mesokurtic	1.02	Fine sand	2.5
Sp2	Very well sorted	-0.53	Coarse skewed	-0.1	Mesokurtic	0.93	Fine sand	2.6
Sp3	Very well sorted	-0.48	fine skewed	0.32	Very leptokurtic	1.64	Fine sand	3.3
Sp4	Very well sorted	-1.0	Coarse skewed	-0.1	Platykurtic	0.8	Coarse sand	0.48
Sp5	Very well sorted	-1.1	Fine skewed	0.22	Leptokurtic	1.34	Medium sand	1.5
Sp6	Very well sorted	-0.51	Nearly symmetrical	0.04	Very leptokurtic	1.68	Fine sand	2.2

Table 4.0: Average values for the grain size parameters

Standard deviation (σ)	-0.7 very well sorted
Mean (Mz)	2.1 Fine sand
Skewness (Sk)	0.05 Nearly symmetrical skewed
Kurtosis (KG)	1.24 Leptokurtic

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Where MZ is the grain size mean, δ1 is inclusive graphic standard deviation (sorting), SK1 is skewness and KG is the graphic kurtosis. When Y1 is less than -2.7411, Aeolian deposition is indicated whereas if it is greater than -2.7411, a beach environment is suggested.

(b) For the discrimination between beach (back- shore) and shallow agitated marine (subtidal) environment, the discriminate function used include;

$Y2 = 15.6534\ MZ + 65.7091\ \delta1^2 + 18.1071\ SK1 + 18.5043\ KG$

If the value of Y2 is less than 65.3650 beach deposition is suggested whereas if it is greater than 65.3650 a shallow agitated marine environment is likely.

(c) For the discrimination between shallow marine and the fluvial environments, the discriminate function below was used

$Y3 = 0.2852\ MZ - 8.7604\ \delta1^2 - 4.8932\ SK1 + 0.0482\ KG$

If Y3 is less than -7.419 the sample is identified as a fluvial (deltaic) deposit, and if greater than -7.419 the sample is identified as a shallow marine deposit.

From the values of Y1, Y2, and Y3 for the analysed samples, 80% of the analysed sand samples showed Y1 values that are less than -2.7411 (table 6.0) and thus indicates Aeolian deposition while 100%

analyzed sand samples showed Y2 values that are greater than 65.3650 and thus, indicates shallow agitated marine environment (table 7.0). 80% of the sand samples showed Y3 values that are greater than -7.419 and thus, is identified as a shallow marine deposit.

The bivariate scatter plots of the discriminate functions (Y1 vs Y2), (Y2 vs Y3) proposed by Sahu, 1964 and mean against standard deviation of (Moiola and Weiser, 1968) improved the success rate and refinement of the discrimination method in relation to depositional environment. The plot of (Y1 vs Y2) shows the samples to be of Aeolin environment /shallow Agitated marine (fig.9.0) while the plot of (Y2 vs Y3) shows 80% of samples to be Shallow/marine Agitated environment (fig.10.0) and this results was validated by Y scatter plot of mean versus the standard deviation (fig.11.0)

Figure 12.0 show the produced lithological map of the study area showing two distinct geologic Formations known as Mamu and Enugu shale. Mamu Formation overly Enugu shale in the Western parts of the Field. Enugu shale dominates in the Eastern Parts.

Table 5.0: Linear discrimination functions (Y1, Y2, and Y3) for the analyzed samples.

Sample No	Y1	Y2	Y3
SP1	-4.566	75.8270	-1.2944
SP2	-5.235	75.1639	-1.1952
SP3	-6.4857	102.9100	-2.5640
SP4	4.6157	86.5188	-8.0900
SP5	2.8409	131.7700	-11.1844
SP6	-3.6780	83.7090	-1.7649

Table6.0. Multivariate results of sandstone of Mamu Formation

SSAMPLE	RESULT	INTERPRETATION
Sp1	-1.2944	shallow marine
Sp2	-1.1952	shallow marine
Sp3	-2.5640	shallow marine
Sp4	-8.0900	fluvial (deltaic)
Sp5	-11.1844	fluvial (deltaic)
Sp6	-1.7649	shallow marine

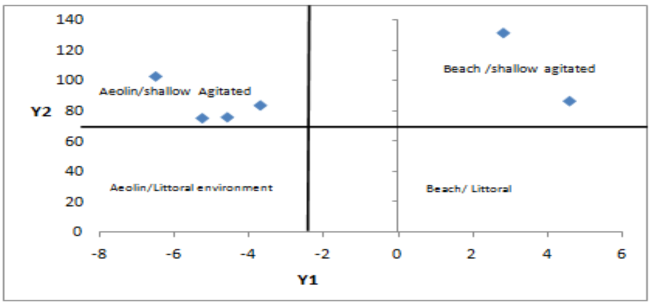

Fig.9.0: Bivariate scatter plot of Y1 vs Y2 (sahu 1967)

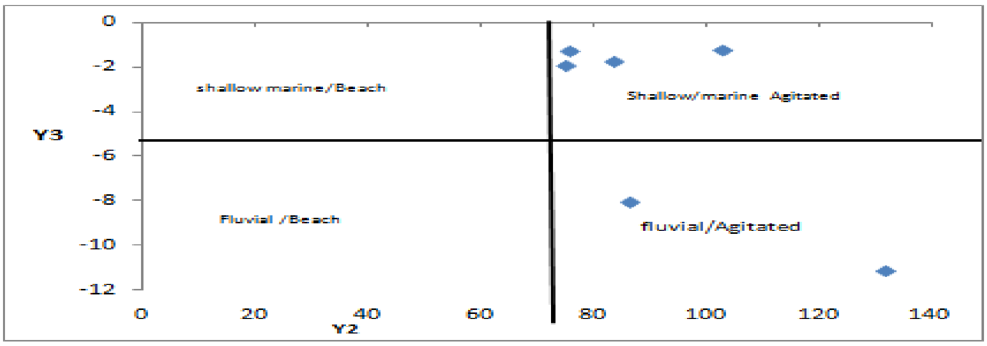

Fig. 10.0: Bivariate scatter plot of Y2 vs Y3 (sahu 1964)

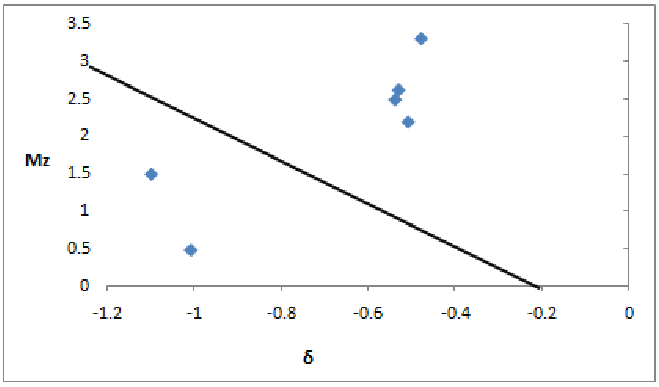

Fig.11.0: Y scatter plot of mean vs standard deviation (After Moiola and Weiser, 1968).

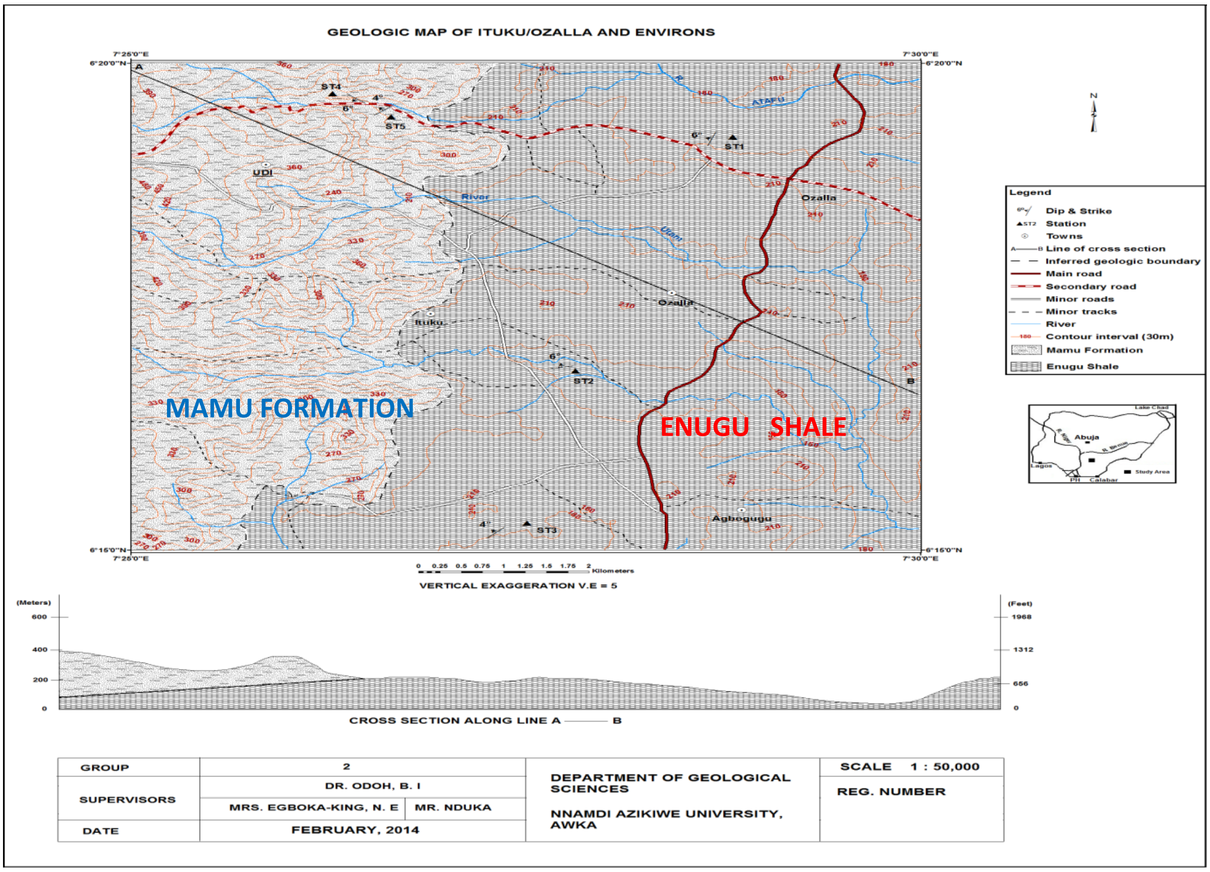

Fig. 12.0: Geologic map of the area showing mamu overlying nkporo shale

IV. Discussion

The paleo environmental interpretation of the Mamu Formation and Enugu shale was attempted based on the facies association, sedimentary structures, and texture, using the concept of process – response model of Folk and Ward (1957), Sahu (1964), Moiola and Weiser (1968). The depositional environment of the study area show two major stratigraphic units of Enugu shale and the Mamu Formation as shown in the lithologic map in figure 12.0. This was interpreted based on sedimentary facies taking cognisance of the fact that sedimentary facies reflect depositional environment, each facies being a distinct kind of sediment for that area or environment. From field data the Enugu Shale is very fissil, light grey .The fissility of the Enugu Shale suggest that it was deposited below the wave base, accumulated in relatively low energy environment i.e in a distal to proximal lagoon (Amaral and Pryor, 1974). The presence of extra formational clast within the Enugu Shale indicates that there was fluvial influence during the period of deposition of Enugu Shale within the Anambra Basin (Tucker, 1996). The light grey color of the shale shows that it was deposited on the surface of the basin where oxidation could take place (Dapple, 1974).

The fine medium grained sandstone, siltstone and fissile shale that dominates Mamu Formation succession as observed from sieve and field relationships suggests that the unit was deposited in an environment where there was little or no existence of tidal or wave action i.e quiet environment where low energy favoured deposition of fine – medium size sediments. The presence of coal beds that alternate the shale, siltstone and sandstone units within Mamu Formation sequence indicates that Mamu Formation was deposited in estuary environment similar to the observation made by Reyment (1965), Nwajide and Reijers (1996). The very well sorted to well sorted (Table 5.0) of Mamu Formation is an evidence of quiet environment with very low energy of deposition. The kurtosis for Mamu Formation revealed leptokurtic to platykurtic (Table 4.0) which suggests that Mamu Formation were sourced from more than one sources which is similar to the observation made by Akaegbobi and Boboye (1999). The bivariate plots and multivariate show that Mamu Formation was deposited in a shallow marine with prevalent of fluvial incursion. The fissility and the fine nature (Grain size) of the Enugu Shale as indicated by the field data suggest that Enugu Shale was deposited below the wave base, accumulated in relatively low energy environment i.e in a distal to proximal lagoon (Amaral and Pryor, 1974). The presence of extraformational clast within the Enugu Shale indicates that there was fluvial influence during the period of deposition of Enugu Shale within the Anambra Basin (Tucker, 1996).The light grey colour of the shale shows that Enugu Shale was deposited on the surface of the basin where oxidation could take place (Dapple, 1974).

V. Conclusion

The geologic map of the study area has been produced with the sections and cross sections of the mapped units. The mapped units are the Enugu shale and Mamu Formation. The ancient environments of the sediments of the study area, part of Anambra Basin has been reconstructed from the field relationships and textural analysis results and have been found to be shallow marine with fluvial incursion. Before the Santonian tectonic event, Anambra Basin was still in platform stage. However, sequel to Santonian tectonism, the study area opened up as Anambra Basin. Thus, the basin began to communicate with the Atlantic Ocean. There was a rise in the sea level during the Campanian times and the sea transgressed into the land. The incursion of the Atlantic Ocean caused the basin to become deeper and quiescent. Thus, Enugu Shale was deposited into the basin. Gradually, the shoreline started withdrawing seaward from the land. Hence, the basin became starved of shale (Enugu Shale) as a result of the gradual increase in depositional energy within the basin. This resulted in the emergent of sediments deposited in a coastal environment of fluvial and marine water interaction. Before the transgression of sea into the land, the land was already covered with giant plants and trees. When transgressions phase set-in, those plants and trees were covered up with water and they began to decompose. Regression phase followed the transgression phase simultaneously and subsequently led to the withdrawal of shoreline seaward such that sediments that were transported from the land were deposited and buried the decomposed plant and tree remains in the study area as Mamu Formation. Thus these plant remains were transformed into coal seams that exist in the Mamu Formation

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