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Research on Hydrocarbon Potentials of the Ameki Formation Sediments Exposed at Ekete Spring, Owerichukwuemeka Spring and Ogbanelu Spring in Southeast Nigeria

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ABSTRACT

The lignite and shale samples from Ekete spring, Owerichukwuemeka spring and Ogbanelu spring are evaluated for hydrocarbon generation potential based on total organic content, foraminifera studies, thin section and polish section analysis. This research involves fieldwork at the town of Umudiji and Umuogazi in the south-eastern part of Nigeria for sampling and laboratory analysis to determine the sedimentology characteristics of the exposed outcrop of the early Eocene Bende Ameki Formation. The investigated area has a total thickness of 1.1m, 2.1m and 2.32m at the Ekete spring, Owerichukwuemeka spring and Ogbanelu spring respectively. The shale component in this area includes quartz, biotite and mainly clay minerals. The noted species are Ammotium, Bolivina, Reophax, Ammobaculites and Gavelinella and their presence indicates a brackish, low oxygen environment with reduced salinity. The shale samples under photomicrography shows presence of quartz, biotite and abundance of clay mineral. TOC values of each sample range from 4.07 to 8.08 wt percent with an average value of 5.67 wt percent, which confirmed that Shale and Lignite from the study area were very good hydrocarbon source rock. The macerals of the study show more of lignite which suggest that the study areas are of type II kerogen that has potential to generate oil and gas.

KEY WORDS: Ameki Formation, Anambra Basin, Hydrocarbon, Organic content, Foraminifera

1.0 INTRODUCTION

Exploitation of coal started at Anambra Basin in 1909 and became a major activity before the commencement of hydrocarbon exploration[1]. Nigeria's major source of income has once been through exploitation of the coal mineral deposits for energy generation and other purposes. Major localities within Anambra Basin total reserves of the sub-bituminous coals were estimated at about 1.5 billion tones and occur principally at the Mamu Formation (Lower coal measures) and the Nsukka Formation (Upper coal measures)[2-4]. Hydrocarbon potential assessments of the successions in the trough revealed a number of organic rich intervals capable of yielding significant quantities of hydrocarbons in the Cretaceous sections[5-7].

Many researchers have formulated models on the origination of the Nigeria Benue Trough and most agree that its origin is related to the continental separation of Africa and South America[6, 8-11]. The Benue Trough contains several rift-related basins that form a part of the Anambra Basin and the trough covers about 80-90km of large fault-bound depression with deformed Cretaceous-Tertiary sedimentary and volcanic rocks of up to 5000m. Geographically, it is subdivided into the Northern, Central and Southern Benue Basins, consisting of the Abakaliki and the Anambra Basin in the south. The significance of the Benue rift in the evolution of the mega-tectonic Atlantic region has led to the development of numerous tectonic models for its origin and evolution[7, 9, 12]. The sediments in the Benue Trough are bordered on either side by Pan-African granites and gneisses which make up the crystalline basement. The basement of the Benue Trough is invaded by numerous intrusive bodies whose sizes range from massive granitic bodies to thin dyke-like bodies that may unite to form massive structures[12, 13]. The first stage of its evolution started in the Aptian, forming isolated basins with continental sedimentation. In the Albian times, a great delta developed in the Upper Benue Trough, while the first marine transgression coming from the opening Gulf of Guinea occurred in the south and reached the Middle Benue[9, 10].

The Nigerian Benue Trough is being generally regarded as a rift structure noted to have many features in common with other intra-continental rifts structures whose evolution is related to the Early Cretaceous opening of the South Atlantic Ocean and the Gulf of Guinea. The rift can be compared with some well-known rift systems such as the East African, the Rhine Graben, the Baikal rift and the Rio Graande rift[5, 6]. The Lower Benue Trough (Anambra Delta), Upper Benue Trough, the Afikpo Basin and the Abakaliki Basin overlap each other surrounding the south-eastern part of Nigeria[14]. The Nanka Sand, Nsugbe Formation, and Ameki Formation formed the Ameki Group[15]. The Eocene Ameki Formation is considered to be the youngest exposed unit in the Afikpo syncline, the formation overlies the marine Imo Shale and underlies the paralic Ogwashi-Asaba Formation. The Ameki Group which includes tidal facies and backshore as well as pro-delta facies, constitutes the outcropping deposits of the Eocene regression, which

marked the beginning of the Niger delta progradation. Alternating shale, sandy shale, clayey sandstone, and fine-grained fossiliferous sandstone with thin limestone bands are primarily the Ameki Formation[1, 16, 17].

Commencement of oil exploration in Anambra Basin and underlying Abakaliki folded basin by Shell BP in the1950s resulted to the drilling of several exploration wells. Part of the results achieved from the samples and data generated from the exploration wells have highlighted Nkporo and Mamu Formations as the main petroleum source rocks in Anambra Basin [18-24]. This study presents detailed hydrocarbon potential of the lignite and shale samples of Ekete spring, Owerichukwuemeka spring and Ogbanelu spring which are discussed based on its total organic content, foraminifera studies, thin section and polish section analysis.

2.0 MATERIALS AND METHODS

It involved collection of spot rock samples at the reference locality for laboratory studies using the appropriate instruments. The collected samples from the study area were subjected to total organic carbon (TOC) determination, thin section petrography analysis, Foraminifera studies and polish section analysis.

2.1.1 STUDY AREA

Ekete spring, Ogbanelu spring and Owerichukwuemeka spring are all located in Umudiji and Umuogazi town, both in Nnewi South Local Government Area of Anambra State, Nigeria. This three outcrops belong to Ameki formation within Anambra Basin and has its geographical coordinates ranging from an area of 49,000 km^2 within latitude 5^o 55$^{'}$ 46.8'' and longitude 6 ^{o} 56$^{'}$ 42.8''.

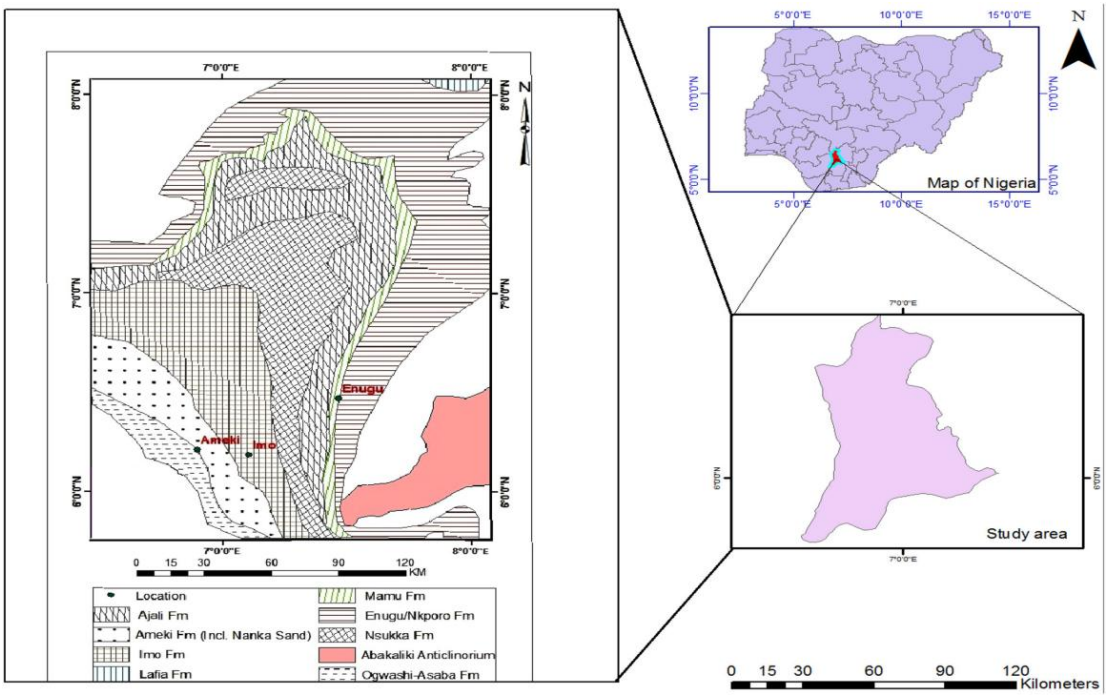

Fig. 1 Map of Anambra Basin showing sampling location; Modified from Obaje[25]

2.1.2 REGIONAL STRATIGRAPHIC SETTING OF ANAMBRA BASIN

The Anambra Basin forms a part of the Benue Trough comprising several rift related basins in Nigeria. The Formation of the sedimentary basin in southern Nigeria followed the break-up in the early cretaceous of the South American and African continents. A rift model was supported by various geomorphological, structural, stratigraphic and palaeontologic evidence[26-28]. Three sedimentary phases characterize the stratigraphic history of the region. These phases are Abakaliki-Benue (Aptian-Santonian), Anambra-Benin (Campanian-Mid Eocene) and Niger Delta (Late Eocene-Pliocene). The Anambra-Benin sediment consisted of the Santonian folding and raising of the Abakaliki region, dislodging the depocenter into the Anambra plateau[27, 29, 30].

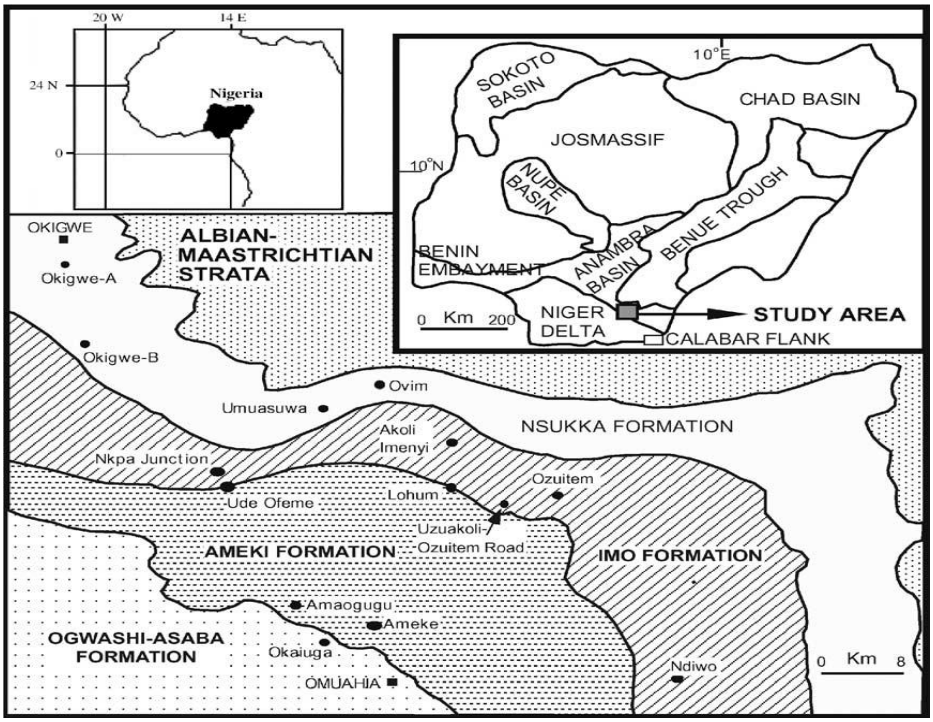

Fig.2 Map of Southeastern Nigeria showing Ameki Formation[17, 31]

2.2 FIELD WORK

The field work involves a trip to Umudiji and Umuogazi town in Nigeria to collect samples and describe sedimentary structures. Photographs of sedimentary interest structures were taken during the collection, packaging and labeling of fresh unweathered representative samples in sustainable polythene bags for easy identification. After the correct drying, the samples were analyzed in the laboratory to determine the total organic content, polish, thin section and foraminifera study.

List of field materials includes the clinometer, field note, geology hammer, chisel, sample bags, masking tape, marker pen, camera, measuring tape, safety ware. Readings related to inclination, positioning and bearings were made using the GPS and the clinometer compass.

2.3 LABORATORY WORK

The collected samples from the study area are subjected to thin section petrography analysis, total organic carbon (TOC) determination, Foraminifera studies and polish section analysis were also involved. As the procedure involved in undergoing this test are stipulated below.

- **Total Organic Carbon Analysis**

  Ten samples (2 Shale & 8 Lignite) from Ekete spring, Owerichukwuemeka spring and Ogbanelu spring were selected for total organic carbon analysis using the Walkey-Black oxidation method. The samples were pulverized and sifted with 0.5mm mesh, selected 20g of each pulverized sample into a 259ml conical flask, after which the $K_2Cr_2O_7$ solution was precisely pipetted into it. In addition, the following procedures were used to complete the analysis:

  -20 ml of concentrated H_2SO_4 was quickly added and shaken together to allow the reagents to be properly mixed with the samples.

  -The suspension remained standing for about 30 minutes, stirring intermittently for complete oxidation.

  -100ml of distilled water added.

  -3 drops of phenothroline ferrous complex indicator added.

  -The above solution was then titrated with a ferrous sulphate solution at a bluish, dark end point.

  -The TOC percentage was then calculated using the formula below.

  TOC percentage = $(M_{eq}K_2Cr_2O_7 - M_{eq}FeSO_4)$ (0.003*F) / Sample weight (g)

  Meq= Solution normality x 1ml of solution used

  F= 1.33 F= 1.33 (Correction factor)

- **Thin Section Petrography Analysis**

For the thin section petrography analysis, two shale (Ogbl-B &Ogbl-T) samples from the Ogbanelu section were selected. The samples were pulverized into powdered form and for further processing;carborundum 120 and 600 grits were used to grind them before mounting them on the glass

slide with araldite. As thinning process continues using carborundum, the mounted samples were continuously observed under petrology microscope to know whether it has been thinned to the required thickness of 0.03mm. Canada basalm was applied on the samples and then touched with covering needle before the glass slide covering was put on top of it for preservation. The glass slide was allowed to cool and then washed with acetone followed by soap solution, rising with fresh water and air dried. The thin section was then observed under petrology microscope to describe the mineralogy composition, mode of deposition and environmental state of deposition.

- **Polish Section Determination**

Five samples of lignite and five shale were prepared in polished slides for organic sample geochemical studies. The following procedure for the preparation of the polished slides using the Logitech polished machine was then adopted;

- The selected shale and lignite samples were pulverized into less than 2mm grains.
- 50g of the sieved lignite and shale was collected and about 20g was weighed.
- The samples were impregnated with epoxy resin and were left for 36hours to harden.
- The harden sample were polished using 90, 120, 280, 400, 600, 800 and 1200 carborundum grits for 10 minutes and subsequently polish with magnesium oxide powder on the surface of the lignite and shale sample.
- Then polish with glycerol using a velvet cloth for about 5 minutes.

- **Foraminifera Study**

Five samples of Shale were selected for the Foraminifera studies. 200g of each of the shale samples were weighed and air dried to remove the water content, pulverized to increase the surface area to allow easy digestion, addition of ration 1:3 hydrogen peroxide concentration to avoid burning of the sample, left for 36 hours to allow proper digestion of the foraminifera from the shale samples, and dried residues were observed under a binocular microscope to identify the species present.

3.0 RESULTS AND DISCUSSION

The quality of hydrocarbon potential of the lignite and shale samples of Ekete spring, Owerichukwuemeka spring and Ogbanelu spring are discussed based on lithological description, total organic content, foraminifera studies, thin and polish section analysis using the below table to display the appropriate source rock quality to generate hydrocarbon.

3.1 LITHOLOGICAL DESCRIPTION

The lithology sections of Ekete spring, Owerichukwuemeka spring and Ogbanelu spring with thickness of 1.1m, 2.1m and 2.3m of Ameki Formation are sketch below:

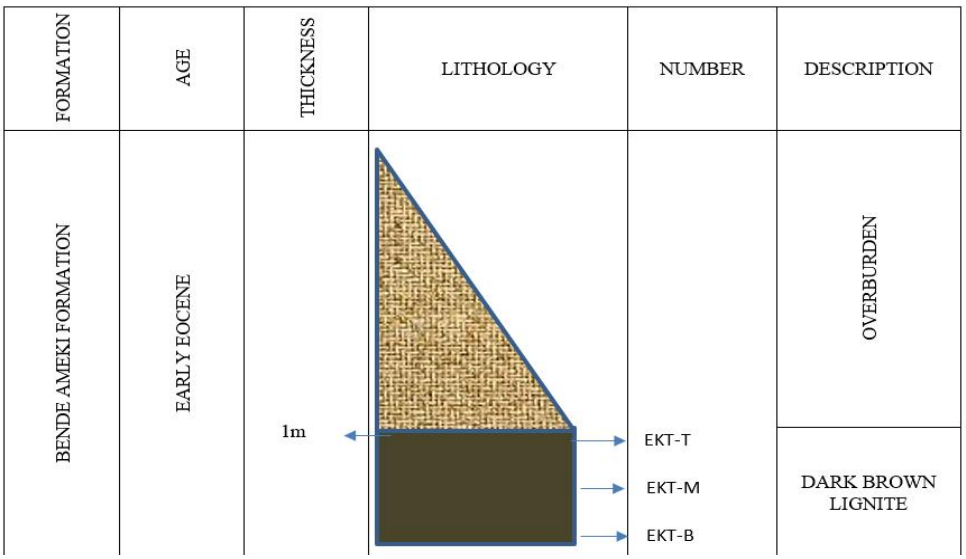

Fig.3 Lithostratigraphic section of Bende Ameki Formation exposed at Ekete spring in Umudiji

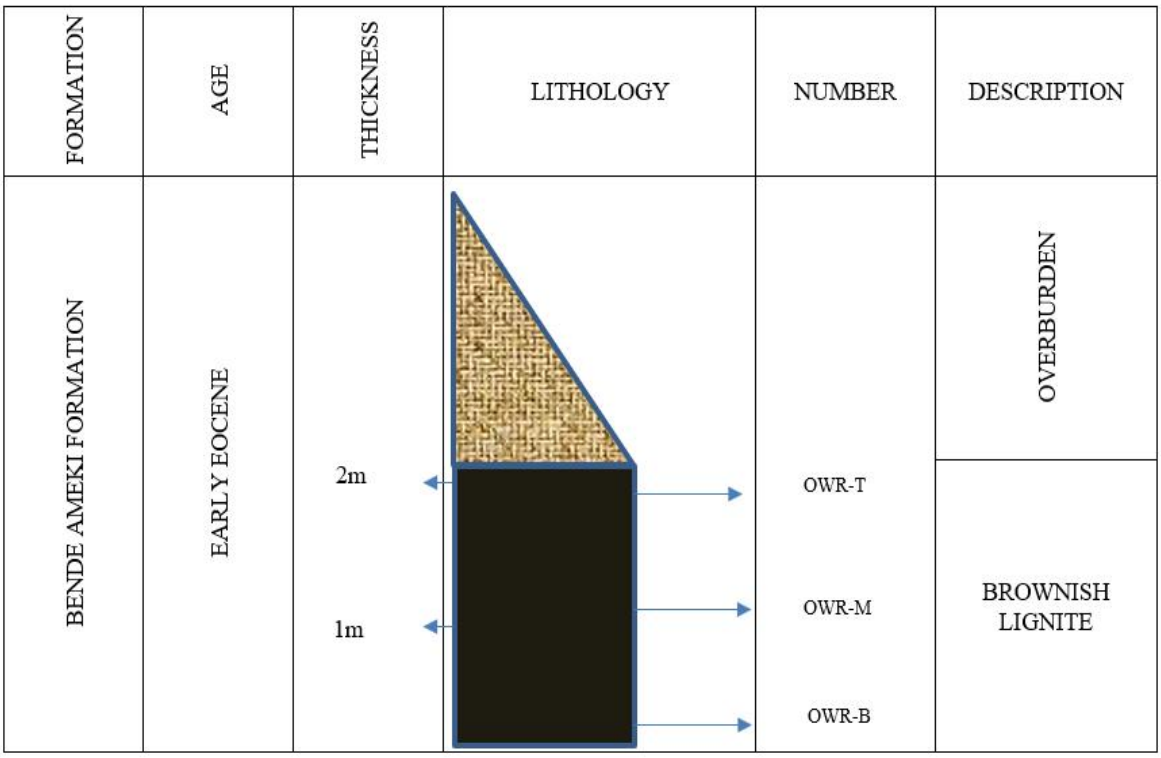

Fig. 4 Lithostratigraphic section of Bende Ameki Formation exposed at Owerichukwuemeka springin Umuogazi

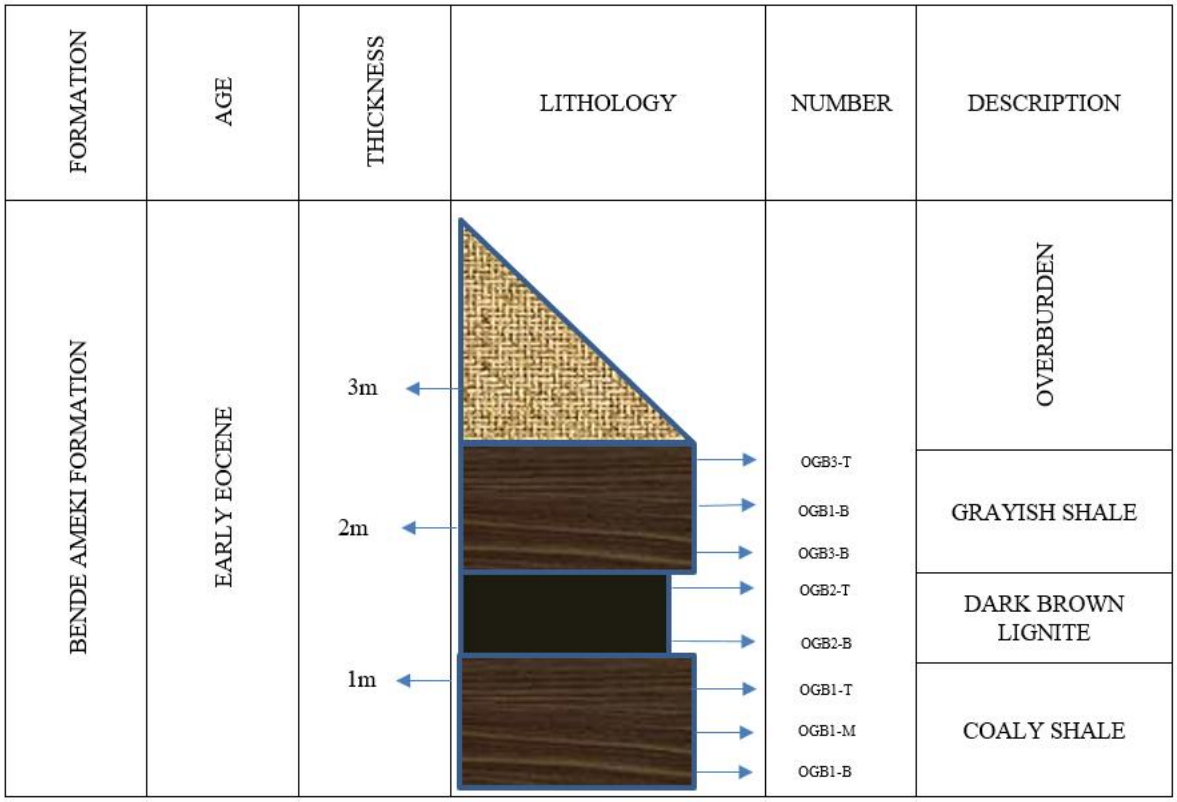

Fig. 5 Lithostratigraphic section of Bende Ameki Formation exposed at Ogbanelu springin Umuogazi

The main lithofacies in the study area of Ekete spring and Owerichukwuemeka spring are mainly of brownish with a thickness 1.1m and 2.1m respectively while the section of Ogbanelu spring is about 2.32m thick of massive lignite seam interbedding carbonaceous shale. Eight lignite facies samples were collected at intervals and labelled: Ekt-B, Ekt-M &Ekt-T (Fig. 3.1); Owr-B, Owr-M &Owr-T (Fig. 3.2); Ogb2-B and Ogb2-T (Fig.3.3). The shale beds were also mapped (some underlined and other overlying the lignite) and labelled: Ogb1-B, Ogb1-M & Ogb1-T; Ogb3-B & Ogb3-T.

3.2 TOTAL ORGANIC TEST RESULT

The below table shows the Total Organic Carbon (TOC) present in both the lignite and shale samples at study area of Ekete spring, Owerichukwuemeka spring and Ogbanelu spring.

Table 1 Preliminary TOC results and their respective petroleum generation qualities

S/N	Sample No	Rock Types	Position	Springs	TOC (WT%)	Quality
1	Ekt-B	Lignite	N5° 55' 46.8'' E6 ° 56' 42.8''	Ekete	4.15	Excellent
2	Ekt-M	Lignite	N5° 55' 46.8'' E6 ° 56' 42.8''	Ekete	4.17	Excellent
3	Ekt-T	Lignite	N5° 55' 46.8'' E6 ° 56' 42.8''	Ekete	4.21	Excellent
4	Ogb1-M	Shale	N5° 55' 56.2'' E6 ° 56' 42.1''	Ogbanelu	8.06	Excellent
5	Ogb1-T	Shale	N5° 55' 56.2'' E6 ° 56' 42.1''	Ogbanelu	8.08	Excellent
6	Ogb2-B	Lignite	N5° 55' 56.2'' E6 ° 56' 42.1''	Ogbanelu	4.07	Excellent
7	Ogb2-T	Lignite	N5° 55' 56.2'' E6 ° 56' 42.1''	Ogbanelu	4.09	Excellent
8	Owr-B	Lignite	N5° 56' 01.9'' E6 ° 56' 31.5''	Owerichukwu Emeka	4.11	Excellent
9	Owr-M	Shale	N5° 56' 01.9'' E6 ° 56' 31.5''	Owerichukwu Emeka	8.04	Excellent
10	Owr-T	Shale	N5° 56' 01.9'' E6 ° 56' 31.5''	Owerichukwu Emeka	7.98	Excellent

The Total Organic Carbon (TOC) in Shale increases as the colour goes from brown to grey to black. The Shale samples do not contain as much organic matter as lignite. The high concentration of organic matter was related to the anoxic state of the Early Eocene – Middle Eocene when the sediment is laid and therefore organic matter is well preserved. The value for TOC for each sample ranges is from 4.07 to 8.08wt% with an average value of 5.67wt%, which confirms the highly good hydrocarbon rock shale and lignite in the study area.

Fig. 6 Field Photograph showing Lignite facies at Ekete spring in Umudiji

Fig. 7 Lignite-Shale boundary Photograph of Ogbanelu springin Umuogazi

3.3 THIN SECTION PETROGRAPHY RESULT

To determine the outcrop's microscopic character, two samples (Ogb1-B & Ogb1-T) of Ogbanelu spring were picked. Generally, the sample analyzed was used to determine the mineralogical composition of the shale. The component of the shale in this area includes quartz, biotite and dominantly of clay minerals.

Fig. 8 Plane view of shale sample (Ogb1-T) under photomicrography showing quartz, biotite and abundant of clay mineral

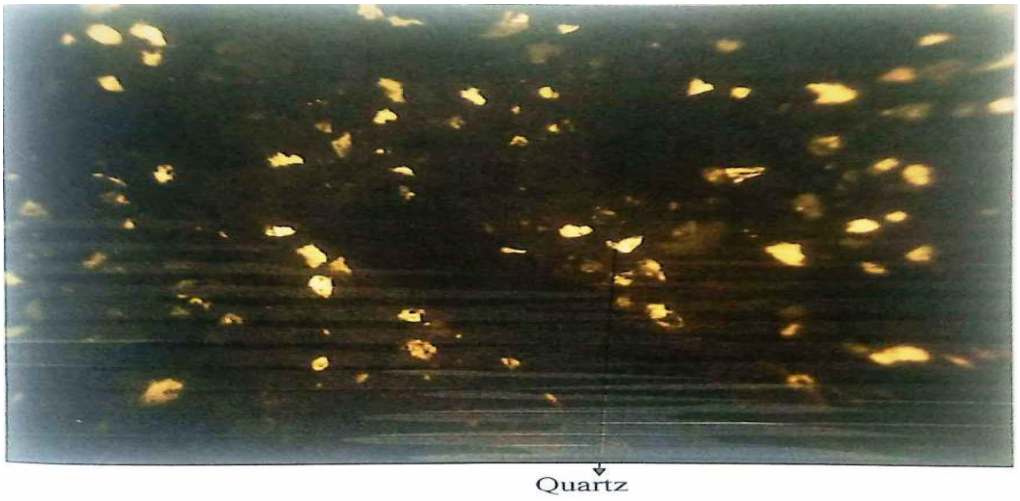

Fig. 9 Cross view of shale sample (Ogb1-T) under photomicrography showing quartz and abundant of clay mineral

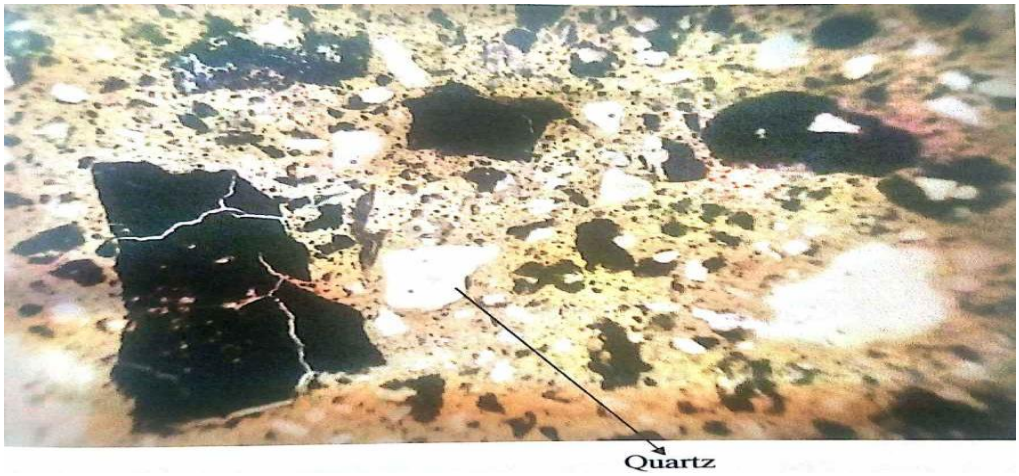

Fig. 10 Plane view of shale sample (Ogb1-B) under photomicrography showing quartz and abundant of clay minerals

3.4 FORAMS OBSERVATION

The approach involves observation of Foraminifera abundance and diversification of the species in assessing the paleoenvironnemental foraminifera study. The detailed study of qualitative and quantitative foraminiferous data base for biotratigraphy and paleoenvironnemental restructuring studies offers high-resolution information[32].Microfossil studies were conducted on the residues of five shale samples obtained at Ogbanelu spring under the Binocular microscope. Foraminifera samples were poor because the shale samples were sandy, and five species were collected in the samples. The species noted are Ammotium, Bolivina, Reophax, Ammobaculites and Gavelinella. Their presence indicates a brackish, low oxygen environment with reduced salinity, which further confirms that the study areas have potential for hydrocarbons.

Table 2 Petroleum Generation Source Rock Quality Required Table[31, 33]

TOC (wt %)	QUALITY
< 0.5	Poor
0.5 – 1.0	Fair
1.0 – 2.0	Good
2.0 – 4.0	Very good
> 4.0	Excellent

CONCLUSION

The Ameki Formation sediments exposed at Ekete Spring, Ogbanelu Spring and Owerichukwuemeka Spring are all located in Umudiji and Umuogazi town in the south-eastern part of Nigeria. Ogbanelu spring consists of shale beds of lignite, while the other study areas consist mainly of massive coal and seam. The total organic carbon values of each sample range from 4.07 to 8.08wt percent with an average value of 5.67wt percent which confirmed that shale and lignite from the study area were very good hydrocarbon source rock. It can also be inferred from the presence of species Ammotium, Bolivina, Reophax, Ammobaculites and Gavelinella (Benthic Foraminifera) at the reference locations that the environment is favorable for the shale to host hydrocarbons

Declarations

Funding: No funding was received for conducting this study

Conflict of interest: The author declare that there is no conflict of interest

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