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Palynological and Organic Geochemical Studies for Source Rock Characterisation and Evaluation of Mamu Formation in the Benin Flank of the Anambra Basin

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ABSTRACT
Organic geochemical and palynological studies were carried out to characterize and evaluate the source rock potentials of the Mamu Formation exposed at Benin flank of the Anambra Basin. Organic geochemical techniques and palynological studies were carried out to determine the organic matter richness, kerogen types, maturation, age and environment of deposition of the deposite. The analytical results of the studied samples reveals that the Total organic carbon content and Hydrogen Index (HI) ranged from 1.08 – 3.81wt% and 260 – 1005 mgHC/g respectively indicating that the samples are fair to good source rocks. The cross-plot of HI/OI indicates that they are predominantly of Type III/II kerogen; Maturity studies present them as immature. TSC/TOC cross-plot indicates that they are of normal marine environment Cross-plot of HI/TOC and TOC/GP shows that they are good potential source rocks and have moderate to very good organic richness. The study area is therefore considered to be of good petroleum potential and the presence of certain index fossils such as Proxaperites cursus, Laevigatosporites sp., Longapertites marginatus, Cingulatisporites ornatus indicate that the exposure is of Maastrichtian age and was deposited in a Continental environment with occasional marine incursions

Keywords: *Palynology, Organic geochemistry, mamu Formation, Source rock, Anambra Basin.*

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I. INTRODUCTION

One of the major factor governing the accumulation of hydrocarbon is the availability of source rock.[4] Understanding of the source potential is key in the exploration process. Integration of palynology and Organic geochemical characterization of source rocks gives a better understanding of the source rock and it entails assessing the hydrocarbon generation potential of sedimentary rocks by taking a look at the sediments capacity for hydrocarbon generation, type of organic matter, type of hydrocarbon that is expected to be generated, the sediments thermal maturity its age and environment of deposition [5]. Preservation of organic matter without degradation is critical and necessary for hydrocarbon generation. Organic matter preserved is subjected to increased temperature and pressure due to burial, and is then converted to kerogen. As organic matter is preserved, so also are certain biological forms known as palynomorphs; these are microscopic organisms that lived in particular age and their study indicates life, environment, and energetic conditions that produced them.

The objective of this study is to characterize the hydrocarbon generative potentials of the source rocks at Imiegba, Benin flank (western part) of the Anambra Basin by assessing its organic richness, type and quality of organic matter, paleodepositional environment and thermal maturity through Organic geochemical analysis, age and environment of deposition determination based on the palynomorph content found within the samples.

1.1. LOCATION AND GEOLOGY OF THE STUDY AREA

The sampled location is at Latitude N07° 11' 28.3" and Longitude E006° 26' 48.1" of the Greenwich Meridian. It falls within the Benin flank of the Anambra Basin [7]. The study area is an exposed section of Mamu formation and occurs as a road.

The sediments of the Benin Flank include the Nkporo Group which indicates a major transgression and the Coal Measure represents a major regression of the Late Cretaceous Sea[14]. In the South eastern end, the Nkporo Shales which constitute prodelta shales and subordinate sands and limestone, its lateral equivalent, Enugu Shales and Owelli Sandstones constitute the basal beds of the Campanian. The Nkporo Shale is replaced by the Lokoja

Basange Sandstone Formation in parts of the Benin Flank. The shallow marine paralic sequence of the Mamu Formation was then deposited which has been described as the Lower Coal Measures and was later overlain by the Continental sequence of the Ajali Formation followed by the paralic deposition of the Nsukka Formation, the Upper Coal Measures[10].(Fig 1).

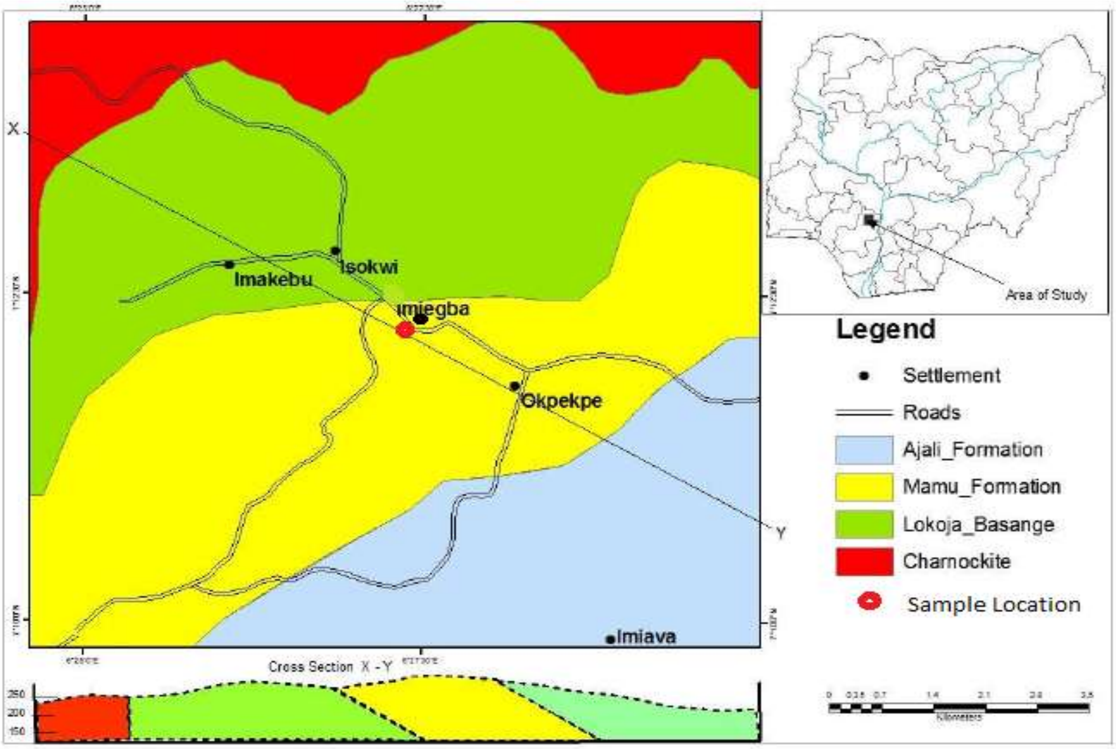

Fig.1: Map showing the Geology of the study area (modified after [9])

II. RESEARCH METHODS

Laboratory studies of the collected samples were based on organic geochemical techniques such as Rock-Eval pyrolysis, Total sulphur content (TS) determination, Total organic carbon content (TOC) determination, Soluble organic matter (SOM) extraction and, Palynological analysis to determine age and environment of deposition.

III. RESULTS AND DISCUSSIONS

3.1 RESULTS OF ORGANIC GEOCHEMICAL STUDIES

3.1.1 QUALITY OF ORGANIC MATTER

The organic carbon richness of the samples taken is important in the evaluation of sediments as a source for hydrocarbons. It is determined using the total organic carbon content, which is the total amount of insoluble organic material (kerogen) present in the rock expressed as a percentage in weight (TOC wt.%). By and large, the higher the TOC, the better the chance of hydrocarbon generation.[16], gave 0.5wt% as the minimum threshold value required for a rock to be regarded as a petroleum source rock. As shown in Table1, the TOC of the samples range from 1.08 to 3.64 w.t% (2.83wt.% average), which exceeds the threshold value of 0.5wt.%. This suggests that the samples are good to very good source rocks. A plot of HI versus TOC (Fig.2) shows that the samples have good potential to generate Hydrocarbon.

3.1.2 PALEODEPOSITIONAL ENVIRONMENT

The Total Sulphur content of the organic matter in the studied samples ranges from 0.22 to 2.90 wt.% (1.25 wt.% average). The TS versus TOC plot in fig. 3 exclusively shows a normal marine depositional environment for most of the samples with sample 5 indicating a deep marine environment and sample 1 tends toward a terrestrial environment.

Table 1: Results of organic geochemical analysis of the studied samples

SAMPLES	TOC	S_1	S_2	S_3	TS	T_{max}	PI	HI	OI	SOM
1	3.82	0.258	0.99	0.82	0.79	332	0.21	260	213	2450
2	2.62	0.663	0.98	0.69	0.35	308	0.40	376	263	2340
3	2.97	0.581	1.32	0.68	0.22	319	0.31	443	229	1620
4	3.64	0.013	3.66	0.049	2.01	423	0.0033	1005	13	1820
5	1.08	0.011	0.46	0.043	2.90	411	0.023	428	40	1101

TOC, TC, TS and SOM are in (wt.%), while S_1, S_2, S_3 and HI are in mgHC/g
T_{max}: Maximum temperature (^{o}C)
PI: Production Index
OI: Oxygen Index (mgCO_2/g)
TS: Total Sulphur content
mgHC/g: Milligram Hydrocarbon per gram
mgCO_2/g: Milligram Carbon dioxide per gram
TOC: Total Organic Carbon
HI: Hydrogen Index
TC: Total Carbon content
SOM: Soluble Organic Matter
Wt%: Weight Percent

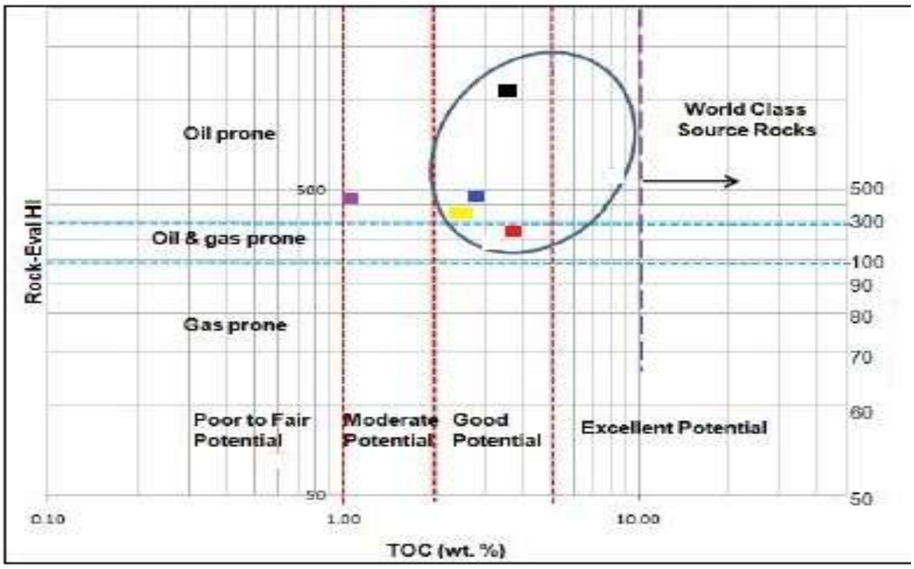

Fig 2: Plot of Hydrogen index against TOC modified showing the generative potential modified from[2]

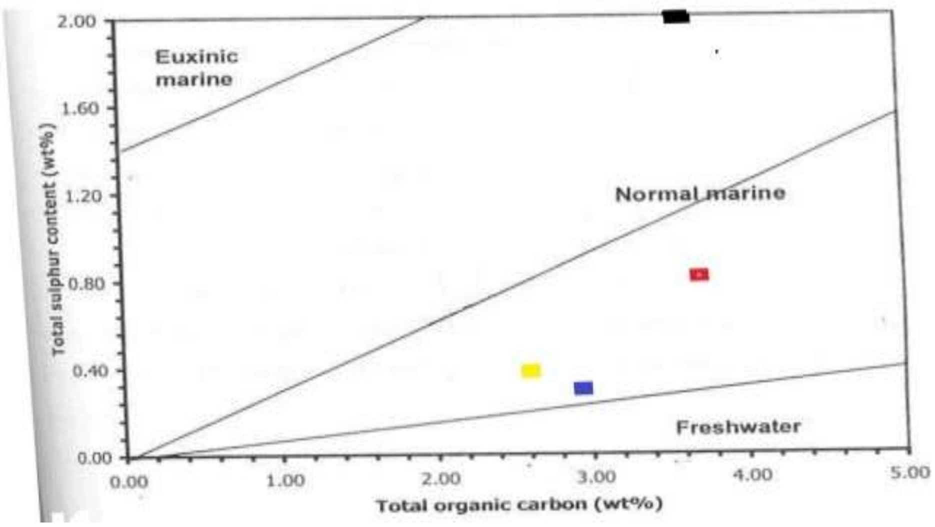

Fig 3: Plot of TS against TOC indicating various aquatic conditions of deposition (modified from[12])

3.1.3 KEROGEN TYPE

The diversity of life forms influences the type of kerogen and the hydrocarbon product generated after maturation. Some being oil-prone or gas-prone, while others are not convertible to petroleum[6].
[12] Proposed that source rocks with HI greater than 600 mgHC/g will generate oil, while those with HI between 200 and 600 mgHC/g will generate wet gas (oil and gas). Rocks with HI values between 50 and 200 mgHC/g will generate gas and those with HI values less than 50 mgHC/g are inert. The HI values for the samples ranges from 260 to 1005 mgHC/g (502 mgHC/g average). The modified Van Krevelen diagram plot (HI versus OI plot) in Fig.4 , and the intermediate values of HI suggest that the studied samples are dominated by type III/II kerogen. This implies that the samples are oil-gas prone source rocks.

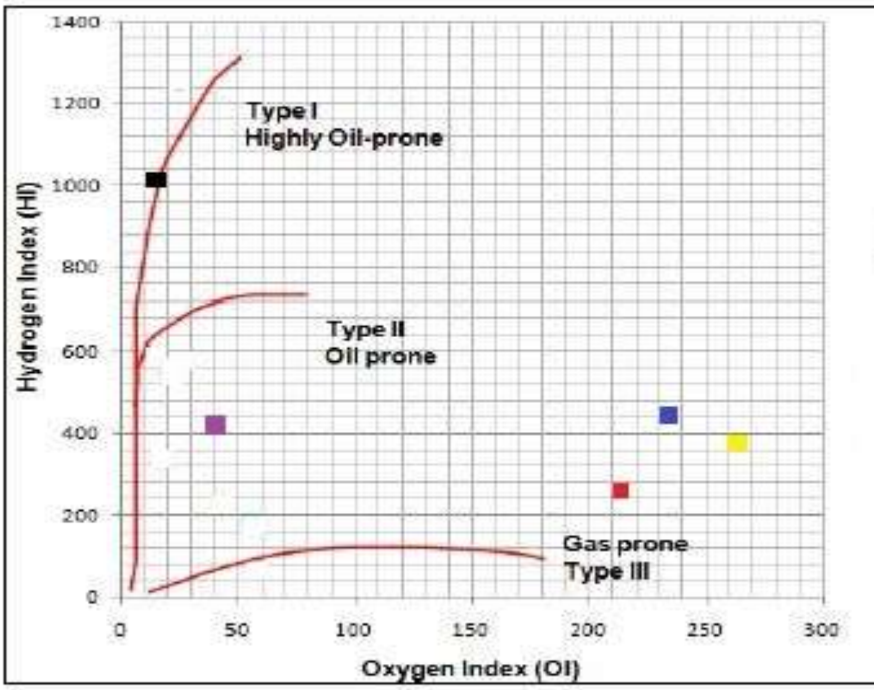

Fig 4: Plot of Hydrogen index against Oxygen index modified showing the organic matter types on modified from Van Krevelen diagram (after [2])

3.1.4 THERMAL MATURATION

Maturation is the process of chemical change in sedimentary organic matter, induced by burial, i.e. the action of increasing temperature and pressure over geological time[13]. The concentration and distribution of the Hydrocarbon contained in a particular source depends on both the type of the organic matter and its degree of thermal maturation. [15]proposed that source rocks with T_{max} values of less than 435°C are Immature, while those with T_{max} value of between 435 - 470°C are Mature and those above 470°C are post mature.
In this present study, the thermal maturity level of the samples has been determined by the study of the Rock-Eval temperature pyrolysis data "T_{max}". The T_{max} ranges from 328 to 423°C (358.6°C average). This suggests that the samples are immature source rocks.

3.2 PALYNOLOGY STUDIES

3.2.1 AGE DETERMINATION

The following stratigraphically important palynomorphs were recovered from the samples studied
1. *Retitricolpites sp.* (Upper Campanian- Early Maastrichtian)
2. *Laevigatosporites sp.* (Early Maastrichtian)
3. *Spinizonocolpites echinatus* (Maastrichtian)[3]
4. *Psilatricolporites* sp. (Early Maastrichtian)
5. *Proxapertites operculatus* (Maastrichtian)[3]
6. *Proxapertites cursus* (Maastrichtian)

Other stratigraphically important ones that are long ranging in this study include
7. *Echitriporites trianguliformis* (Campanian- Maastrichtian)[3]

8. *Longapertites marginatus* (Campanian- Maastrichtian)[3]
9. *Cingulatisporites ornatus* (Campanian- Maastrichtian)[1]
10. *Monocolpopollenites* sp. (Maastrichtian)[1]

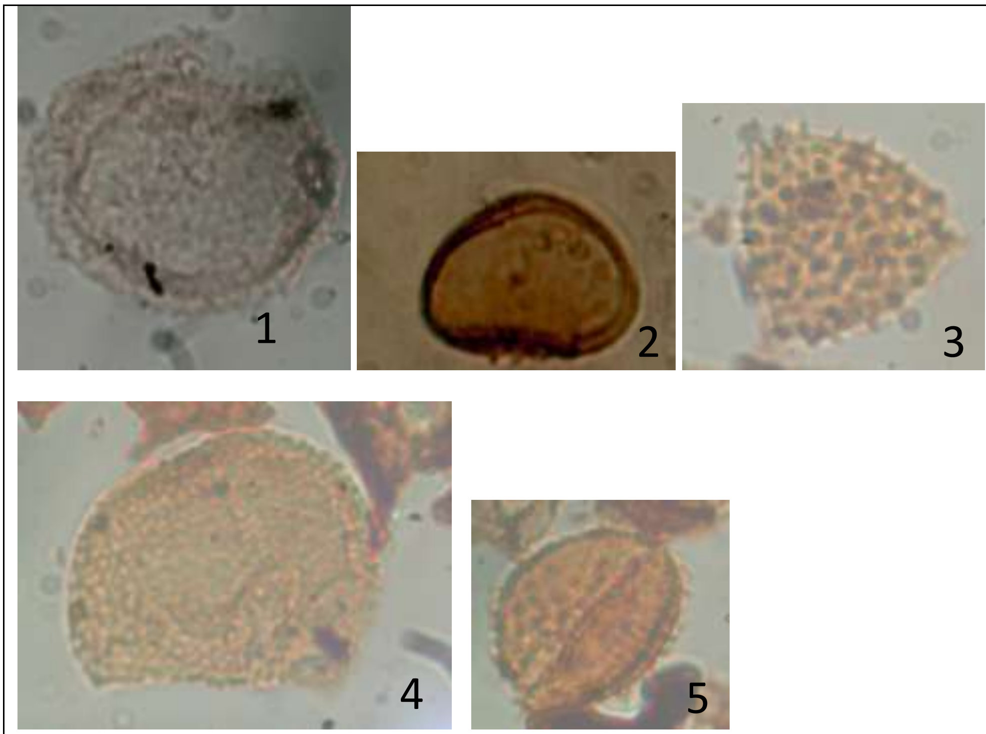

Fig. 5: Some of the Marker Palynomorphs found in the samples

1. *Constructipollenites ineffectus*
2. *Laevigatosporites sp*
3. *Echitriporites trianguliformis*
4. *Proxapertites cursus*
5. *Spinizonocolpites echinatus*

The age of samples was determined based on the polynomophs listed and proposed Maastrichtian age. The forms here correspond with the P100 zone that indicates an age range of Maastrichtian to Early Paleocene [8]

3.2.2 PALEOENVIRONMENT INTERPRETATION

The scarcity of dinoflagellate cysts and microforaminifera wall lining coupled with the presence of pteridophyte and brackish water spores (Verrucatosporites sp, Laevigatosporites sp, Acrostichum aureum) and predominance of continental pollens such as Psilatricolporites sp, Monoporites annulatus , Erecipites sp, Echitricolporites triangulates, Longerapertites marginatus, Psilatricolporites sp, Monocolpopollenites sphaeroidites, Retitricolporites sp, Syndemicolpites typicus, Proxapertites operculatus, Perfotricolpites digitatus in Sample 1, 2 and 5 indicate a Continental environment.

The presence of Deflandrea sp and Diatom frustule in Sample 3 and the predominance of dinoflagellate cysts such as Andalusiella Polymorpha, Andalusiella sp, Paleocystodinium gwolzoensis, Impagidinium dispertitum, Lingulodinium machaerophorum in Sample 4 indicate a nearshore environment and marine environment.

It can then be said that the environment of deposition of the Mamu Formation at Imiegba is that of progradation with occasional transgressive phases giving rise to the observed parallic sequences which matches works done by previous researchers of the Mamu Formation. This result here matches that of the plot of T.S against TOC which indicates a Normal Marine environment to Terrestrial (Continental) environment.

IV. CONCLUSION

Organic geochemical assessment and palynological analysis of the studied samples indicates that the samples have good generative potential and are capable of generating hydrocarbons. Paleodeopositional and hydrocarbon origin studies show that the organic matter present was deposited in a terrestrial environment to normal marine environment, they are petroleum source rocks and characterized by autochthonous hydrocarbons. Type of kerogen evaluation shows that they are predominantly of Type III/II Kerogen, as such are capable of generating gas and wet gas. Maturity studies on the kerogen presents their status as immature. Thus, the samples are good potential source rocks. A Maastrichtian age has been assigned to the samples and the exposure as a whole due to the presence of certain diagnostic palynomorph forms present in the samples.

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