Palynofacies And Kerogen Analysis Of Upper Cretaceous (Early Campanian To Maatrichtian) Enugu Shale And Mamu Formation In Anambra Basin, South-Eastern, Nigeria

Chiaghanam, O.I., Chiadikobi, K.C., Ikegwuonu, O.N., Omoboriowo, A.O., Onyemesili, O.C., Acra E.J.

ABSTRACT: The palynofacies and kerogen analysis of the Upper Cretaceous units (Campanian-Maastrichtian) of the Anambra Basin, Southeastern Nigeria was carried out in the studied area. Two major palynofacies types were identified based on the abundance of particulate organic matter. The palynofacies "A" is characterized by abundant phytoclasts, frequent opaqes common amorphous organic matter and carbon to rare palynomorphs, while palynofacies "B" is characterized by abundant opaque debris, frequent phytoclast common terrestrial palynomorphs and rare amorphous organic matter. The pollen colour ranged from pale yellow in palynofacies "B" to yellowish / yellowish brown in palynofacies "A", these corresponds to TAI of 1+ to 2-/2 and vitrinite reflection (Ro %) of 0.2 to 0.3/0.5 for both palynofacies. The studied sediments are made up of particulate organic matter that is immature but has the potential to generate gas.

Key words: Palynofacies, Kerogen, Campanian-Maastrichtian, Phytoclast, Vitrinite, Cretaceous and Anambra Basin

1. INTRODUCTION

The Anambra basin (fig1) which is a Cretaceous Basin is located in the Southern part of the regionally extensive northeast- southwest trending Benue Trough. It is a synclinal structure consisting of more than 5,000 thick of Upper Cretaceous to Recent sediments, representing the third phase of marine sedimentation in the Benue Trough [3],[10],[13]. The Basin evolved consequently to the late Jurassic to Cretaceous Basement fragmentation, block faulting, subsidence, rifting and drifting apart of the South American and African plates and therefore representing part of the West African rift systems [7],[8],[13].

- *Chiaghanam, O.I. is a Ph.D holder in Stratigraphy/Sedimentary Geology in Nnamdi Azikiwe University, Nigeria. He is a Senior Lecturer in Anambra State University, Uli, Anambra State, Nigeria. Email: oichiaghanam@yahoo.com*
- *Chiadikobi, K.C. is currently pursuing doctoral degree in Structural Geology in the Federal University of Technology, Akure, Nigeria. He is a Lecturer in Anambra State University, Uli, Anambra State, Nigeria. Email: kinsomino@yahoo.com*
- *Ikegwuonu O.N. is currently pursuing masters degree in Paleontology in the University of Nigeria Nsukka, Nigeria. Email: okeynick2010@yahoo.com*
- *Omoboriowo, A.O. is currently pursuing doctoral degree in Biostratigraphy in the University of Port Harcourt, Port Harcourt, Nigeria. Email: adeboriowo@yahoo.com*
- *Onyemesili, O.C. is currently pursuing doctoral degree in Petroleum Geochemistry in Anambra State University, Uli, Anambra State, Nigeria. She is a Lecturer in Anambra State University, Uli, Anambra State, Nigeria.*
- *Acra, E.J. is currently pursuing doctoral degree in Petroleum Geology in University of Port Harcourt, Port Harcourt, Nigeria. He is a Lecturer in Niger Delta University, Yenogoa, Bayelsa State, Nigeria.*

Stratigraphic history of Anambra basin shows that the basin comprises of the Campanian to Maastrichtian Enugu/Npkoro/Owelli Formation. This is succeded by the Maastrichtian Mamu and Ajali Formations. The sequence is capped by the tertiary Nsukka Formation and Imo Shale (table 1). [1],[13],[15],[16]. The petroleum geology, biostratigraphy and peleoenvironmental description of Anambra basin have been carried out by many Authors. [2] shows that the Awgu and Npkoro Shales constitute the main source and seal rocks in the Anambra Basin. [6] described the Nkporo Shale as an example of a marine source rock composed of type II/III kerogens with low but consistent contribution from marine organic matter. [20] reported that the organic facies of the Npkoro Shale are provincial with the Calabar Flank having the highest oil potential while those in the Anambra basin and Afikpo syncline are gas prone. [4],[5] use the application of Sequence stratigraphy, palynological analysis and Lithofacies to describe the hydrocarbon potential of Campanian- Maastrichtian in the Anambra Basin. [12] also describe the hydrocarbon potential of the Nkporo Group (Campanian- Maastrichtian) in Anambra Basin.

This paper attempts to:

1) Describe the surface lithologic sections of Mamu and Enugu Formations.
2) Determine the quality of Shales in relation to it Kerogen quality/maturity.
3) Model for basin wide prediction of source rock.

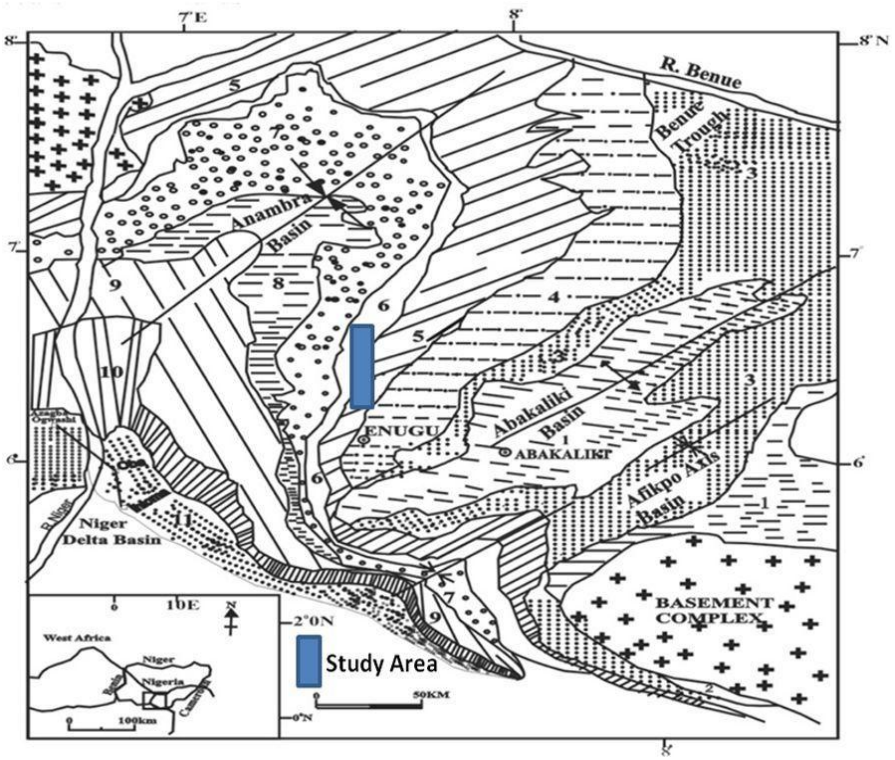

Fig. 1. Geologic Map of Anambra Basin and Afikpo Basin South-Eastern Nigeria showing the study area: 1. Asu River Group; 2. Odukpani Formation; 3. Ezeaku Shale; 4. Awgu Shale; 5. Enugu/Nkporo Shale; 6. Mamu Formation; 7. Ajali Sandstone; 8. Nsukka Formation; 9. Imo Shale; 10. Ameki Formation; 11. Ogwashi Asaba Formation.

Table 1: Lithostratigraphic framework for the Early Cretaceous- Tertiary period in southeastern Nigeria [11].

<table>
<tr><td colspan="2">AGE (M. Y)</td><td>ABAKALIKI – ANAMBRA BASIN</td><td>AFIKPO BASIN</td></tr>
<tr><td>30</td><td>Oligocene</td><td>Ogwashi – Asaba Formation</td><td>Ogwashi – Asaba Formation</td></tr>
<tr><td>54.9</td><td>Eocene</td><td>Ameki/Nanka Formation /Nsugbe Sst.</td><td>Ameki Formation</td></tr>
<tr><td>65</td><td>Paleocene</td><td>Imo Formation
Nsukka Formation</td><td>Imo Formation
Nsukka Formation</td></tr>
<tr><td>73</td><td>Maastrichtian</td><td rowspan="3">Ajali Formation
Mamu Formation
Nkporo/Owelli Sandstone /Enugu Shale
(Incuding Lokoja Sandstone and Lafia Sandstone)</td><td>Ajali Formation
Mamu Formation
Nkporo shale/Afikpo Sandstone</td></tr>
<tr><td rowspan="2">83</td><td>Campanian</td></tr>
<tr><td>Santonian</td><td>Non deposition/Erosion</td></tr>
<tr><td>87.5</td><td>Conacian</td><td rowspan="2">Agbani Sandstone/ Awgu Shale</td><td rowspan="2">Ezeaku Group
(including Amasiri Sandstone)</td></tr>
<tr><td>88.5</td><td>Turonian</td></tr>
<tr><td>93</td><td rowspan="2">Cenomanian
-
Albian</td><td rowspan="2">Eze Aku Group</td><td rowspan="2"></td></tr>
<tr><td>100</td><td>Asu River Group</td><td>Asu River Group</td></tr>
<tr><td>119</td><td>Aptian
Barremian
Hauterivian</td><td colspan="2">Un-named units</td></tr>
<tr><td colspan="2">Precambrian</td><td colspan="2">Basement Complex</td></tr>
</table>

2. METHODOLOGY

20 kerogen slides were prepared from samples belonging to the Early Campanian to Maastrichtian beds of Enugu Shale (Ozalla) (6 slides) and Agbogugu, Nkporo Formation (13 slides), and (1 slide) from Udi, Mamu Formation. Each slide was examined using the transmitted light microscopy at x10, 20, and x40 magnifications in order to carry out a qualitative as well as quantitative analysis of the particulate organic matter (POM), determination of the palynofacies and kerogen types, examine exine spores /pollen colouration and assessment of Thermal Alteration Index (TAI), vitrinite reflectance (Ro %) and organic thermal maturation. Each slide was counted for its (POM) content, in which the first 200 particles were counted. The percentage frequency is shown as: *abundant* (>35 %), *frequent* (16-35 %), *common* (5-15 %) and *rare* (<5 %) [9], [21].

3. RESULTS

Table 2 show the semi-quantitative distribution of the various (POM) recorded from the studied sections of the Enugu shale and Mamu Formations. Representatives of the studied (POM) are photographed and illustrated in figure 2.

Palynofacies and kerogen types:

The studied sections from the Enugu Shale and Mamu Formations at Ozalla (OZ/L5/01 to OZ/L5/06), Agbogugu (AG/L6/01 to AG/L7/05), and Udi (UD/L4/03) respectively, can be classified into two major palynofacies types on the basis of the abundance (POM) groups .They include from oldest to youngest as follow:

I - Palynofacies A (phytoclast and opaque facies)

This facies is the oldest one ranging from sample no. OZ/L5/04 at the base of the section in Ozalla to AG/L7/04 in Agbogugu town, and belongs to the Enugu Shale **(Fig. 2).** It is characterized by abundant phytoclasts, frequent opaques, common amorphous organic matter (AOM) and common to rare palynomorphs (Table 2). The phytoclasts consist mostly of moderately to well preserve structured terrestrial plant fragments with yellowish brown colour (e.g., tracheids, xylem tissues and cuticles). Tracheids are the most common structured phytoclast constituents usually in the form of elongate lath-shaped particles [18],[21].

Kerogen type 111: Based on the presence of high abundant of yellow to yellowish brown phytoclasts and frequent opaques, a gas-prone material is suggested for this facies.

II – Palynofacies B (Opaques and phytoclasts)

This facies is associated with samples AG/L7/05 and UD/L4/03, Agbogugu coal and Udi shale respectively, belonging to the Mamu Formation (Fig.2). It is characterized by abundant opaque debris, frequent phytoclasts, common terrestrial palynomorphs and rare amorphous organic matter (AOM). The opaques are mainly dark brown to black in colour, consisting of well preserved equant to lath-shaped fragments of varying size and form. [18] noted that such equant particles may break up into lath-shaped ones by splitting along the grain. The phytoclasts are generally pale yellow coloured. The AOM are rare to absence.

Kerogen type: 111, gas – prone material also is suggested for this facies on the basis of large amount of dark brown to black opaque debris and frequent pale yellow phytoclasts.

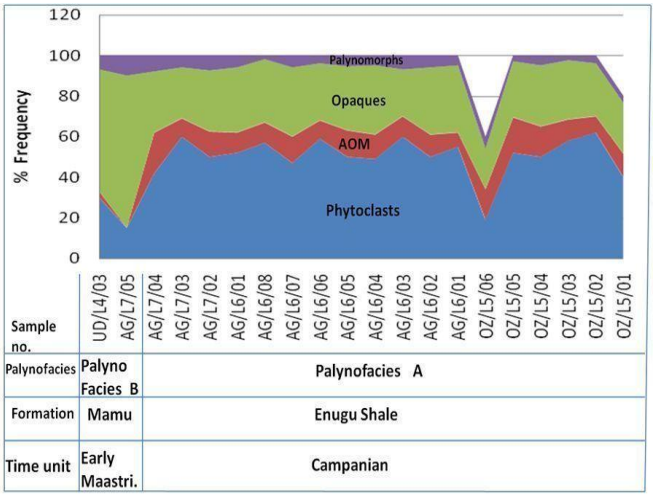

Fig. 2: Percentages of (POM) groups within the defined palynofacies of the Nkporo and Mamu Formations.

Table 2: Semi-quantitative distribution of the various (POM) recorded from the Enugu Shale and Mamu Formation in terms of abundant (A), frequent (F), common (C) and rare (R).

Sample no.	Phyto clasts	AOM	Opaq ues	Palyno morphs
UD/L4/03	F	R	A	C
AG/L7/05	F	R	A	C
AG/L7/04	A	F	F	C
AG/L7/03	A	C	F	C
AG/L7/02	A	C	F	C
AG/L7/01	A	C	F	C
AG/L6/08	A	C	F	R
AG/L6/07	A	C	F	C
AG/L6/06	A	C	F	R
AG/L6/05	A	C	F	C
AG/L6/04	A	C	F	C
AG/L6/03	A	C	F	C
AG/L6/02	A	C	F	C
AG/L6/01	A	C	F	C
OZ/L5/06	F	C	F	C
OZ/L5/05	A	F	F	R
OZ/L5/04	A	C	F	C
OZ/L5/03	A	C	F	R
OZ/L5/02	A	C	F	R
OZ/L5/01	A	C	F	R

4. INTERPRETATION AND DISSCUSION

The different kerogen components and its distribution throughout the studied sequence starting from the oldest to youngest show a clear change in organic facies from normal terrestrially influenced organic facies down the sequence to a high terrestrially dominant facies towards the top (Fig. 3). However, the studied section was subdivided and grouped into two palynofacies units based on this change in organic facies constituents mentioned above. Palynofacies A constitutes the lower to middle parts of the section (from sample no. OZ/L5/01 at the base to AG/L7/04) and is mainly composed of both structured and unstructured phytoclasts, frequent opaques and common (AOM).Marine and terrestrially derived palynomorphs were also observed and recorded for this facies. Palynofacies B characterizes the upper part of the sequence (from sample no. AG/L7/05 to AG/L4/03) and predominantly consists of opaque debris reaching up to 70 % in coal and with few amounts of pale yellow phytoclasts. Terrestrial palynomorphs were also encountered but no marine palynomorph was observed. Based on the kerogen quanlity and quantity mentioned above, one source rock zone was identified from phytoclast and opaque dominant to mostly opaque dominant facies. Following the kerogen classification scheme of [18], a type 3 kerogen (gas-prone material) was interpreted for both palynofacies A and B (Fig. 3). The exine colours of the encountered angiospermic pollen grains belonging to the tricolporate group of origin were critically examined to determine the organic thermal maturity of the identified palynozones as well as their associated sediments. [14] spore/pollen colour standard calibration together with other thermal maturity parameters as documented by [17] was employed to theoretically estimate the vitrinite reflectance (Ro%) and thermal alteration index (TAI) values (Fig. 3). The pollen colour observed generally ranged from pale yellow in palynofacies B to yellow / yellowish brown in palynofacies A. These, therefore, correspond to TAI of 1+ to 2- / 2 and vitrinite reflectance (Ro %) of 0.2 to 0.3 / 0.5 for both palynofacies B and A respectively. Finally, the studied sediments, therefore, contain particulate organic matter (POM) that is still immature to generate hydrocarbon but have the potential capacity to generate gas.

5. CONCLUSION

The investigated section has shown that the sediments (shale) of the Upper Cretatceous, Campanian-Maastrichtian, Enugu Shale and Mamu Formation in the Anambra Basin, SE, Nigeria has polen colours that ranged from yellow to yellowish brown which also coresponds to the thermal alteration index of 1 + to 2 -12, with vitrite refletance of (Ro %) of 0.2 to 0.3/0.5 for the palynofacies B and A. The kerogen quality as identified from the phytoclast and /opaque dominant to mostly opaque dominant facies indicate that the study studied area is of type III, meaning that they are gas prone. Based on the particulate organic matter, the thermal maturation of the studied sediments is still immature to generate hydrocarbon but has the potential of generating gas. The works shows that studied section of the Anambra basin should be considered to be gas prone zone which correspounds to the type III kerogen.

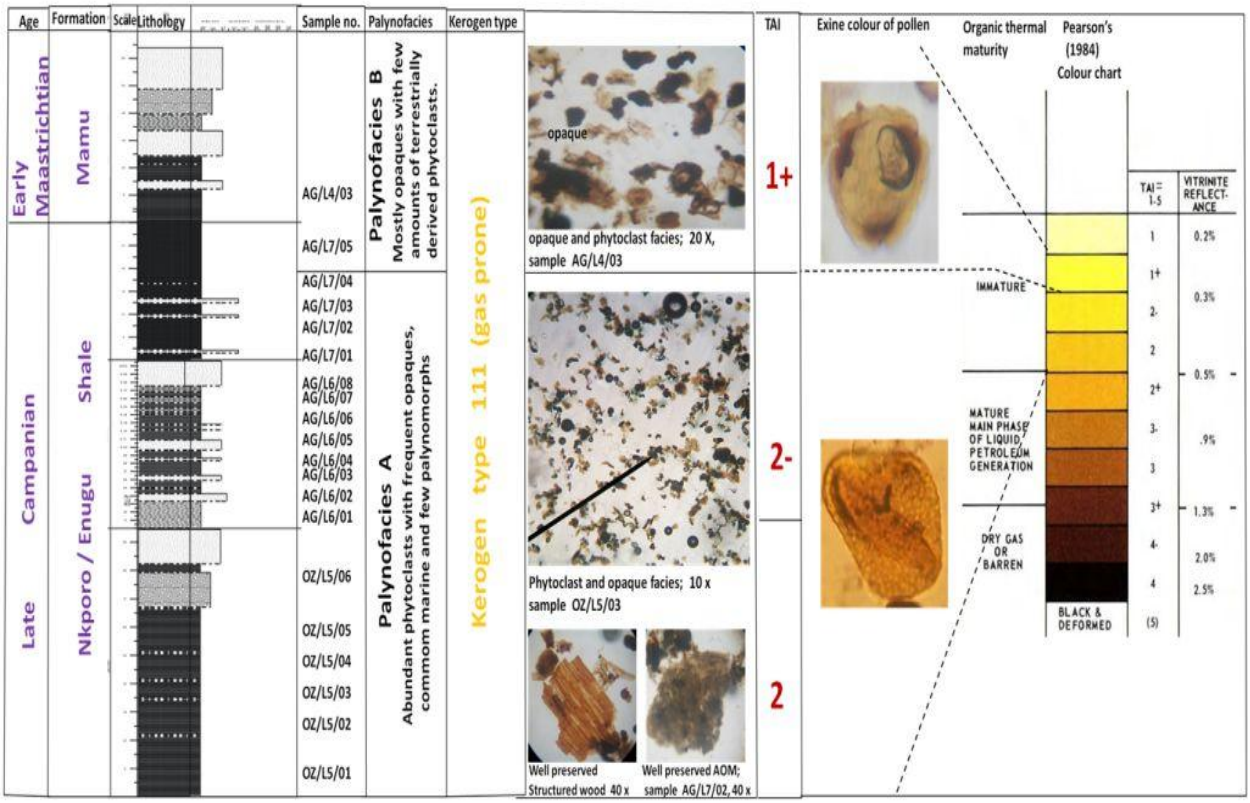

Figure 3: Composite chart of the studied sequence showing sample positions, lithologic types, palynofacies associations and kerogen types, and organic thermal maturity.

REFERENCES

[1]. O.K. Agagu, E.A. Fayose, and S.W. Petters, 1985. Stratigraphy and Sedimentation in the Senonian Anambra Basin of SE Nigeria. Journal of mining and Geology 22:25-35

[2]. O.K. Agagu and C.M. Ekweozor 1982. Source Rock characteristics of Senonian Shales in the Anambra Syncline, Southern Nigeria. Journal of Mining and Geology 19:52-61

[3]. S.O. Akande, and B.D. Erdtman 1998. Burial Metamorphism (thermal maturation) in Cretaceous sediments of the Southern Benue Trough and Anambra Basin, American Association of Petroleum Geologist Bulletin 82: 1191-1206.

[4]. O.I. Chiaghanam, O.N. Ikegwuonu, K.C. Chiadikobi, K.K. Nwozor, A.E. Ofoma and A.O. Omoboriowo, 2012. Sequence Stratigraphy and Palynological Analysis of late Campanian to Maastrichtian Sediments in the Upper-Cretaceous, Anambra Basin. A Case Study of Okigwe and its Environs, South-Eastern, Nigeria. Advances in Applied Science Research, 2012, 3 (2): pp. 964

[5]. O.I. Chiaghanam, K.K. Nwozor, K.C. Chiadikobi, A.O. Omoboriowo, C.G. Soronnadi-Ononiwu, L.N. Onuba, and A.E. Ofoma, 2013. Lithofacies, Palynology and Paleoenvironmental Study of Early Campanian to Mid-Maastrichtian deposits of Udi and Environs in the Anambra Basin, South Eastern, Nigeria. International Jornal of Science and Technology, Vol. 2, No. 6, pp. 453-470.

[6]. C.M. Ekweozor, and J.R. Gormy, 1983. Petroleum Geochemistry of the Early Tertiary Shales Penetrated by the Akwakwa -2 well in the Anambra Basin Southern Nigeria". Journal of Petroleum Geology 6:207-216.

[7]. J.D. Fairhead and C.S. Okereke, 1987. A regional gravity study of the west African rift system in Nigeria and Cameroon and its tectonic interpretation tectonoptsisc 4:141-143

[8]. G.J. Genik 1992. Regional framework structural and petroleum prospect of rift basin in Nigeria tectonophysics 213: 169-185.

[9]. M. I. A. Ibrahim, N.M. Abul Ela and S.E. Kholeif, 1997. Paleoecology, palynofacies, thermal maturation and hydrocarbon source-rock potential of the Jurassic-Lower Cretaceous sequence in the subsurface of the north Eastern Desert, Egypt. Qatar Univ., Sci. J., v. 17 (1), p. 153-172.

[10]. K.O. Ladipo, 1988. Paleogeography, sedimentation and Tectonics of the Upper Cretaceous Anambra Basin Southeastern Nigeria Journal of Africans Earth sciencies 7: 815-821.

[11]. C.S. Nwajide, 2005. Anambra Basin of Nigeria: Synoptic Basin Analysis as a Basis for Evaluation its Hydrocarbon Prospectivity, In Okogbue, C.O., (Ed.), Hydrocarbon potentials of the Anambra Basin, PTDF Chair, pp: 2-46.

[12]. S.O. Odunze and G.C. Obi, 2013. Sedimentology and Sequence Stratigraphy of the Nkporo Group (Campanian to Maastrichtian) Anambra Basin, Nigeria. Journal of Paleogeography, Vol. 2, No.2, pp. 192-208

[13]. O.J. Ojo, O.A. Kolawole and S.O. Akande, 2009. Depositional Environments, organic pictures and petroleum generating potential of the Campanian to Maastrichtian Enugu Formation, Anambra basin Nigeria. The pacific journal of science and technology vol. number 1 614-628.

[14]. D.L. Pearson, 1984. Pollen/Spore Color "Standard", Version 2. Phillips Petroleum Company privately distributed.

[15]. S.W. Petters, 1978. Stratigraphic Evolution of the Benue Trough and its implications for the Upper Cretaceous Paleogeography of West Africa. Journal of Geology. 86:311-322.

[16]. J.J.A. Reijers 1996. Sedimentary geology and Sequence Stratigraphy in Nigeria and three case studies and a field guide: selected chapters In geology: Shell Petroleum Development of Nigeria corporate reprographics servile Warri 197.

[17]. A. Traverse, 2007. Paleopalynology, 2nd ed.: Springer, Dordrect, The Netherlands, 813 p.

[18]. R. V. Tyson, (1993). Palynofacies analysis. Applied Micropalaeontology, Kluwer Academic Publishers, p. 153-191.

[19]. R. V. Tyson, (1995). Sedimentary Organic Matter. Organic facies and palynofacies, Chapman and Hall, London, p.615.

[20]. G.I. Unomah, and C.M. Ekweozor, 1993. Petroleum Source Rock Assesment of the Campanian Nkporo Shale Lower Benue Trough Nigeria. "Nigeria Association of Petroleum Explorationists Bulletin 8:172-186

[21]. M.K. Zobaa, M.S. Zavada and M.J. Whitelaw, 2007. Palynofacies analysis, source rock evaluation and organic thermal maturation of the Gray Fossil Site, Gray, Tennessee. In: Eastern Section, AAPG 36th Annual Meeting, Abstract, Lexington, Kentucky, USA, pp. 60.