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By

Ola-Buraimo A.O., Adebayo, O.F. and Umaru S.

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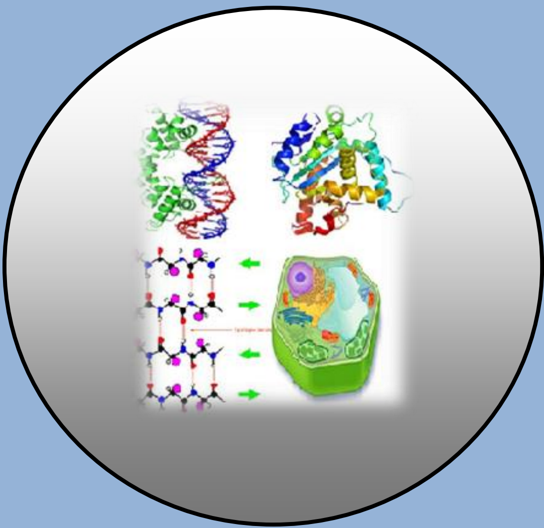

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A.O. Ola-Buraimo
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jbiolchemres@gmail.com
info@jbcr.in

RESEARCH PAPER

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Ola-Buraimo A.O., *Adebayo, O.F. and **Umaru S.
Palystrat Limited, Ibadan, Nigeria
*Department of Geology, Ekiti State Unuversity, Ado-Ekiti, Nigeria
**Al-Hikmah University, Ilorin, Nigeria

ABSTRACT

Palynological analysis was carried out in order to determine the organic richness, kerogen type, and thermal maturity of the recovered macerals. Laboratory analysis for the pollen and spore follows standard procedure but the kerogen was not oxidized in order to preserve the original colour of the maceral. One lithofacies unit of light to dark grey fissile shale, deposited in marginal marine environment is present for the entire section.

The organic matter content is generally fair in frequency within a range of 14 – 69; the kerogen type is mainly Type 2, while interval 1265 – 1270 is Type 3. The thermal maturity indicates that most of the kerogen is dominated by Brown Kerogen and is interpreted to be within katagenesis zone (oil window). The interval that is incapable of generating oil is internal 905-975m characterized by lean kerogen and corresponds to upper part of Fika Shale. The interval 1365-1360m has more than minimum organic content but is thermally immature. However, the interval 1010-1330m within the Gongila and Fika formations is organically rich, dominated by Type 2 kerogen and is within Katagenesis zone (oil window); thus capable of generating oil and gas except interval 1265-1270m that is of kerogen Type 3 and only capable of generating gas.

Keywords: Maturity, Kerogen, maceral, Brown kerogen, Katagenesis, Kerogen Type and Oil window.

INTRODUCTION

The use of palynology in unraveling geological problems has been intensified and has yielded good results in recent times. However, apart from routine use in determining the biozones and relative geological ages, and paleo environment of deposition for correlation purposes, this study is geared toward using this method to further determine the organic matter content, kerogen type and its thermal maturity. Microscopic analysis of dispersed organic matter in determining kerogen and type of kerogen is uncommon in palynological research nowadays; though it is usually carried out by specialist such as palynologist. Secondly, the use of rock eval pyrolysis has reduced its importance but in terms of cost effectiveness, it is highly recommended to act as sieves in selecting final samples for pyrolysis analysis. The stage of maturity of the kerogen can be determined by the amount of discoloration of the organic matter. Robertson Research Group used spore coloring index (S.C.I) of a 10 point scale while Staplin, (1969) (Thermal Alteration Index; T.A.I.) is on 5 point scale. The two methods have merits and demerits while the latter is used more commonly within the oil industry.

The cost of the analysis and time required to complete the analyses are fundamental factors that put microscopic kerogen analysis in vantage position over the geochemical analysis. Therefore, the use of palynological analysis in determining hydrocarbon potential of a source rock assists in petroleum exploration whereby it helps to eliminate those parts of the geological section having little or no petroleum generating potential so that the more sophisticated analysis can be concentrated on the favorable parts at cheaper rates. This investigation is based on the fact that macerals tend to change in color during burial as a result of gradual increase in temperature due to thermal gradient.

Geologic Setting and Stratigraphy

The studied well is Kemar-1 well located in Bornu Basin; situated in the northeastern part of Nigeria (Fig.1). The basin has continued to attract the attention of many geologist partly because of the likely accumulation of hydrocarbon and for further understanding of its lithostratigraphy architecture and subsurface geology Among the earlier workers in the basin are Falconer, (1911), Carter et al, (1963), Barber (1965) and Reyment, (1968). The evolution of the Bornu basin is controversial; a school of thought believes that the origin of the basin is predicated on the theory of the third failed arm of the triple junction formed during the Albian period led to the opening of the south Atlantic Ocean (Wright, 1968; Burke et al, 1970), while others are in support of the plate tectonic theory (Genik, 1933; Kings, 1950 and Avbovbo et al, 1980).

The stratigraphy of the Bornu Basin have been extensively studied; these include the works of Adegoke et al, (1973), Petters, (1978b), Kogbe, (1979), Petters, (1981) and Avbovbo et al, (1986). Some of the works carried out on the biostratigraphy of the basin include those of Barber and Jones, (1960), Carter et al, (1963), Reyment, (1965), Adegoke, (1978), Adegoke et al, (1978), Petter, (1978, 1981,1982), Odusina etal, (1983), Wonzy and Kogbe, (1983), Popoff et al, (1986), Oti, (1990), Okosun, (1995) and Olugbemiro, (1997).

Among the recent researchers on the basin are Ola-Buraimo (2005, 2009, and 2013), Boboye, (2007), Ola-Buraimo and Boboye, (2011). In terms of palynostratigraphic studies other well documented works are detail palynostratigraphy of Bornu basin based on research of Tuma-1 well (Ola-Buraimo, 2012); others are the works of Adegoke, (20120 and Boboye, (2012) and Ola-Buraimo, (2013). The Pre-Bima and Bima Formations were lithologically differentiated, palynologically dated Albian-Cenomanian and renamed as Bima Group (Ola-Buraimo and Oluwajana, 2012). On the other hand palynological study has been used extensively to date and reconstruct paleoenvironment of deposition of Gombe Formation in the Bornu Basin (Ayinla et al, 2013).

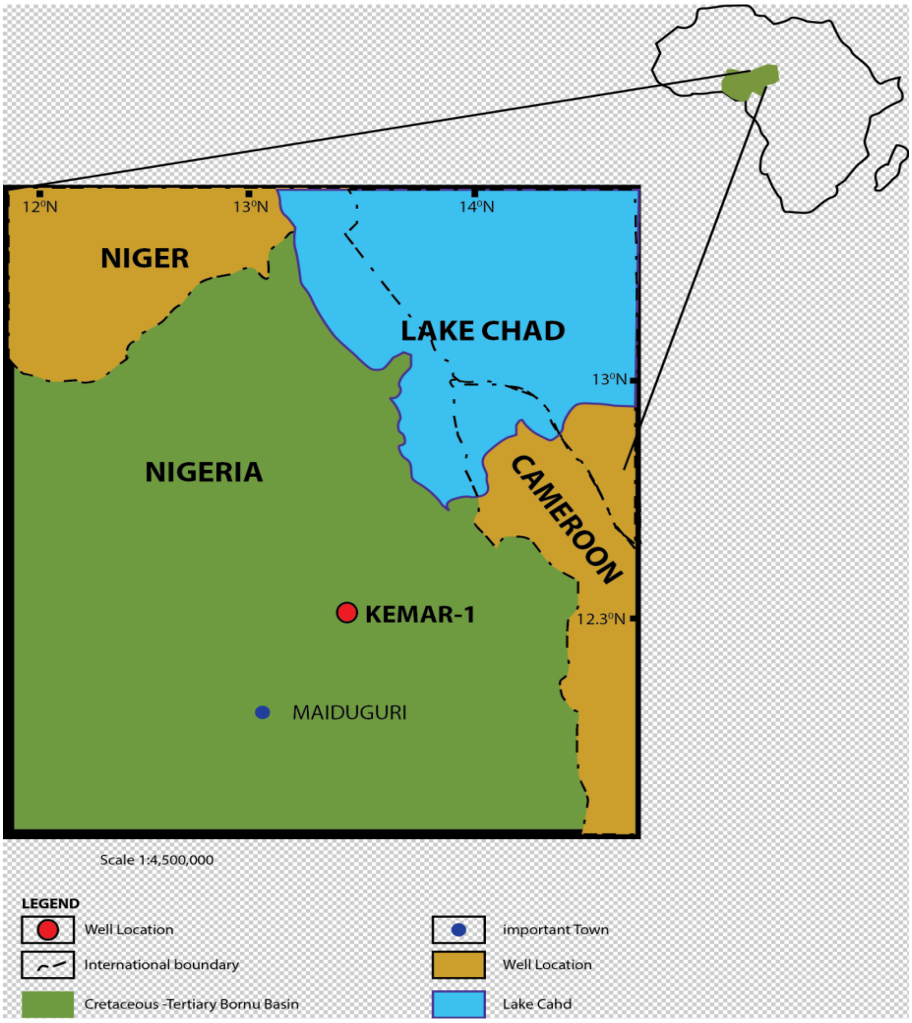

Figure 1. Location map of Kemar-1 (exploration well) in NE Bornu Basin (insert map shows position of Chad Basin in Nigeria and Africa respectively).

MATERIAL AND METHODS

The recovery of kerogen for this study involved the digestion of fifteen ditch cutting samples of 20gm each in weight in hydrofluoric acid and removal of it from the remaining rock residue by sieving, through floatation in Zinc bromide ($ZnBr_2$) and centrifuging. It is important to note that the digested rock is not oxidized or bleached in Nitric acid because this will alter the original or natural color of the kerogen that have undergone changes due to the increase in temperature with progressive burial and time. The method of preparation is similar to that used for the preparation of residues for palynology determinations except oxidation that does not take place in the kerogen preparation. This will yield sufficient kerogen for any or all of the analyses desired. The recovered kerogen was later mounted on glass slides for observation under the binocular microscope. Point counts of the pollen, spores, dinoflagellates and algae of different kerogen colors were noted for statistical purposes.

RESULTS AND DISCUSSION

Kerogen Analysis

Kerogen materials are derived from both animal and plants. There are various processes that take place once sediment is deposited such as diagenesis, fermentation, sapropelisation and other chemical processes known as polycondensation. These are followed by insolubilization which consists of intermediate substances of single stable substance known as KEROGEN. Therefore, Kerogen is a relatively inert substance that cannot be dissolved in acids/alkaline, also insoluble in water or simple organic solvents such as Chlorophorm or Benzene. It is also resistant to bacteria attack. However, such geochemical definition includes the palynological components such as pollen, spores, dinoflagelletes and similar substances.

Petrographic source rock analysis could serve as preliminary examination apart from the most useful log which is gamma ray-sonic log. The organic shales are often highly radioactive because the radioactive residuals usually (uranium salts) taken from solution are trapped in the organic matter. The organic matter in the rock decreases the velocity of sand waves passing through it and can be used as a check. However, other useful but definitive logs are the self potential log which shows high S.P, high resistivity, and low density. But these logs are less useful as several other rock types have the same characteristics. But when combined suites of logs are used based on the concept of sequence stratigraphy in the identification of prolific source rock, then, they become a reliable tool in identifying source beds. (Akinlabi and Ola-Buraimo, 2009).

Some rocks have been identified on logs in Niger Delta, Nigeria based on the identification of the maximum flooding surface (MFS), flooding surface (FS) and condensed sections (CS) which are the saltiest and organically–rich facies (Akinlabi and Ola-Buraimo, 2009). This is best achieved when there is relative increase in resistivity values associated with high gamma ray, combined with wide separation between the neutron and density log signatures compared with the underlying and overlying facies which could depict a source rock (Akinlabi and Ola-Buraimo, 2009).

The importance of preliminary geological screening using sample examination and logs cannot be over emphasized. Sample sets from wells are generally incomplete or biased in favour of reservoir formations, and chemical analysis of large suites of samples is time consuming, expensive and not always exclusive, especially for ditch cuttings (Meyer and Nederlof, 1984). Rich source beds with high potential are often less than 50ft and are likely to be missed if sampling is done on interval basis, therefore, adequate importance must be attached to the type of lithofacies that is being selected. Shale samples that are dark gray to black or dark brown in color, fissile and fossiliferous in nature are recommended.

However, preservation of organic matter in sediments is dependent on the inter-play of three (3) factors:

- Rate of supply of organic material
- Anaerobic environment of deposition
- Rate of burial

Organic Richness

The organic richness of the analyzed interval was determined based on the palynomorh abundance and diversity. In this study, the organic richness is categorized as follows:

- 0-20 Lean kerogen
- 20-40 Fair
- 40-80 Good
- > 80 Organically rich (or very rich)

Therefore, from the Table 1 and Figures 2 and 3 below the organic richness is interpreted to vary from lean to good. The intervals that are lean are 905-975m which is interpreted to be incapable of generating hydrocarbon when all other conditions required are favorable. While the intervals 1010-1095m, 1150-1185m, 1230-1270m, and 1325-1360m are categorized to be fair in organic richness, thus, are capable of generating oil or gas. However, intervals1120-1125m, 1205-1210m, and 1295-1300m are good in organic richness. The minimum threshold for organic generation is suggested to be 20 in terms of palynomorph abundance.

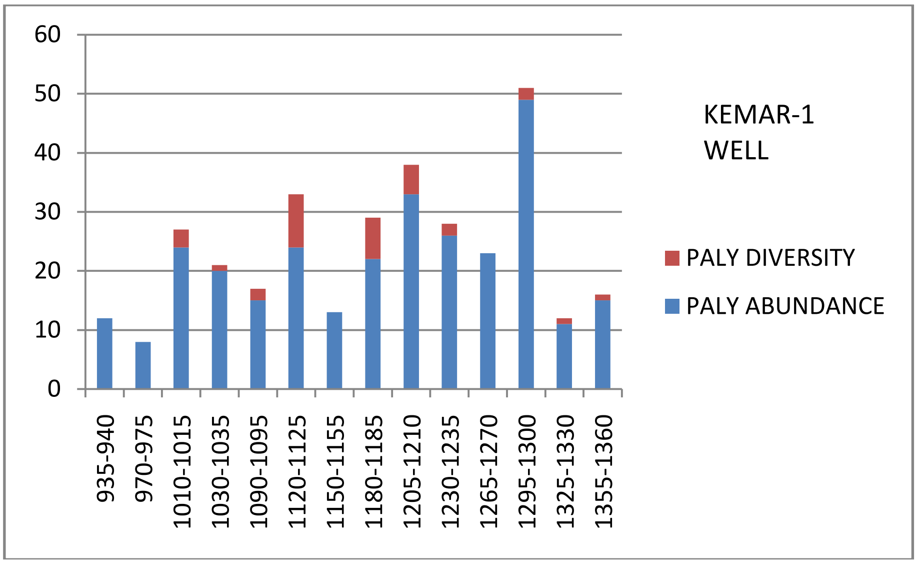

Figure 2.Histogram plot of Palynomorph Abundance and Diversity against Depth.

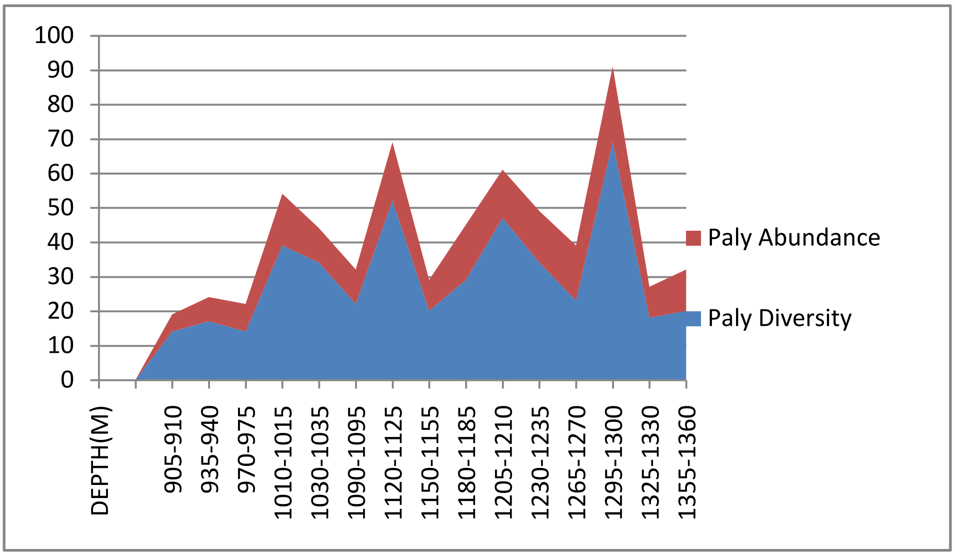

Figure 3. Palynomorph Abundance and Diversity Picks.

Table 1. Abundance and Diversity of Palynomorphs in analyzed Interval.

DEPTH(M)	ABUNDANCE	DIVERSITY
970-975	14	8
1010-1015	39	15
1030-1035	34	10
1090-1095	22	10
1120-1125	52	17
1150-1155	20	9
1180-1185	29	16
1205-1210	47	14
1230-1235	34	15
1265-1270	23	16
1295-1300	69	22
1325-1330	18	9
1355-1360	20	12

Correlation of the organic richness with the formations shows that the organically lean interval is equivalent to uppermost part of Fika Formation (905-1010m) while the organically rich intervals are equivalent to substantial part of the Fika Formation, Gongila (1180-1355m) and Upper Bima Formations (1355-1360m) in the Bornu Basin.

Table 2. Pollen, spores, dinoflagellates, and algae abundance.

DEPTH(M)	POLLEN AND SPORES	DINOFLAGELLATES	ALGAE	FORMATION
905-910	8	0	6	
935-940	12	0	5	
970-975	8	0	6	
1010-1015	24	3	12	Fika
1030-1035	20	1	13	
1090-1095	15	2	5	
1120-1125	24	9	19	
1150-1155	13	0	7	
1180-1185	22	7	0	
1205-1210	33	5	9	
1230-1235	26	2	6	
1265-1270	23	0	0	Gongila
1295-1300	49	2	18	
1325-1330	11	1	6	
1355-1360	15	1	4	Bima

TYPE OF KEROGEN

The type and amount of petroleum produced from a particular Kerogen depends on the Kerogen characteristics which in-turn depends on the organic source material and the diagenetic history of the Kerogen conserved.

A three-four (3-4) fold division of Kerogen types has been proposed by Tissot and Welte, (1978); Dow, (1977); Harwood, (1977). The classification is as follows:

TYPE I: Alginitic
TYPE II: Liptinitic-Exinitic
TYPE III: Vitrinitic-Huminitic
TYPE IV: Inertinitic

TYPE I: It is usually composed of algae and copepods.

TYPE II: Usually composed of pollen, spores, dinoflagellates and other micro organisms such as foraminifera.

TYPE III: Usually composed of leaves, back of woods and wax, usually amorphous components. Broadly, the land derived plants are referred to as humic (Tissot and Welte, 1978) while the marine-sourced kerogens are called kerogenous (Meyer and Nederlof, 1984).

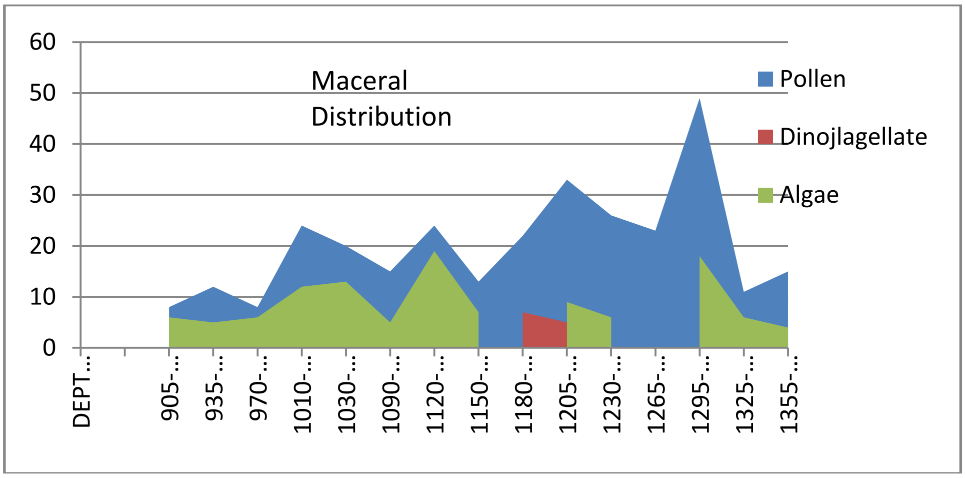

Figure 4. Maceral Distribution against Depth.

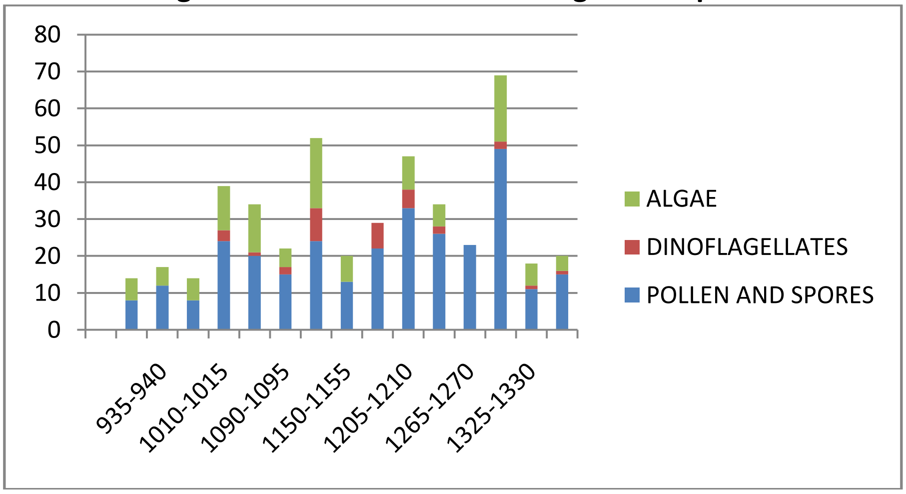

Figure 5. Plot of the abundance of pollen and spores, dinoflagellates and algae present in each sample in interval 905-1360m of Kemar-1 well. Bornu Basin, Nigeria.

The source of the kerogen can broadly be divided into three- land, lacustrine, and marine derived. The Table 2 above shows the list of palynomorphs that were derived from the analyzed samples covering the interval 905-1360m.

This was broadly classified into pollen, dinoflagellate and algae. The pollen are land derived, the dinoflagellates are marine sourced while the algae are lacustrine. Therefore, a plot in Figure 3 shows the abundance peak of the macerals against depth. However, Figures 4 and 5 show the macerals distribution against depth where interval 1130-1295m and 1150-1180 are dominated by pollen (land derived source) alone; intervals 905-1150m and 1295-1355m are dominated by pollen and algae (land and lacustrine), while interval 1180-1230 is dominated by pollen, algae and dinoflagellates (admixture of land, lacustrine and marine) sourced.

Table 3. Kerogen Precursors and kerogen Type in the analyzed intervals

DEPTH(M)	LAND SOURCED KEROGEN	MARINE SOURCED KEROGEN	KEROGEN TYPE 2	KEROGEN TYPE3
905-910	8	6	**2**	
935-940	12	5	**2**	
970-975	8	6	**2**	
1010-1015	24	15	**2**	
1030-1035	20	14	**2**	
1090-1095	15	7	**2**	
1120-1125	24	28	**2**	
1150-1155	13	7	**2**	
1180-1185	22	7	**2**	
1205-1210	33	14	**2**	
1230-1235	26	8	**2**	
1265-1270	23			3
1295-1300	49	20	**2**	
1325-1330	11	7	**2**	
1355-1360	15	5	**2**	

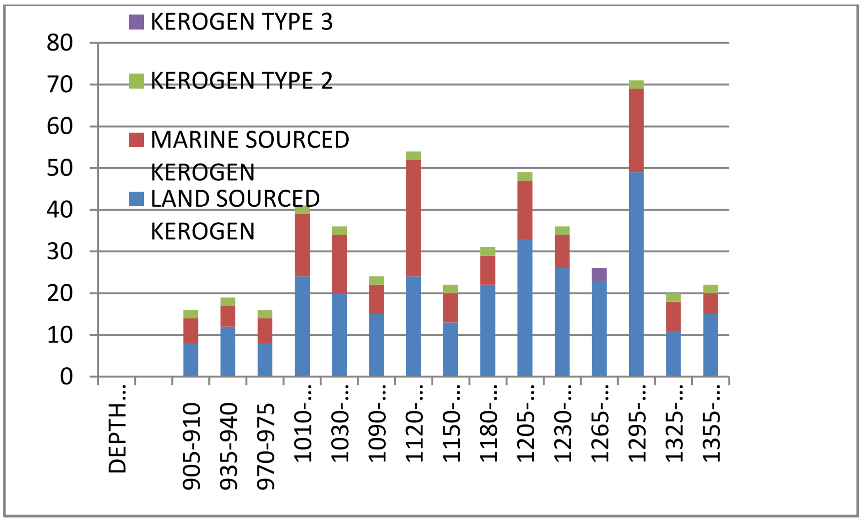

Figure 6. Depth against Land sourced, Marine sourced kerogens, and Kerogen Types.

In order to give a clearer picture of the kerogen type, a table is generated to illustrate the precursors of the macerals and their associated kerogen types as categorized in this study (Table 3). The Table 3 shows that almost all the intervals analyzed contain land and marine sourced macerals except interval 1265-1270m that is predominantly land sourced. Therefore, it is suggested that all the intervals analyzed belong to kerogen type 2 except interval 1265-1270m that is of Type 3 kerogen (See Figure 6).

The interval (1010-1065m) is organically rich as described in Table 3 and Figure 6 above. It is suggested and categorized as Type 2 kerogen. It is suggested that when the kerogen within the interval is subjected to adequate conditions of temperature and pressure, they are capable of generating oil and gas except interval 1265m which might be capable of generating gas only.

KEROGEN THERMAL MATURITY

Thermal maturity from microscopic analysis of macerals present was carried out on the samples analyzed from interval 905-1360m. The laboratory procedure follows international standard but without oxidation of the samples in order to prevent bleaching of the samples. Therefore, the palynomorphs under the microscope were associated with different colors that they had been subjected to at different temperatures due burial at various depths. The colors obtained vary from 'Yellow, through Yellow-Brown, Brown to Black'.

YELLOW → ORANGE → BROWN → BLACK

DIAGENESIS $\xrightarrow{\text{Early}}$ KATAGENESIS $\xrightarrow{\text{Late}}$ METAGENESIS

Several workers had noted the discoloration of organic matter thermal alteration with increasing temperature during progressive burial. The Thermal Alteration Index (T.A.I) scale was proposed by Staplin in (1969); based on the observation of macerals under the microscope by measuring the Thermal Alteration in the Kerogen Staplin, (1969) indicated that occurrence of oil is limited to stages 1-3, while, only dry gas is found in stage 4. Further studies show that stage1 (light Yellow color) is an immature stage of Kerogen evolution, while oil generation occurs only in stages 2 and 3 (Yellow-Brown; Brown).

The advantage of this research is that it provides a means whereby screen and microscopic analysis can be carried out on samples to indicate the possibility of an important source bed in which a chemical back up analysis such as pyrolysis may be carried out to confirm the type of Kerogen present.

Substantial intervals of the analyzed section are characterized by Brown Kerogen and few Yellow -Brown Kerogen (Table 4, and Figure 7). This suggests that the kerogen is at the point of oil generation and also within the oil window. However, despite the fact that the color suggests that they have been subjected to adequate temperature, those intervals that are lean in organic richness such as interval 905-975m are incapable of generating hydrocarbon. Notable also is interval 1355-1360m, though satisfies minimum organic richness required but cannot source hydrocarbon because it contains substantial amount of Yellow Kerogen, which suggests that the source rock is immature (Fig. 7).

The source beds within the Gongila Formation and the substantial part of the Fika Formation are within the Katagenesis zone and are capable of generating hydrocarbon. The kerogen typing for the intervals is Kerogen Type 2 belonging to katagenesis zone and capable of generating oil and gas. Interval 1265-1275m is characterized by Kerogen Type 3 and this is suggested to have capability of generating gas only (Fig. 7).

Table 4. Kerogen Color Distribution in Intervals analyzed.

	KEROGEN			
DEPTH(M)	YELLO	YELLOW-BROWN	BROWN	BLACK
905-910	0	0	14	0
935-940	0	0	17	0
970-975	1	2	11	0
1010-1015	2	4	39	2
1030-1035	1	0	34	0
1090-1095	0	0	22	0
1120-1125	0	0	52	0
1150-1155	0	0	20	0
1180-1185	0	1	29	0
1205-1210	0	0	47	0
1230-1235	0	2	34	0
1265-1270	0	0	23	0
1295-1300	0	3	69	0
1325-1330	1	1	18	0
1355-1360	11	0	20	0

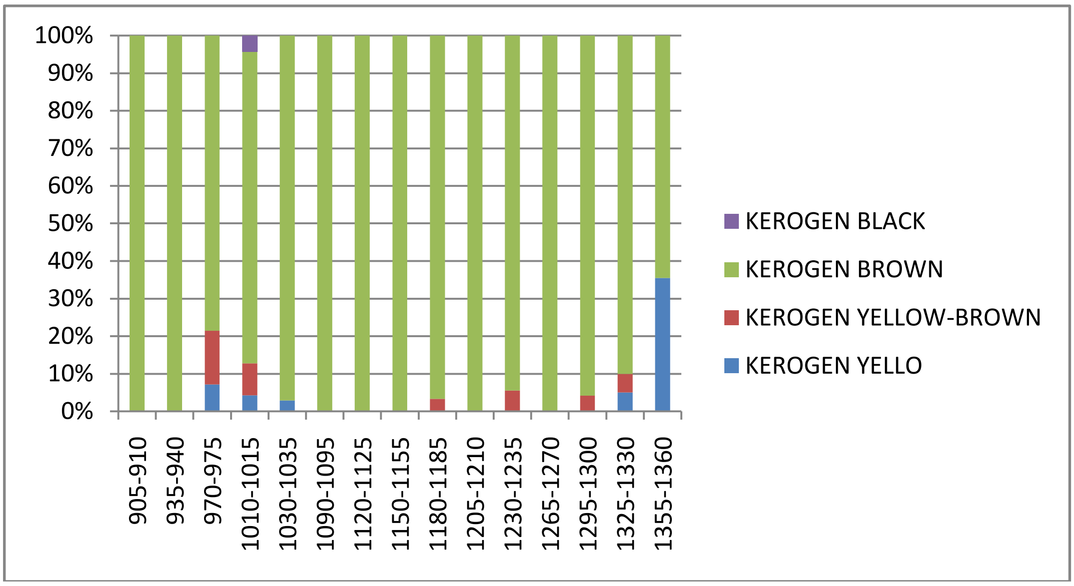

Figure 7. Percentage of Kerogen color distribution at different intervals analyzed.

CONCLUSION

Organic matter richness of the studied interval is fair except the uppermost part (905-975m) that is lean in organic content.

In terms of kerogen type, the analyzed section is generally of type 2, characterized by combination of land and marine derived macerals, while the interval 1265-1270 meters is dominated by land derived macerals only.
The thermal maturity measured in terms of kerogen color, shows that the source rock within the interval was subjected to enough temperature. They are within katagenesis zone characterized by Brown Kerogen. The major source rocks are within the Gongila and Fika Formation. However, the Bima Formation source rock is immature in nature because the kerogen color is Yellow and Yellow to Brown. In terms of hydrocarbon generation only source rocks within interval 1010-1355m are capable of generating oil and gas because they have enough organic content greater than 20, they are of Type 2 and type 3 kerogen and they are also within Katagenesis zone. However, interval 1265-1270m is only capable of generating gas because the macerals are land derived Type 3 kerogen. The interval 1360-1365 belonging to Bima Formation, though contain enough organic content but is thermally immature, therefore, it is incapable of generating hydrocarbon.
The results of this preliminary examination have indicated source beds, whereby such rocks can be sampled and can now further be subjected to screen geochemical analysis to confirm the source beds potentials. By so doing, the study would have reduced the cost of analysis and time wastage.

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REFERENCES

Adegoke, A.K. 2012. Biostratigraphy and depositional environment of the sediments in Bornu Basin, Northeastern Nigeria. Indian J. science technology, 2800-2809.

Adegoke, O.S., 1978. Stratigraphic study of the Bornu Basin. *Rec. Geol. Surv. Nigeria*. n. 14, p.7-20

Adegoke, O. S., Jan du Chene, R. E, Agumanu, E. A. and Ajayi, P. O., 1978 . Palynology and age of the Kerikeri Formation, Nigeria. *Nigeria Revista Espanola Micropal*. Vol. 10, n.2, 2.

Adeigbe, O.C., 2009. Geochemical characterization of the Upper Cretaceous – Tertiary clastic sediments in Bornu basin Northeastern Nigeria. *Geol. M.V*. 87, p 353-359.

Akinlabi, I.A. and Ola-Buraimo A.O., 2009. Identification of organically-rich rocks and mature source rocks on logs. A case study from offshore Niger Delta, Nigeria, *Science Focus*, vol.14, n.3, p. 354-363

Avbovbo, A. A., 1980. Basement geology in the sedimentary basins of Nigeria. *Geology***,** 8, p. 323-327.

Avbovbo, A.A., Ayoola, E.O., Osahan, G.A., 1986. Depositional and structural styles in Chad Basin, Northeastern Nigeria. American Association of Petroleum Geologists Bulletin, vol. 70, p. 1788-1798

Ayinla H.A, Ola-Buraimo A.O., Adeigbe, O.C., Bankole, S.A., and Adebowale, M., 2013. Biostratigraphy and high resolution paleo environmental reconstruction of part of Kemar-1 well, Bornu Basin, Northeastern Nigeria. *Journal of Research in Environmental Science and Toxicology*, Vol. 2, n. 3, p. 53-63

Barber, W., 1965 . Pressure water in the Chad Formation of Bornu and Dikwa, Northeastern Emirate, Bornu province. *Bulletin Geology Survey*. Nigeria. 35, 138pp

Barber, W. and Jones, D.J., 1960 . Geology and hydrology of Maiduguri Bornu province REC. *Geology*. *Survey*. *Nigeria*, 1958, 5-20.

Boboye, O.A., 2012. Albian- Eocene palynological and biostratigraphy of three wells in the Nigeria sector of Chad Bornu Basin*. J. Min. Geology*. vol. 482, p. 127-157

Burke, K. Dessauvagie, T. F. J. and Whiteman, A. J. 1970. Geological history of the Benue valley and adjacent areas. In. Dessauvagie, T. F. J. and A.J. Whiteman edt. . African Geology. Cretaceous Rocks of Nigeria and Adjacent Areas. University of Ibadan Press. Ibadan. 187-205.

Carter, J. D., Barber, W. and Jone, G. P. 1963. The geology of parts of Adamawa, and Bornu provinces in northeastern Nigeria, *Bull. Geol. Surv. Nigeria*. 30,109p.

Dow, W.G., 1977. Application of oil correlation and source rock data in the Williston Basin. *AAPG Bull*. Vol. 58, n. 7, p. 1253-1262.

Falconer J. D., 1911 .The geology and Geography of Northern Nigeria. Macmillan, London.

Genik, G. J. 1993. Petroleum Geology of Cretaceous-Tertiary rift basins in Niger, Chad and Central African Republic. *AAPG Bull*. Vol.77, n. 8, p. 1405-1434.

Harwood, R. J., 1977. Oil and gas generation by laboratory pyrolysis of kerogen. *AAPG. Bull*. vol. 61, n.12, p. 2082-2102

Kings L. C 1950 . Outline and disruption of Gondwanaland, *Geol. M. ,V*. 87, p 353-359.

Kogbe, C.A., 1976. The Cretaceous and Paleocene sediments of Southwestern Nigeria. In.

C.A. Kogbe ed , Geology of Nigeria, Elizabethan Publishing Company , Lagos, pp.50-61

Meyer B.L. and Nederlof, M.H., 1984. Identification of source rocks on wireline logs by Density/Resistivity and Sonic transit time crossplot. *AAPG Bulletin*, vol. 68, n.2, p. 121-129.

Odusina, A. A., Mubarak, S. O., Beka, F. R. and Nwangwu, U. 1983 . Geology and petroleum potential of the Nigerian sector of Chad Basin. *Research Bull*. Vol. III, Expl. Resear. Section R&D , Project no. ER/RD/**42**, NNPC, Port-Harcourt, Nig. 47.

Okosun, E. A. 1995 . Review of the Geology of Bornu Basin *Jour. Min. and Geol*., vol. 31, n.2, p. 133 – 122.

Ola-Buraimo A.O., 2005. Sediment logical Characterization of the Chad Formation, Damagum area, Bornu State, Nigeria. *Earth Sciences Research Comm*. vol.1, no.4, p 35-54

Ola-Buraimo A.O., 2009. Granulometric and heavy mineral studies of Kerrikerri Sandstone, Daura, Bornu Basin, Nigeria. *Science Focus*, vol. 14 no. 1 p. 110-129.

Ola-Buraimo A.O., 2012. Lithostartigraphy and palynostratigraphy of Tuma -1 well, Bornu Basin, Northeastern Nigeria*. Journal of Biological and Chemical Research*, vol. 29, n. 2, p. 206-223.

Ola-Buraimo, A.O., 2013. Biostratigraphy of section of Murshe-1 well, Bornu Basin, northeastern Nigeria. *British Journal of Applied Science and Technology*, vol. 3 2 . 361-375.

Ola-Buraimo, A.O., 2013. Biostratigraphy and pale environment of deposition of Bima and Gongila Formation in M-1 well, Bornu Basin, Northeastern Nigeria. International *Journal of Scientific and Technology Research*, vol. 2, Iss. 8, p. 320-328

Ola-Buraimo, A. O., and Boboye, O. A., 2011. Palynological investigation of the Albian to Lower Cenomanian Bima Formation Bornu, Nigeria. *World Applied Sciences Jour*. vol. 12, n. 7, p. 1026-1033.

Ola-Buraimo, A. O., and Oluwajana, O. A., 2012.Sedimentological and palynological assessment of Bima Group, Bornu Basin, Northeastern Nigeria. *The Pacific Journal of Science and Technology*, Vol.13, n. 2, p.397-406

Olugbemiro, R. O. 1997. Hydrocarbon Potential, maturation and paleo environments of the Cretaceous series in Bornu Basin, NE Nigeria. Ph.D. Thesis, Institut und Museum fur Geologie and Palaontologie der Universitat Tubingen, Germany, 14, 150.

Oti, M. N. 1990. LowerTuronian Carbonates on the Zambuk Ridge, S.E. Chad Basin. The Ashaka Limestone. In. OFOEGBU, C.O. Ed. – The Benue Trough. Structure and Evolution. Friedr. Vieweg and Sohn Verlagsgesells chaftmbH.

Petters, S. W., 1978. Mid-Cretaceous paleo environment and biostratigraphy of the Benue Trough, Nigeria. *Bull. Geol. Soc. America*, vol. 89, p. 151-154

Petters, S.W., 1981. Stratigraphy of Chad and Iullenmeden Basins West Africa Eclogee Geol. *Helvetiae*. Vol. 74, n. 1, p. 139-159.

Petters, S. W. 1982. Central West African Cretaceous-Tertiary benthic Foraminifera and stratigraphy. *Palaeontographica* Abt. A. 179, 1-104.

Reyment, R.A., 1968. Aspect of geology of Nigeria. Ibadan University Press, 145p

Stamplin, F.L., 1969. Sedimentary organic matter, organic metamorphism and oil and gas occurrence. *Canadian Petroleum Geology*, vol. 17, n. 1, p. 44-76

Tissot, B.P. and Welte, D.H., 1978. Petroluem formation and occurrence. Stringer-verlag Press, New York. 538p.

Corresponding author: Ola-Buraimo A.O., Palystrat Limited, Ibadan, Nigeria
Email: rolaburaimo@yahoo.com