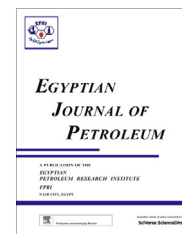




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FULL LENGTH ARTICLE

# Preliminary hydrocarbon analysis of crude oils from Umutu/Bomu fields, south west Niger Delta Nigeria

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**Abstract** Seven different crude oil samples were collected from two oil fields in the Niger Delta Nigeria. The bulk properties of these crude oils which include API gravity, Reid vapour pressure; kinematic viscosity, dynamic viscosity, moisture, gum content and cloud point were analysed. Aliphatic biomarkers were used as supporting tool to deduce the geochemical characteristics such as thermal maturity, depositional environments, source of organic matter and extent of biodegradation. Results show that API<sup>o</sup> gravity ranged from 29.00<sup>o</sup> to 85.00<sup>o</sup>, specific gravity 0.65 to 0.88, 3.00 to 9.00, Reid vapour pressure 3.00 to 9.00 kPa, kinematic viscosity 0.90 to 10.10 cSt, dynamic viscosity 0.70 to 8.90 cP, moisture content 0.13% to 26.00%, gum content 6.27 to 45.84 mg/L, cloud point 3.00 to 12.00 °C, pour point −7.00 to 4.00 °C and flash point < 30.00 °C. Distribution of *n*-alkanes (Pr/Ph, and isoprenoide/*n*-alkanes ratios) reflects that the oil samples originated mainly from terrestrial organic sources deposited in an oxic paleoenvironment.

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**1. Introduction**

The Niger Delta is important in crude oil correlation studies because it is one of the major hydrocarbon provinces of the world, with an estimated reserve of about 23 billion barrels of oil and 183 trillion cubic feet of natural gas [1]. Defining and evaluating exploration are helpful to characterise the

hydrocarbon source rocks, their range of thermal maturities and types of products generated [2].

An appreciable number of studies have been done on the Niger Delta crude oils which include the works of [1,3–5] but the question is, whether the hydrocarbons found within the Niger Delta basin are of the same origin. Hydrocarbons within the basin have been found to occur at different productive horizons at very great depth apart. The migration processes that determined the pooling of the hydrocarbons at different depths are yet to be clearly understood but it is known that the properties and composition of any petroleum systems are controlled by complex geological, physicochemical and biological processes during generation as well as accumulation in reservoirs.

The two fields of study are the Umutu field and the Bomu oil field in the Niger Delta Nigeria. Umutu field was termed

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marginal field, No empirical, analytical and geochemical data have been reported on the crude oil samples from these fields since their discovery.

This paper examines the preliminary geochemical parameters of these two oil fields which include bulk properties, aliphatic biomarkers of the crude oils and molecular ratios with the aim of understanding the type and quality of crude oils, their correlation, degree of thermal maturity, organic matter source, depositional environment and subsequent alteration.

### 1.1. Geologic setting of study area

The Niger Delta is one of the world's largest Tertiary delta systems and an extremely prolific hydrocarbon province. It is situated on the West African continental margin at the apex of the Gulf of Guinea [6]. It occupies an area of about 75,000 km<sup>2</sup> with clastic sequence which reaches a maximum thickness of 9000–12,000 m of sediment and a total sediment volume of 500,000 km<sup>3</sup> [7].

Stratigraphically, the thick sedimentary sequence is made up of three principal lithostratigraphic units namely, the Benin, Agbada and Akata formations [8]. The Benin formation is the alluvial or upper coastal plain depositional environment of the Niger Delta complex. It consists of mainly fluvial gravels and sands. It has a thickness in excess of 1820 m.

The Agbada formation underlies the Benin formation and is made up primarily of alternating sandstones and shales which are of fluvio-marine origin. The Akata formation is

the lowest unit of the Niger Delta complex. It was deposited in a typical marine environment.

The hydrocarbon habitat of the Niger Delta is mostly within the sandstone reservoir of the Agbada formation where they are usually trapped in over anticlines associated with growth faults.

## 2. Materials and methods

Seven crude oil samples were collected at stratigraphic depths ranging from 10500 to 11200 ft in two producing fields (Umutu and Bomu) onshore Niger Delta. The sample locations are shown in Fig. 1. Bulk properties of seven crude oil samples were measured and calculated using ASTM methods, i.e. Specific gravity [9], API° gravity [10], pour point [11], kinematic viscosity [12], Reid vapour pressure [13] and [11], dynamic viscosity [14], moisture content [15], gum content [16], Cloud point [17] (Table 2).

### 2.1. Column chromatography

The crude oils were fractionated by column chromatography on silica gel. The saturated, aromatic hydrocarbons and polar compounds were eluted using petroleum ether (75 ml), dichloromethane (75 ml) and methanol (75 ml) respectively. The fractions were recovered by careful evaporation of the solvent on the sand bath, followed by removal of residual solvent under nitrogen gas as reported by Abrakasa [18].

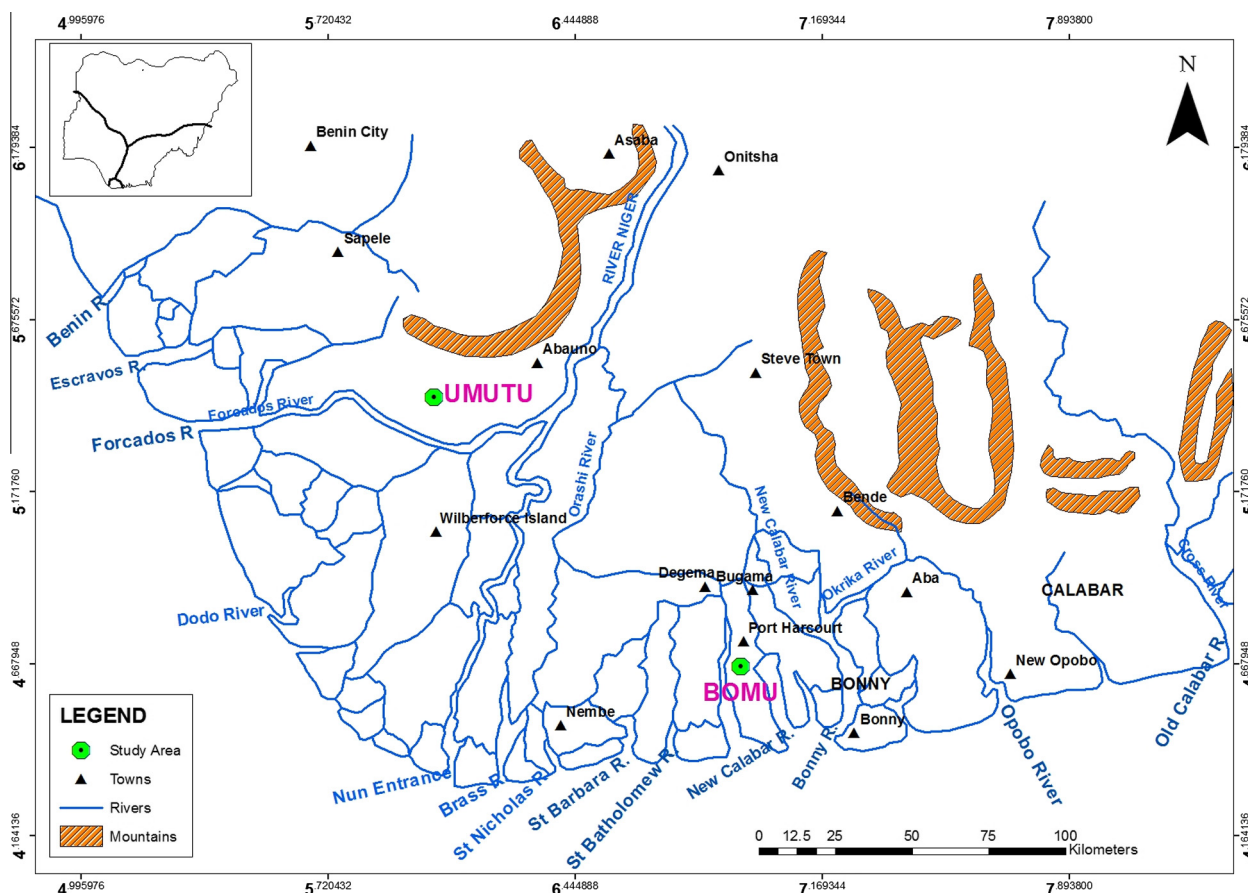


Figure 1 Map of Niger Delta showing the study locations.

**Table 1** Results of the bulk properties of crude oils from the Bomu oil field.

Parameter	Unit	KD 01	KD 02	KD 03
Density at 15 °C	g/cm <sup>3</sup>	0.87	0.85	0.88
Specific gravity 60/60 °F	g/cm <sup>3</sup>	0.87	0.85	0.88
API° gravity 60 °F	°	31.00	35.00	29.00
Reid vapour pressure (RVP)	kPa	7.00	9.00	3.00
Kinematic viscosity	cSt	5.30	4.00	10.10
Dynamic viscosity	cP	4.60	3.40	8.90
Moisture	%	0.13	0.20	0.38
Gum content	mg/L	38.46	30.02	45.84
Cloud point	°C	5.00	8.00	8.00
Pour point	°C	-17.00	-5.00	4.00
Flash point	°C	< 30.00	< 30.00	< 30.00

cSt = centistroke, cP = centipoise.

## 2.2. Gas chromatography (GC-FID)

The saturated fractions obtained by liquid chromatography were subjected to Capillary GC-FID analysis. Gas chromatography (GC) analysis of the saturated fractions was carried out using a Shimadzu 14B series Gas Chromatograph, equipped with FID, 30 m × 0.25 mm (i.d) film thickness 0.25 µm fused silica capillary columns, coated with methyl silicone (OV-1). The sample (1 µL) was injected in splitless mode by means of a syringe through a rubber septum into the column. Detector (FID) and injector temperatures were kept at 250 and 280 °C, respectively. The oven temperature was programmed from 60 to 280 °C at 4 °C/min with an initial hold time of 1 min and final hold time of 15 min. Nitrogen at a linear velocity of 2 mL/min was used as carrier gas. The data were collected from retention time: 0–71 min. The chromatograms are shown in Figs. 4–10.

## 3. Results and discussion

### 3.1. Bulk analysis of crude oils

Bulk properties of crude oils are useful for initial screening and tentative identification of genetically related oils (Tables 1 and 2). Specific gravity gives an idea about the presence of light and high molecular weight hydrocarbons. The lesser the value of

specific gravity, the higher the amount of hydrocarbons in the Petroleum [19]. The crude oil samples from U45, U2T, U4L, U7L have lower specific gravity than the samples from KD01, KD02 and KD03. This implies that the hydrocarbon content of the former samples is more than the latter samples.

API° gravity is reverse of specific gravity and describes the nature of crude oils, i.e., light or heavy. API° can be used to determine the commercial importance and the market value of crude oils. Samples KD 01, KD 02 and KD 03 have lower API° gravity than samples U45, U2T, U4L and U7L. This also shows that these groups of oils are lighter than the first group and will have a better market value than the latter.

Pour point is an import parameter used to measure the wax content of crude oils. The pour point measures the temperature at which a crude oil no longer flows, and for paraffinic crude oils, pour points are usually between -12 °C and -15 °C, and are determined by operation of the dewaxing unit. The pour points of naphthenic crude oils, which can have very low wax content, may be much lower (-30 °C to -50 °C). The pour points of crude oil samples under study range from -17 °C to 4.0 °C. These crude oil samples are within the paraffinic base oils. Values greater than 15 °C indicate that the crude oil samples have high wax contents. Tables 1 and 2 show that all the crude oils from the two fields under investigation have minimal wax content. The kinematic viscosity of the KD 01, KD 02 and KD 03 crude oil samples are higher than those of U45, U2T, U4L, and U7L. This high value again confirms the presence of high molecular weight hydrocarbons in the former groups of samples than the latter.

Reid vapour pressure (RVP) is the measure of vapours of light weight hydrocarbons present above the crude oil surface, the higher the value of RVP, the higher the percentage of light hydrocarbons in the crude oils samples. KD 01, KD 02 and KD 03 samples have higher values of RVP than samples U45, U2T, U4L, and U7L indicating that they contain more light hydrocarbons than the former group of samples.

The flash point measures the temperature at which there is sufficient vapour above a liquid sample to ignite and is a significant feature in product applications where it is used as a common safety specification. Flash points are reflections of the boiling point of crude oils samples. The flash points of the crude oil samples under study are less than 30.00 °C.

In crude or heavy oils, cloud point is synonymous with wax appearance temperature and precipitation temperature. It is a specific temperature where crude oils or petroleum products

**Table 2** Results of the bulk properties of crude oils from Umutu oil field.

Parameter	Unit	U45	U2T	U4L	U7L
Density at 15 °C	g/cm <sup>3</sup>	0.77	0.78	0.65	0.76
Specific gravity 60/60 °F	g/cm <sup>3</sup>	0.77	0.78	0.65	0.76
API° gravity 60 °F	°	52.00	50.00	86.00	55.00
Reid vapour pressure (RVP)	kPa	4.80	4.70	5.70	4.90
Kinematic viscosity	cSt	1.00	1.10	1.20	0.90
Dynamic viscosity	cP	0.80	0.90	0.80	0.70
Moisture	%	11.00	11.00	12.00	12.00
Gum content	mg/L	13.43	13.14	15.13	6.27
Cloud point	°C	4.00	3.00	9.00	12.00
Pour point	°C	-4.00	-17.00	-1.00	-3.00
Flash point	°C	< 30.00	< 30.00	< 30.00	< 30.00

cSt = centistroke, cP = centipoise.

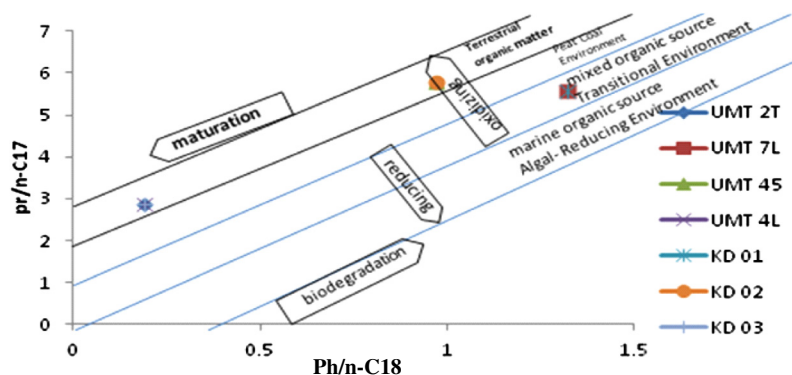


Figure 2 Cross plot of Pr/ nC17 versus Phy/nC18.

Table 3 Various aliphatic biomarker ratios.

Sample	Pr/Ph	Pr/n-C <sub>17</sub>	Ph/n-C <sub>18</sub>	nC <sub>25</sub> /nC <sub>18</sub>	CPI	(Pr + C <sub>17</sub> )/(Ph + C <sub>18</sub> )
UMT 2T	4.05	0.56	0.16	0.53	1.01	1.52
UMT 7L	2.31	1.30	0.16	0.49	0.72	1.52
UMT 45	2.31	1.35	0.65	0.67	1.08	1.58
UMT 4L	1.88	0.77	0.42	0.64	1.02	1.26
KD 01	3.36	0.48	0.16	0.40	1.09	1.40
KD 02	3.44	0.45	0.16	0.38	1.02	1.53
KD 03	3.40	0.44	0.16	0.37	1.04	1.50

begin to show “cloudiness”. The cloudiness forms as a “finite and detectable” amount of wax or waxy crystals. The values for the cloud point for samples KD01, KD02 and KD03 range from 5.00 °C to 8.00 °C while U45, U2T, U4L, U7L samples range from 3.00 °C to 12.00 °C. It was observed that crude oils from these fields under investigation have low wax content.

Other bulk parameters determined for the crude oils samples are moisture and gum contents. The moisture content of crude oils is an important quality determining parameter. The moisture content of KD 01, KD 02 and KD 03 ranges from 0.13% to 0.38% and those of samples from U45, U2T, U4L, U7L ranges from 11.00% to 12.00%. Water present in crude oils is difficult to remove if it is in colloidal form. This implies that the first set of crude oils samples are of a higher quality considering their water content.

The gum content is the measure of the degree of unsaturated hydrocarbons in crude which can easily combine with atmospheric oxygen to form a non volatile sticky substance called gum. The gum content of samples KD 01, KD 02 and KD 03 ranges from 30.03 to 45.85 mg/L while that of U45, U2T, U4L, U7L ranges from 6.27 to 15.13 mg/L. This implies that the first set of samples have higher unsaturated hydrocarbons than the second sets of samples.

### 3.2. Normal alkane and isoprenoid distribution

The saturated fraction of a representative crude oil sample is shown in Fig. 2, *n*-alkanes from *n*-C<sub>8</sub> to *n*-C<sub>37</sub> are seen in the chromatograms. Low molecular weight hydrocarbons (<*n*-C<sub>8</sub>) were not observed, probably because of evaporative loss during sample processing. In crude oil correlation, the ratios of isoprenoids to *n*-paraffin are often used for oil-source correlation, maturation and biodegradation studies [1,18]. Various

ratios of isoprenoids to *n*-alkanes were computed such as the Pr/Ph, Pr/*n*-C<sub>17</sub>, Ph/*n*-C<sub>18</sub>, nC<sub>25</sub>/nC<sub>18</sub>, (Pr + C<sub>17</sub>)/(Ph + C<sub>18</sub>), (Table 3). The crude oil samples have a high Pr/Ph ratio which ranges from 1.88 to 4.05. Pr/Ph ratios were used to assess the depositional environment of the crude oils. The high Pr/Ph ratios suggest that oils are derived from source rock with a significant terrestrial contribution, deposited in an oxic paleoenvironment [19,20].

Several authors have used a plot of Pr/*n*-C<sub>17</sub> versus Ph/*n*-C<sub>18</sub> to classify oils and rock extracts in different groups as shown in Fig. 2, Source, maturation, migration and biodegradation are the major factors responsible for differences in crude oil composition. Values less than 1.0 are indicative of non-biodegraded oils. Both Pr/*n*-C<sub>17</sub> and Ph/*n*-C<sub>18</sub> decrease with maturation due to increasing prevalence of the *n*-paraffins. The values of Pr/Ph, Pr/*n*-C<sub>17</sub> and Ph/*n*-C<sub>18</sub> for analysed crude oils are given in Table 3. Pr/*n*-C<sub>17</sub> and Ph/*n*-C<sub>18</sub> ratios have been widely used as indicators of source rock types, depositional environments and organic matter maturation [23,24]. The lower Pr/*n*-C<sub>17</sub> and Ph/*n*-C<sub>18</sub> ratios in most of the studied samples are probably being caused by their maturity in addition to the source of organic matter. Generally, the Pr/*n*-C<sub>17</sub> and Ph/*n*-C<sub>18</sub> ratios decrease with increasing thermal maturity [24].

All Samples have Ph/*n*-C<sub>18</sub> values less than one (<1.0) indicating that these samples are non biodegraded [20,22].

Fig. 3 also shows that the crude oils under investigation are from mixed organic matter source.

### 3.3. Carbon preference index (CPI)

Carbon Preference Index was the first maturity indicator applied to crude oils [17]. Some researchers observed immature

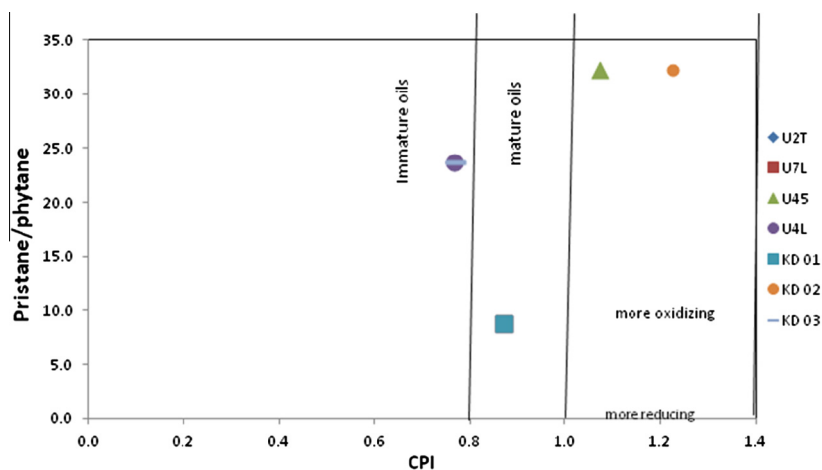


Figure 3 Cross plot of pristane/phytane versus carbon preference index (CPI).

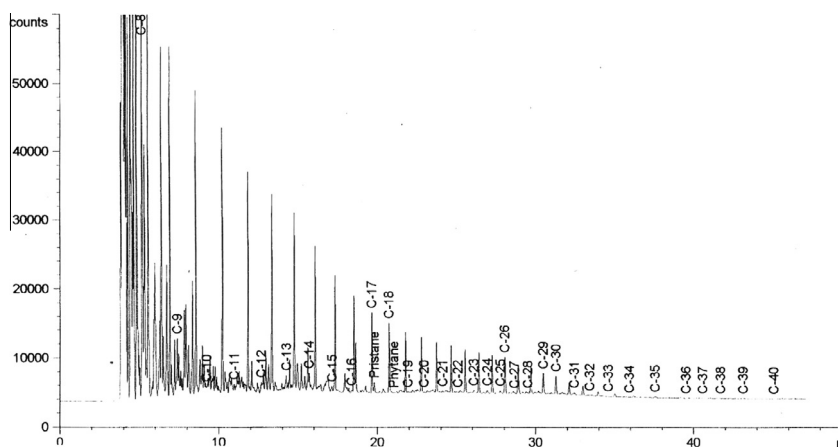


Figure 4 Gas chromatogram of crude oil sample U2T from Umutu field.

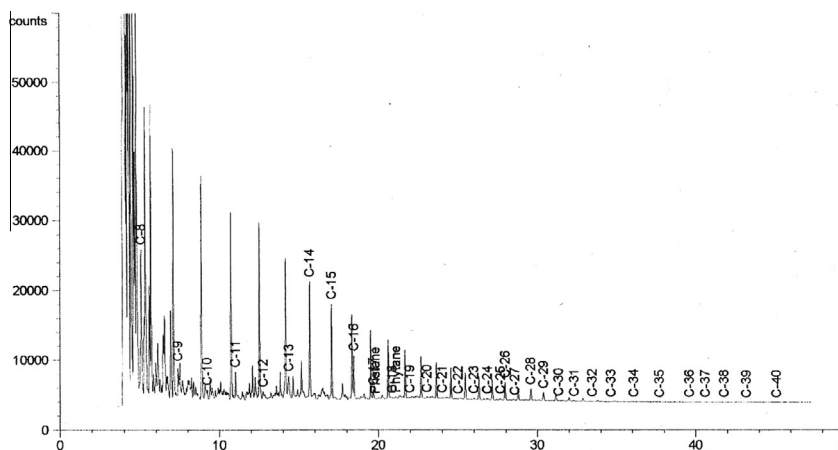


Figure 5 Gas chromatogram of crude oil sample U7L from Umutu field.

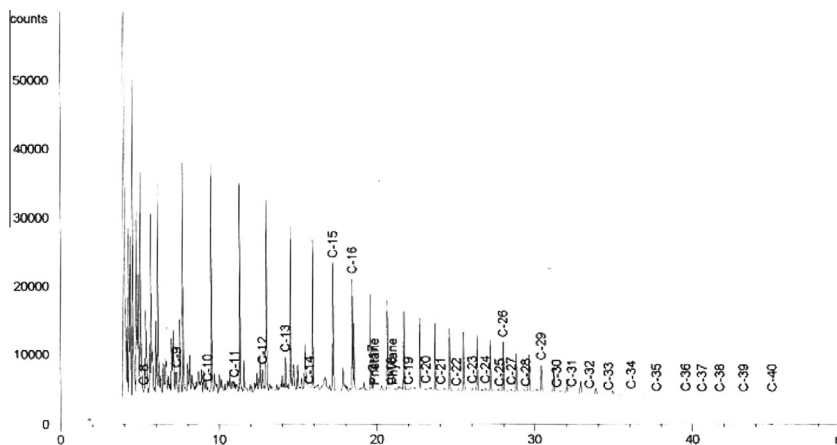


Figure 6 Gas chromatogram of crude oil sample U45 from Umutu field.

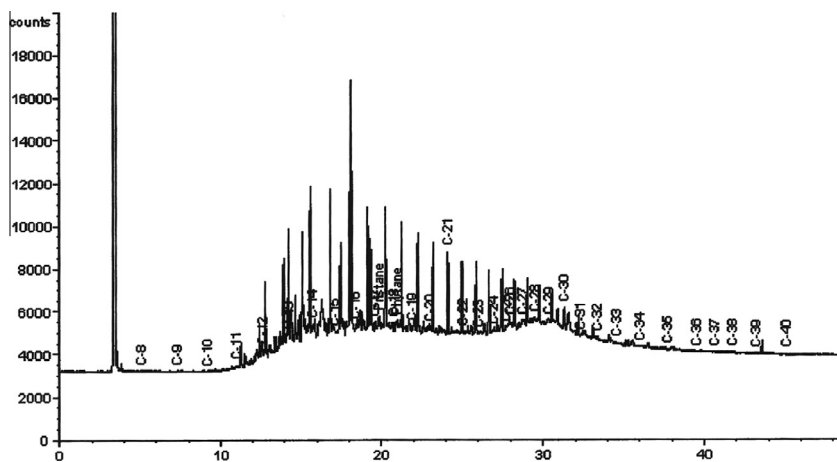


Figure 7 Gas chromatogram of crude oil sample U4L from Umutu field.

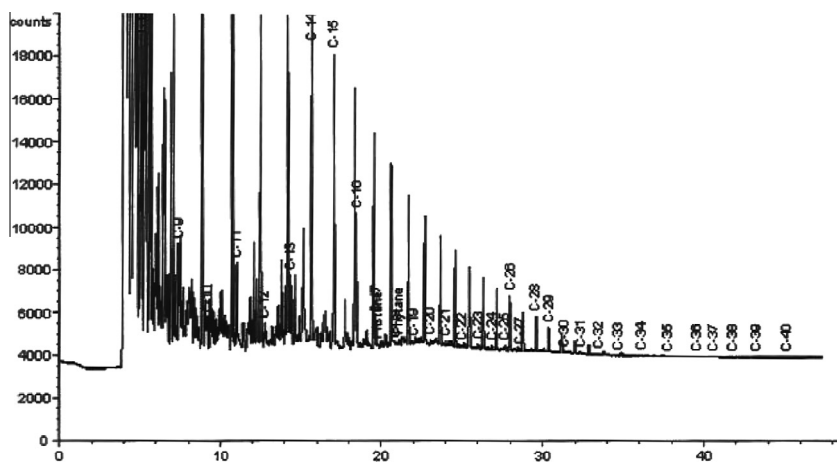


Figure 8 Gas chromatogram of crude oil sample KD01 from Bomu field.

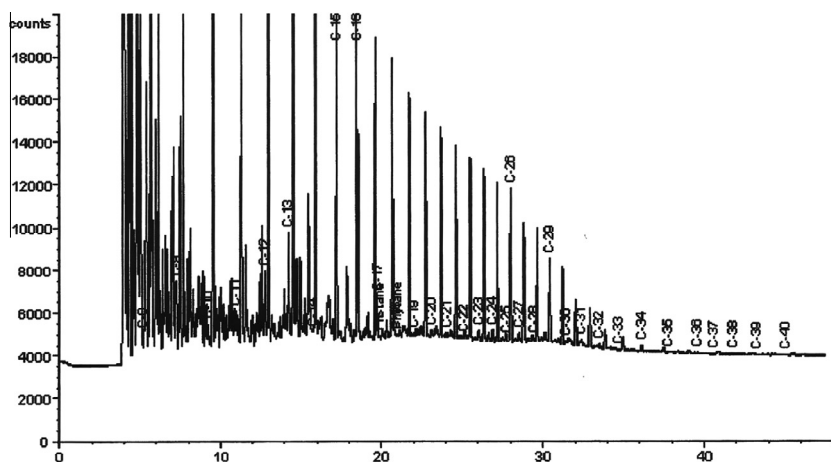


Figure 9 Gas chromatogram of crude oil sample KD02 from Bomu field.

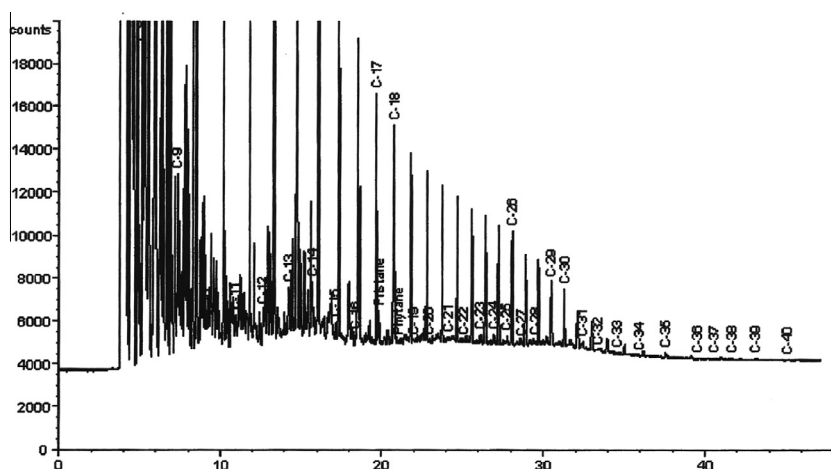


Figure 10 Gas chromatogram of crude oil sample KD03 from Bomu field.

rocks often had high CPI values ( $> 1.5$ ), whereas those of mature oils were almost always below 1.0. Listed in Table 3 are the values of CPI of the crude oil samples. All the values are above 1.0 except sample UMT 7L with a value of 0.72. The implication is that the crude oils are matured [21].

#### 4. Conclusion

Examination of the preliminary characteristics of the crude oils under study showed two groups of crude oils with similar characteristics but two different sources. Saturated hydrocarbon molecular composition of these crude oils revealed that the oils were formed in source rocks containing mixed kerogen (marine and terrestrial) deposited in an oxic environment. The aliphatic biomarker maturity parameters show that the oils were formed from early mature source rocks but lacked any maturity trends.

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#### References

- [1] O. Sonibare, H. Alimi, D. Jarvie, O.A. Ehinola, *J. Pet. Sci. Eng.* 61 (2008) 99.
- [2] I.J. Muhammad, T. Fazeelat, S. Hina, *Chin. J. Geochem.* 29 (2010) 82.
- [3] C.M. Ekweozor, J.I. Okogun, D.U.E. Ekong, J.R. Maxwell, *Chem. Geol.* 27 (1979) 11.
- [4] C. Eneogwe, O. Ekundayo, *J. Pet. Geol.* 26 (2003) 95.
- [5] J.I. Nwachukwu, A.F. Oluwole, O.I. Asubiojo, R.H. Filby, C.A. Grimm, S.A. Fitzgerald, in: M.N. Oti, Postma (Eds.), *Geology of Delta*, A.A. Balkema, Rotterdam, 1995, p. 287.
- [6] H. Doust, *Petroleum Geology of the Niger Delta*, *Geol. Soc. Lond. Spec. Publ.*, 1990, p. 365.
- [7] T.A. Adedosu, O.O. Sonibare, *J. Appl. Sci.* 5 (2005) 906.
- [8] K.C. Short, A.J. Stauble, *Outline of Geology of Niger Delta*, AAPG, 1967, p. 761.
- [9] ASTM standard test method for specific gravity of crude petroleum by hydrometer, 05.01, D12998-85.
- [10] ASTM standard test method for API gravity of crude petroleum by hydrometer, 0.5.01, D287-92.

- [11] ASTM standard test method for pour point of petroleum 05.01, D97-98. ASTM standard test method for sediments and water in crude oils by centrifuge method, 05.02, D4007-81.
- [12] ASTM standard test method for kinematic viscosity of transport and opaque liquids, 05.01, D445-88.
- [13] ASTM standard test method for vapour pressure of petroleum products (Reid method), 05.01, D323-90.
- [14] ASTM D7042 – 11a Standard Test Method for Dynamic Viscosity and Density of Liquids by Stabinger Viscometer.
- [15] ASTM D1744 – 92 D1744-92 Standard Test Method for Determination of Water in Liquid Petroleum Products by Karl Fischer Reagent.
- [16] ASTM D381 – 12 Standard Test Method for Gum Content in Fuels by Jet Evaporation
- [17] ASTM – D 2500 – 91 ASTM D2500 – 11 Standard Test Method for Cloud Point of Petroleum Products.
- [18] S. Abrakasa, *J. Chem. Res.* 11 (2006) 15.
- [19] J. Connan, Biological markers in crude oils, in: *Petroleum Geology in China*, 4th ed., Pennwell, Oklahoma, 1980.
- [20] M.R. Mello, J.R. Maxwell, in: B.J. Katz (Ed.), *Lacustrine Basin Exploration*, 50, AAPG Mem., 1990, p. 77.
- [21] J.M. Hunt, *Petroleum Geochemistry and Geology*, W.H. Freeman and Company, New York, USA, 1996.
- [22] J. Connan, A.M. Cassou, *Geo. Cosmo. Acta* 44 (1980) 1.
- [23] Y. Duan, Z.P. Wang, H. Zhang, X.B. Zhang, Y.R. Qian, G.D. Zheng, *J. Pet. Geol.* 29 (2006) 175.
- [24] K.E. Peters, M.J. Moldowan, *The Biomarker Guide: Interpreting Molecular Fossils in Petroleum and Ancient Sediments*, Prentice-Hall, Englewood Cliffs, 1993, p. 363.