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Biomarker-Based Geochemical Characterization and Oil–Oil Correlation of Oredo (Nigeria) and Agadem (Niger Republic) Crude Oils"

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ABSTRACT
This study evaluated the geochemical characteristics and possible genetic relationship between Agadem crude oils from the Niger Republic and Oredo crude oils from the Niger Delta, Nigeria, based on thermal maturity, organic matter source characteristics, and depositional conditions. Five crude oil samples were investigated, comprising two samples collected from different oil wells in the Agadem oil field, Niger Republic, and three samples obtained from different oil wells in the Oredo oil field, Niger Delta, Nigeria. The samples were collected in clean glass bottles and analysed using gas chromatography–mass spectrometry (GC–MS) to characterise their hydrocarbon and biomarker compositions. The identified biomarkers included *n*-alkanes, hopanes, steranes, phenanthrenes, and triaromatic steroids. Molecular maturity and depositional-environment characteristics were assessed using carbon preference index (CPI), odd–even predominance (OEP), diagnostic equivalent weight (DEW), and pristane/phytane (Pr/Ph) ratios. The CPI values obtained were 1.0049 for Agadem[1], 0.9524 for Agadem[2], 0.9423 for Oredo[5], 0.9477 for Oredo[8], and 0.9482 for Oredo[11], indicating that the oils generally exhibit CPI values close to unity and have undergone substantial thermal alteration. The Pr/Ph ratios ranged from 1.15 in Agadem[1] to 0.18 in Oredo[5], indicating variations in the redox conditions of the depositional environments. DEW and OEP values also showed variations among the samples, with DEW ranging from 0.94 to 2.34 and OEP from 0.83 to 1.02. The occurrence and distribution of the investigated biomarkers reveal appreciable similarities among the Agadem and Oredo crude oils, suggesting comparable source characteristics and depositional conditions. These similarities provide evidence supporting an oil–oil correlation between the two areas.

Keywords: Biomarkers; Crude oil; GC–MS; Oil–oil correlation

INTRODUCTION

Petroleum geochemistry provides an important framework for evaluating the origin, thermal history, depositional environment, and relationships among crude oils and their potential source rocks. Molecular biomarkers are particularly valuable in this regard because their distributions preserve information derived from the biological precursors and depositional conditions of the organic matter from which petroleum was generated. Consequently, biomarker assemblages and diagnostic molecular ratios are widely applied in source characterization, maturity assessment, depositional-environment interpretation, and oil–oil and oil–source-rock correlation (Zhang, J. *et. Al.* 2026). Gas chromatography–mass spectrometry (GC–MS) provides a high-resolution approach for characterizing these molecular signatures through the identification and distribution of saturated and aromatic hydrocarbons and biomarkers such as *n*-alkanes, hopanes, steranes, phenanthrenes, and triaromatic steroids.

The Niger Delta Basin is one of the major petroleum-producing sedimentary basins of West Africa and contains a complex petroleum system developed within a thick Tertiary clastic succession. Geochemical investigations have demonstrated that Niger Delta crude oils commonly contain mixed terrestrial and marine organic matter contributions, although the relative contribution of these sources varies spatially and among petroleum systems. Biomarker and isotopic studies have also demonstrated variations in depositional conditions and thermal maturity among oils from different depobelts and reservoir intervals. For example, studies of Niger Delta oils have used *n*-alkane and isoprenoid distributions, steranes, hopanes, oleanane, and aromatic biomarkers to distinguish source facies, depositional environments, and maturity and to establish oil–oil relationships (Takyi, B *et.al.*2026).

The Agadem oil field occurs within the Termit Basin of eastern Niger, a Mesozoic–Cenozoic rift basin associated with the Central African Rift System. Unlike the predominantly deltaic petroleum setting of the Niger Delta, the Termit Basin records a complex succession of marine, transitional, fluvial, deltaic, and lacustrine depositional systems. Upper Cretaceous Donga and Yogou formations constitute important marine source-rock intervals, while Paleogene Sokor formations include lacustrine and deltaic source rocks associated with a younger petroleum system (Riza *et.al*. 2026).

Biomarker studies of Termit Basin petroleum have further demonstrated considerable geochemical diversity. Analysis of 60 crude oils identified two major oil families, with most oils showing characteristics consistent with an anoxic marine source, whereas a smaller group displayed lacustrine signatures. More recent integrated petroleum-system studies have identified three oil families and linked them to different source-rock intervals, including the Yogou, Sokor-1, and Donga formations. These studies demonstrate that oil composition within the Termit Basin reflects differences in

source facies, depositional setting, and thermal maturity. Thus, the Agadem petroleum system cannot be adequately characterized by a single depositional or organic-matter model; its petroleum geochemistry reflects a complex interaction between marine and continental source systems.

Biomarker parameters provide a means of comparing crude oils from these two petroleum provinces despite their contrasting geological settings. The distribution of *n*-alkanes and acyclic isoprenoids can provide information on organic-matter input and depositional redox conditions, while sterane and hopane distributions are useful for assessing source characteristics and petroleum-system relationships. Diagnostic maturity parameters derived from steranes, hopanes, aromatic hydrocarbons, and related molecular indices can provide independent constraints on thermal alteration. In addition, parameters such as the pristane/phytane (Pr/Ph) ratio, carbon preference index (CPI), odd–even predominance (OEP), and diagnostic equivalent weight (DEW), when interpreted collectively and in conjunction with biomarker distributions, can provide complementary evidence for assessing depositional conditions, maturity, and oil similarity. Importantly, no single molecular parameter is sufficient to establish a genetic relationship because individual ratios may respond to multiple geological and geochemical processes.

Although extensive biomarker investigations have been undertaken independently on crude oils from the Niger Delta and the Termit Basin, comparative geochemical assessment of Agadem crude oils and oils from the Oredo field in the Niger Delta remains limited. Existing studies have established distinct petroleum systems within both regions, but they have primarily addressed intra-basin oil families, source characteristics, depositional environments, and maturity rather than directly evaluating the molecular similarities between these geographically separated petroleum provinces. This creates an important research question: whether similarities in biomarker composition between Agadem and Oredo oils reflect comparable organic-matter inputs and depositional conditions, a common or related petroleum-generating history, or merely convergent molecular characteristics produced under different geological conditions.

The present study addresses this question through comparative GC–MS characterization of five crude oil samples comprising two Agadem oils from the Termit Basin, Niger Republic, and three Oredo oils from the Niger Delta, Nigeria. The study evaluates *n*-alkanes, hopanes, steranes, phenanthrenes, and triaromatic steroids together with selected diagnostic parameters, including CPI, OEP, DEW, and Pr/Ph ratios, to assess thermal maturity, organic-matter characteristics, depositional conditions, and molecular similarity among the oils. The specific objective is to determine whether the combined biomarker characteristics provide sufficient evidence for an oil–oil correlation between the Agadem and Oredo crude oils. Rather than assuming a genetic relationship a priori, the study tests the proposed correlation using an integrated molecular-geochemical approach and identifies the extent to which the available biomarker evidence supports or limits such an interpretation.

T also known as black gold, is a dark brown or greenish liquid found in formations in the earth (Jenny, 1999). It is a mixture of compounds having simple to complex structures made up of combinations of carbon, hydrogen, oxygen, nitrogen, sulphur, trace metal and even mineral salt (Patin, 1999).

Biomarkers are organic components occurring in geological material (sediments, petroleums, coals) which possess structures that attest to their origin from discrete molecular constituents of organisms.Thus, a major application of biomarkers lies in the use of their patterns of occurrences to characterized source rocks and petroleum. Specifically, the variety and diversity of biomarkers provide a sensitive tool for the differentiation of individual source rock and petroleum samples and has given rise to the use of 'fingerprinting' to describe the patterns of compounds observed in GC traces and Mass chromatograms obtained from GC-MS or GC-MS/MS analyses (Brassel, 1993).The overwhelming geochemical and geological evidence from both sediment and petroleum studies of the past few decades clearly shows that most petroleum originated from organic matter buried with the sediments in sedimentary basins (Engel and Macko, 1993).

Biomarkers

Biomarkers are individual organic constituents of sediments, sedimentary rocks and petroleum which drive from biological precursors. They constitute only a minor proportion of sedimentary organic matter, but their variety and structural diversity are invaluable aids to the decipherment and assessment of sediments, maturity and depositional settings.

Also, biomarkers undergo systematic and sequential transformations during diagenesis and the changes in their compositions can therefore be used as measures of the thermal history of sediments. Futhermore, the temperature range of biomarker transformation is sufficient that a combination of diagnostic reactions can quantify maturity changes from the earliest stages of sedimentation through the phases of petroleum generation by the thermal breakdown of organic matter (Mohammed S.S. *et.al*. 2026)

Oredo Oil Field in Nigeria

Nigeria has a total of 159 Oil fields and 1481 wells in operation according to the Ministry of Petroleum Resources. Exports of Nigerian crude oil to the outside world started in February 1958, when the production reached 6000 barrels per day (Akinsola, 2007). The most productive region of the nations is the coastal Niger Delta basin in the Niger Delta or " South-South " region which encompasses 78 of the 159 oil fields.

The oredo field is located in the North-West part of the Niger Delta, approximately 35 kilometres South-East Benin city in Edo State.

Agadem Oil Field in Niger

The Agadem oil field began producing in November 2011, with production estimated to reach a capacity of 20,000 barrel per day (bpd) in 2012. The Agadem block will also provide the Soraz Oil Refinery with gas, with an expected yield of 44-200 tonnes of liquefied petroleum gas(LPG).The state owned National Petroleum Products Company, Society Nigerienne de Products Petroliers (SONIDEP) will undertakes the marketing of the nations refined products.

Gas Chromatography Mass Spectrometry

The most effective tool for the separation and identification of compounds present within highly complex mixtures is gas chromatography (GC). This technique can be employed in the investigation of mixtures of organic compounds that can be volatilized at temperature of $<320^0$C.

Mass spectrometry (MS) is the most useful technique for the identification of organic compounds at PPb levels. This technique involves the generation, seperation and detection of the diagnostic ions formed when organic compounds are bombarded with electrons under vacuum.

The coupling of a gas chromatograph to a mass spectrometer as an integrated GC-MS system achieves that objective and

the development of GC-MS has played a vital and central role in biomarker geochemistry, permitting evaluation of biomarkers in highly complex mixture. (Brassel 1993).

MATERIALS AND METHODS

Crude oil samples from separate oil wells in Agadem blocks and Oredo oil field in Niger Republic and Nigeria respectively were used for the geochemical correlation and heavy metals determination in the research work.

Sample Collection

Two crude oil samples (1L each) from different oil wells were collected from Agadem oil fields (Niger) in a well cleaned glass bottles.

And three crude oil samples (1L each) from different oil wells were collected from Nigerian Petroleum Development Company (NPDC) Benin City, Nigeria in well cleaned glass bottles.

Biomarker Analysis

The principal requirement in biomarker analysis are the identification and quantification of individual compounds or families of components. To facilitate these objective biomarkers need to be liberated or extracted from the sediment, rock matrix or petroleum and subsequently, the complex mixtures obtained need to be simplified to a sufficient degree that individual constituents can be characterized (Brassel, 1993).

Sample Preparation/Column Chromatography

1.00g of alumina was measured and poured into 5.00ml beaker that is properly washed and rinsed with the solvent after drying.

30mg of the oil was measured with a glass pipette and drop onto the centre of alumina and was shaken until the oil is uniformly distributed in the alumina.

The column was rinsed with n-hexane and small piece of cotton fibre was inserted into the column. 10.00g of silica gel was measured and wetted with n-hexane which is transferred and packed into the column to form stationary phase.

After stationary phase a 1.00cm^3 thick layer was formed by adding alumina and then loaded our sample and was covered by another 1.00cm^3 layer of the alumina.

Saturated compounds were eluted by using 45.00ml N-hexane while aromatics were eluted using 50.00ml mixture of N-hexane &DCM (70:30).

GC/MS Analysis

Saturated and aromatic hydrocarbon fractions from the column chromatographic fractionation of the oils was analysed by GC/MS at both scan and selected ion monitoring modes for identification and quantification of the compounds, respectively with internal standard. GC linked to MS was used for the analysis. The GC oven was programmed from 50^0C (held for 5 min.) and raised at 7^0C/min to 300^0C where it was held for 30min and helium was used as carrier gas.

MS was set at the mass spectra of 50-550M/Z; compound was identified from their respective mass spectra in comparison with published mass spectra and mass chromatograms. Mass spectrometry (MS) is the most useful technique for the identification of organic compounds at PPb levels. This technique involves the generation, seperation and detection of the diagnostic ions formed when organic compounds are bombarded with electrons under vacuum. In the source of a mass spectrometer the electrons are produced by a heated filament and impact the molecules causing ionization. The molecular ion (M^+) of the compound is the most important initial species formed. It is generated by the loss of an electron and therefore possesses both a positive ($^+$) and an unpaired electrons (-) other ions may form from the molecular ions according to the following reactions.

$M.^+ - A^+ + B$ (fragmentation)

The coupling of a gas chromatograph to a mass spectrometer as an integrated GC-MS system achieves that objective and the development of GC-MS has played a vital and central role in biomarker geochemistry, permitting evaluation of biomarkers in highly complex mixture (Brassel, 1993).

Saturate and Their Parameters

This class of biomarkers are saturated and they are identified by GC/MS at Mz=85.They contain pristane and phytane which their peaks were attached to (n-C_{17}) and (n-C_{18}) respectively. Their parameters were used to analysed information on maturity, Depositional condition, source rock and others (Sarraj, R. H. A., and Mohialdeen, I. M. J. 2021)

$\Rightarrow \frac{\text{Pristane}}{\text{phytane}}$ Ratio (1)

$\Rightarrow$ Carbon Preference Index (CPI)

$$\text{CPI}= \frac{2\{C23+C25+C27+C29\}}{\{C22+2(C24+C26+C28)+C30\}} \quad (2)$$

$\Rightarrow$ Odd Even predominance (OEP)

$$\text{OEP}= \frac{(C25+C27+C29)}{4C26+4C28} \quad (3)$$

Degree of waxiness (DEW)

$$\Rightarrow \text{DEW}= \frac{\sum_{(C21-C31)}}{\sum_{(C15-C20)}} \quad (4)$$

Steranes and Their Parameters

Steranes and diasteranes give a prominent M/Z 217 ion in their mass spectra, so this mass fragmentogram is used to monitor their distribution in a sample.In mature samples their finger print can be very complex, but identifications may be helped by monitoring the more specific ions for diasteranes(M/Z259) and 5^{α}(H), 14^{β}(H), 17^{β}(H)-steranes.

The parameters below were used to identify maturity, source organic matter and depositional condition.

$$\Rightarrow \frac{\text{C27dias}}{\text{C27}(\alpha\alpha\alpha_{+}\alpha\beta\beta)} \quad (5)$$

$$\Rightarrow \frac{\text{C27}\,\alpha\alpha\alpha_{\text{20R}}}{\text{C28}\,\alpha\alpha\alpha_{\text{20R}}} \quad (6)$$

$$\Rightarrow \frac{\text{C27}\,\alpha\alpha\alpha_{\text{20R}}}{\text{C29}\,\alpha\alpha\alpha_{\text{20R}}} \quad (7)$$

$$\Rightarrow \frac{\text{C27}\,\alpha\alpha\alpha_{\text{20S}}}{(\text{C27}\,\alpha\alpha\alpha_{\text{20S+C27}}\,\alpha\alpha\alpha_{\text{20R}})} \quad (8)$$

$$\Rightarrow \frac{\text{C29}\,\alpha\alpha\alpha_{\text{20S}}}{(\text{C29}\,\alpha\alpha\alpha_{\text{20S+C29}}\,\alpha\alpha\alpha_{\text{20R}})} \quad (9)$$

$$\Rightarrow \frac{\text{C29}\,\alpha\beta\beta}{\text{C29}\,\alpha\alpha\alpha_{+\text{C29}}\,\alpha\beta\beta} \quad (10)$$

The parameters that were calculated for M/Z 218 steranes and the relative percentage of C_{27}, C_{28} and C_{29}.

$$\%C_{27}= \frac{C27\ (R+S)}{C28(R+S)+C29(R+S)} *100 \quad (11)$$

$$\%C_{28}= \frac{C28\ (R+S)}{C27(R+S)+C29(R+S)} * 100 \quad (12)$$

$$\%C_{29}= \frac{C29\ (R+S)}{C27(R+S)+C28(R+S)} * 100 \quad (13)$$

Hopanes and Their Parameters

Hopane distributions are generally more complex in immature sediment samples than in mature sediments or oil. M/Z 191 mass fragmentograms with all major constituents are been identified. Hopanoids are abundant constituents of many bacteria, usually in the form of C_{30} or C_{35} hopanols or hopenes(Rezanka, T.*et al.,* 2010). The hopanes were the first class of biomarker to be employed in the assessment of thermal maturity, based on the temperature -controlled convertion of one molecule to another.Hopane distribution are generally similar in many oils and mature sediments, even of different environments.The parameters were used for maturity depositional environment and sources lithology were listed below:

$\Rightarrow \frac{Ts}{Tm}$ ratio (14)

$$\Rightarrow \frac{Ts}{(Ts+Tm)} \quad (15)$$

$$\Rightarrow \frac{{}_{31}\alpha\ \beta_{22S}}{(22S+22R)} \quad (16)$$

$$\Rightarrow \frac{{}_{32}\alpha\ \beta_{22S}}{(22S+22R)} \quad (17)$$

$$\Rightarrow \frac{{}_{32}\alpha\ \beta_{22S}}{(22S+22R)} \quad (18)$$

$$\Rightarrow \frac{{}_{30}\alpha\ \beta}{(\alpha\ \beta + \beta\ \alpha)} \quad (19)$$

$$\Rightarrow \frac{32rearr}{(30rearr+29\ \beta\ \alpha)} \quad (20)$$

$$\Rightarrow \frac{{}_{30}\beta\ \alpha}{({}_{30}\alpha\ \beta)} \quad (21)$$

$$\Rightarrow \frac{{}_{35}\alpha\ \beta}{{}_{34}\alpha\ \beta} \quad (22)$$

Penanthrenes and its Isomers Parameter

The distribution of phenanthrene are controlled by thermal maturity in the approximate range 0.6-1.7% mean vitrinite reflection (Rm). Phenanthrenes are tricyclic aromatic hydrocarbons, and they are identified at mass fragmentogram of M/Z=178 and M/Z
192 respectively. The phenanthrenes maturity,
Source rock, depositional Environment and Depositional condition parameters were listed below:

$\Rightarrow$ Methylphenanthrene ratio (MPR)

$$MPR=\frac{2-MP}{1-MP} \quad (23)$$

$\Rightarrow$ Ethyl phenanthrene index (MPI-1)

$$MPI\text{-}1= \frac{1.5[2-MP+3-MP]}{[P+1-MP+9-MP]} \quad (24)$$

Methyl phenanthrene distribution factor (MPDF)

$$MPDF = \frac{(3-MP+2-MP)}{(2-MP+2-MP+1-MP+9-MP)} \quad (25)$$

$\Rightarrow$ Vitrinite reflection.

a. $Rm_{(1)}+1.1*[\log_{10}{}^{MPR} +0.95]$ (26)

b. $\%R_0 = 2.242*MPDF-0.1666$ (27)

Triaromatic Steroids

The triaromatic steroids occur in at least two series, one demethylated series monitored by M/Z231 and a non-methylated series monitored by M/Z245. The triaromatic steroids have a much simpler distribution than the monoaromatic steroids due to the absence of isomers at
C-5, and no rearrangement. The parameters used were listed below:

$$TA\ ratio = \frac{C20}{C20+C28} \quad (28)$$

RESULTS AND DISCUSSION

Aliphatic Fractions

The aliphatic fractions of all the crude oils obtained from column chromatography using the same measurements and reagents shows similarities of both colourless colour. This indicate that all the samples are saturated.

Aromatic Fractions

The aromatic fractions of all the crude oils obtained from column chromatography using the same measurements and reagents indicated that all the Niger republic crude oils appeared to be dark yellow while the Nigeria crude oils appeared to be light yellow. This shows that they all have aromatic compounds, but there is variations in chemical compositions of Nigeria and Niger republic crude oils.

Molecular Composition of the Oils

Biomarkers identified in the crude oil samples (Table: 1-10) are N-alkanes (mz-85), Hopanes(mz-191), Steranes (mz 217 and mz 218), Phenanthrenes (mz 178), phenanthrenes isomers (192) and Triaromatic Steroids (231). Some heavy metals where identified in the samples (Table 2) by the use of Atomic Absorption Spectrometry.

Biomarker hydrocarbons are particularly useful in the correlation of oils and source rocks. However, correlation is achieved by comparison of the relative distribution of components within a class of biomarkers (often specific to source rock/or depositional environments) in a particular source rock (and hence in its related oil) is advantageous.

From the results of the relative distribution of C_{27}:C_{28}:C_{29} steranes revealed that, the Nigeria and Niger Republic crude oils are genetically related because they have uniform distribution of C_{29} steranes>C_{27} steranes >C_{28} steranes.

Result of Biomarker Analysis

The results of biomarker analysis (n-alkanes, phenanthrenes, triaromatic steroids, hopanes and steranes) where presented below:

Result of Saturated Compounds (N-Alkanes)
The results of saturated compounds parameters present in all the samples were presented in the table below;

Table 1: Saturated Hydrocarbon Biomarker Parameters of the Studied Crude Oils

RATIOS	CPI	0EP	DEW	PRIS/PHY
Agadem1	1.004986	1.045719	0.942707	4.356819
Agadem2	0.952461	0.967707	0.944184	0.690382
Oredo 5	0.942304	0.919436	1.963168	0.167013
Oredo 8	0.947799	0.912847	1.238139	0.18838
Oredo 11	0.948221	2.36642	1.312871	1.090817

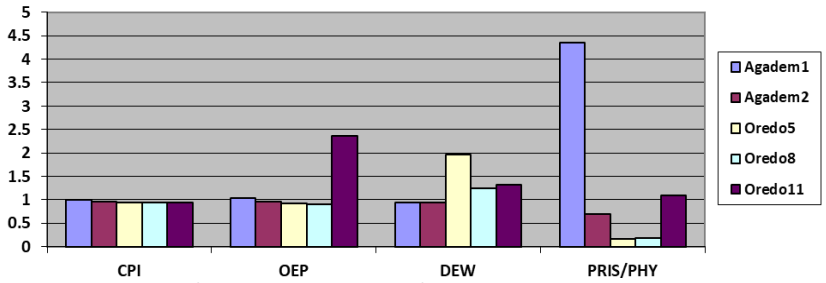

Figure 1: Barchat of Biomarker Analysis of the crude oil samples

Result of Steranes (217 & 218)
Result of steranes 217 & 218 that were present in the crude oil samples is presented in the table below;

Table 2: Distribution of Sterane 217 in the Crude Oil Samples

PEAKS	IUPAC NAME	STERIO CHEMISTRY	MOLECULAR FORMULA
M/Z217	13β(H)-17α(H)-20S-Dicholestane	20S	$C_{27}H_{48}$
	13β(H)-17α(H)-20R-Dicholestane	20R	$C_{27}H_{48}$
	24-Methyl-13β, 17α-Dicholestane	20S	$C_{28}H_{50}$
	24-Methyl-13β, 17α-Dicholestane	20R	$C_{28}H_{50}$
	5α, 14α, 17α-20S-Cholestane	20S	$C_{27}H_{48}$
	5α, 14α, 17α-20R-Cholestane	20R	$C_{27}H_{49}$
	5α, 14β, 17α-20S-Cholestane	20S	$C_{27}H_{50}$
	5α, 14β, 17α-20R-Cholestane	20R	$C_{27}H_{51}$
	24-Methyl-5α,14α, 17α20S-Cholestane	20S	$C_{28}H_{50}$
	24-Methyl-5α,14β, 17β20R-Cholestane	20R	$C_{28}H_{50}$
	24-Methyl-5α,14β, 17β20S-Cholestane	20S	$C_{28}H_{50}$
	24-Methyl-5α,14α, 17α20R-Cholestane	20R	$C_{28}H_{50}$
	24-Ethyl-13β, 17α20S-Cholestane	20S	$C_{29}H_{52}$
	24-Ethyl-13β, 17α20R-Cholestane	20R	$C_{29}H_{52}$
	24-Ethyl-5α,14α, 17α-Cholestane	20S	$C_{29}H_{52}$
	24-Ethyl-5α,14β, 17β-Cholestane	20R	$C_{29}H_{52}$
	24-Ethyl-5α,14β, 17β-Cholestane	20S	$C_{29}H_{52}$
	24-Ethyl-5α,14α, 17α-Cholestane	20R	$C_{29}H_{52}$

Table 3: Distribution of Sterane 218 Compound in the Crude Oil Samples

PEAKS	IUPAC NAME (M/Z 218)	STERIO CHEMISTRY	MOLECULAR FORMULA
$C_{27}\alpha$ ββ20S	5α(H)-14β(H)-17β(H)-20S-Cholestane	20S	$C_{27}H_{52}$
$C_{27}\alpha$ ββ20R	5α(H)-14β(H)-17β(H)-20R-Cholestane	20R	$C_{27}H_{52}$
$C_{28}\alpha$ ββ20S	24-Methyl-5α(H)-14β(H),17β(H)-20S-cholestane	20S	$C_{28}H_{50}$
$C_{28}\alpha$ ββ20R	24-Methyl-5α(H)-14β(H),17β(H)-20R-cholestane	20R	$C_{28}H_{50}$
$C_{29}\alpha$ ββ20S	24-Ethyl-5α(H)-14β(H),17β(H)-20S-cholestane	20S	$C_{29}H_{52}$
$C_{29}\alpha$ ββ20R	24-Ethyl-5α(H)-14β(H),17β(H)-20R-cholestane	20R	$C_{29}H_{52}$

Table 4: Percentage Analysis of Steranes Distribution

PARAMETERS	%C_{27}	%C_{28}	%C_{29}
Agadem1	19.96071	6.514191	73.5251
Agadem2	26.11951	20.49544	53.38505
Oredo5	9.267416	39.19098	51.5416

PARAMETERS	%C_{27}	%C_{28}	%C_{29}
Oredo8	35.57046	19.87107	44.55847
Oredo11	31.66128	16.97112	51.3676

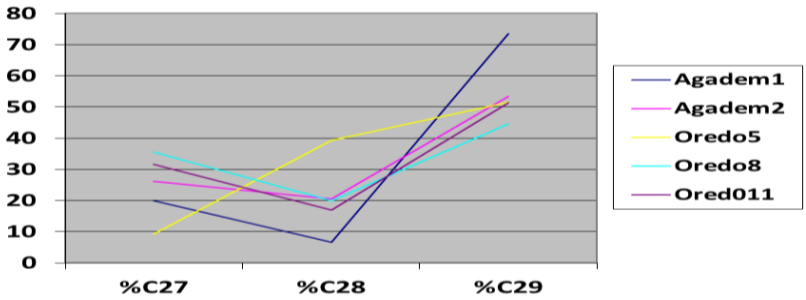

Figure 2: Line chart of percentage sterane distribution

Result of Hopane and its Parameters

The hopane and its parameters that are in the samples were presented in the tables below:

Table 5: Distribution of Hopane Compounds in the Crude Oil Samples

PEAKS	IUPAC NAME	STERIOCHEMISTRY	MOLECULAR FORMULA
Ts	18α(H)-Trisnorneohopane	NIL	
Tm	17α(H)-22,29,30-Trisnorhopane	NIL	
17β(H)	17β(H)-22,29,30-Trisnorhopane	NIL	
29αβ	17α(H)-21β(H),29,30-Norhopane	NIL	$C_{29}H_{50}$
29neo	18α(H)-30-Norneohopane	NIL	
29βα	17β(H)-21α(H)-Normortane	NIL	$C_{29}H_{50}$
30rearr	15αMe-17α(H)-27-diahopane	NIL	$C_{30}H_{52}$
30αβ	17α(H)-21β(H)-Hopane	NIL	$C_{30}H_{52}$
30βα	17β(H)-21α(H)-Moretane	NIL	$C_{30}H_{52}$
31αβS	17α(H)-21β(H)-22-Homohopane	22S	$C_{31}H_{54}$
31αβR	17α(H)-21β(H)-22-Homohopane	22R	$C_{31}H_{54}$
32αβS	17α(H)-21β(H)-22-Bishomohopane	22S	$C_{32}H_{56}$
32αβR	17α(H)-21β(H)-22-Bishomohopane	22R	$C_{32}H_{56}$
33αβS	17α(H)-21β(H)-22-Trishomohopane	22S	$C_{33}H_{58}$
33αβR	17α(H)-21β(H)-22-Trishomohopane	22R	$C_{33}H_{58}$
34αβS	17α(H)-21β(H)-22-Tetrakishomohopane	22S	$C_{34}H_{60}$
34αβR	17α(H)-21β(H)-22-Tetrakishomohopane	22R	$C_{34}H_{60}$
35αβS	17α(H)-21β(H)-22-Pentakishomohopane	22S	$C_{35}H_{62}$
35αβR	17α(H)-21β(H)-22-Pentakishomohopane	22R	$C_{35}H_{62}$

Table 6: Analysis of Hopane Distribution in the Crude Oil Samples

	Hopane Parameters								
	I	II	III	IV	V	VI	VII	VIII	IX
Agadem1	0.450871	0.310759	0.248738	0.557792	0.299313	0.353148	0.25965	2.340987	0.790577
Agadem2	0.616258	0.381287	0.341358	0.561844	0.304047	0.683273	0.498157	2.288963	1.013019
Oredo5	1.025286	0.506243	0.509889	NIL	0.618881	0.872169	0.815449	0.61582	NIL
Oredo8	0.882002	0.468651	NIL	NIL	0.218197	0.407126	0.577662	3.58302	NIL
Oredo11	0.860372	0.462473	0.520175	0.777751	0.26111	0.658995	0.138721	2.829805	NIL

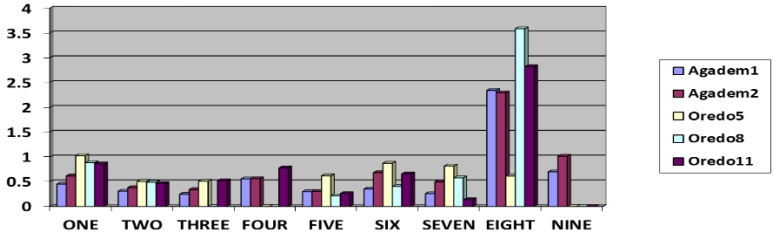

Figure 3: Bar chart of hopane parameters distribution analysis

Result of Phenanthrene and Its Isomers

Table7: Distribution of Phenanthrene compounds

M/Z	NAME
178	Phenanthrene
192	3-Methyl-phenanthrene
192	2-Methyl-phenanthrene
192	9-Methyl-phenanthrene
192	1-Methyl-phenanthrene

Table 8: Distribution Phenanthrene Parameters Analysis

PARAMETERS	MPR	MPI-1	MPDF	Rm1	%Ro
AGADEM [1]	0.464883	0.235707	0.287626	0.95	0.478858
AGADEM [2]	1.250362	0.577093	0.517538	0.95	0.994319
OREDO [5]	1.152107	0.796993	0.46145	0.95	0.868571
OREDO [8]	1.153154	1.095249	0.622677	0.95	1.230041
OREDO [11]	1.136694	0.814817	0.449323	0.95	0.841382

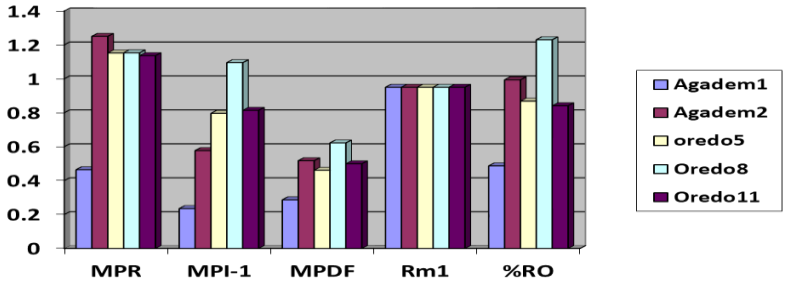

Figure 4: Distribution of phenanthrene parameters analysis

Triaromatic Steroids Parameters and Ratios

Table 9: Distribution of Triaromatic Steroids in the Crude Oil Samples

M/Z	IUPAC NAME
231	C_{20} Triaromatic steroids(TA)
231	C_{28} Triaromatic steroids(TA)

Table10: Distribution of Triaromatic Steroids Analysis

SAMPLES	T.A Ratio (%)
AGADEM[1]	0.038901
AGADEM[2]	0.021576
OREDO [5]	0.671629
OREDO [8]	0.294095
OREDO [11]	0.516134

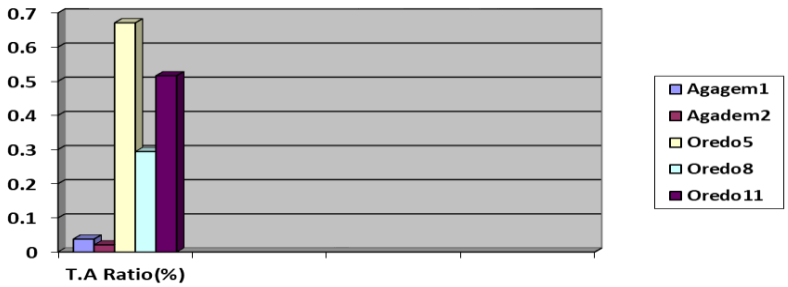

Figure 5: Bar Chart for distribution of Triaromatic

Discussion

The results of the biomarker analysis are discussed below:

Thermal Maturity

Several studies have confirmed oil CPI values to be around 1.0((Wang et. al. 2003 and kalaitzoglou et. al. 2004)**. CPI** or OEP values significantly above (odd preference) or below

(even preference) 1.0 indicate low thermal maturity, values of 1.0 suggest but do not prove an oil or rock extract is thermally matured and values below 1.o are unusual and indicate low-maturity oils or bitumens from carbonates. From the results obtained shows that, the values are Agadem[1] (1.0049), Agadem[2] (0.9524), Oredo[5] (0.9423), Oredo[8] (0.9477), Oredo[11] (0.9482). This are arranged in order of increasing maturity as Agadem[1]>Agadem[2]>Oredo[11]>Oredo[5]>Oredo[8].This show that, Agadem[1] is thermally matured while others crude oils are about to reach their thermal maturity (1.0).

22S/(22S+22R) of C_{31} is maturity parameter that is used for immature to early matured petroleum of oil window stage, it has a maximum value of 60%. According to peters and moldowan (1993). The values obtained in this research is 0.00% to 55% which is within the range. The 22S/(22S+22R) of C_{32} has equilibrium point of 60%. The result obtained indicate that the ranging from 0.00% to 56% with exception of Oredo[11] 77%. According to peters and moldowan (1993) high ratio of 30rearr/ (30rearr+29βα) is also maturity parameter which increases with maturity. The values are 35% to 87% this indicate that the oil is becomming more matured, the 29Ts (29Ts+29αβ) also proved as 30rearr/ (30rearr+29βα) aboved. Methyl phenanthrene index ratio also used as maturity parameter. According to peters et. al.(2005)(0.0-0.08):immature, (0.8-1.0) moderately mature and (1.o-above)exceptionally mature. from the results obtained revealed that , almost all the Nigeria crude oil(Oredo[5],Oredo[8],Oredo[11]) are moderately mature with exception of Niger republic crude oils(Agadem[1] and Agadem[2]: immature) Methyl Phenanthrene distribution factor, this give result of 0.28 to 0.62%Ro the values are below 1.0 with exception Oredo[11](1.23).The result revealed that agadem[1]:0.47(maginally mature), agadem[2]:0.99(middle of oil window) oredo[5]: 0.86(middle of oil window), Oredo[8]:1.23(end of oil window), Oredo[11]:0.84(middle of oil window).Triaromatic steroids are used for thermal maturity identification of biomarkers, from the results obtained indicate that values are 44,5% to 73%, thi revealed that the aromatic content are in high concentration more expecially the Niger republic crude oil with 53% and 73%.

Organic Matter Source

Peters et. al. (2005) revealed that C_{29} steroids dominates in terrigenous organic matter while marine organic matters are rich in C_{27} steroids.

The results obtained in this research indicates that $\%C_{27}$ steranes range from 9.2% to 35.5% and $\%C_{28}$ from 6.5% to 39.1% while $\%C_{29}$ from 44.5% to 73.5%. The $\%C_{29}$ steranes is dominant, with highest contribution followed by $\%C_{27}$ steranes then $\%C_{28}$ steranes(C_{29}>C_{27}>C_{28}), this proved that, the samples received significant contribution from terrigenous organic matter.

Depositional Environment

Peters et al. (2005) revealed that; CPI/OEP Values greaterthan one (>1), the depositional environment is lacustrine while values below one (<1) the deposional environment is less lacustrine. This prove that the depositional environment of all the samples is LESS LACUSTRINE.

From the results obtained of pr/ph ratio shows that all the crude oil samples has the pri/ph ratio below two (<2) this indicate that, the depositional environment is aquatic.Also 30βα/30αβ is hopane parameter that identify depositional environment of oils, the results obtained revealed that only the Niger republic crude oils that indicate their depositional environment with values (Agadem[1]:1.0049) and (Agadem[2]:09524). The 35βα/34αβ parameter used for depositional conditions. All the values are greaterthan 0.5(>0.5) this revealed that the depositional environment is terrestrial influence and fall with maturity.

Depositional Condition

Pristane/ Phytane ratio may therefore provide a measure of redox condition during diagenesis. According to peters *et. al*.2005, values greaterthan one (>1) suggest degree of oxicity while values below one (<1) are generally recorded for anoxic conditions that extend from the sediment up into the water column. is reducing conditions. From the results obtained indicate that the depositional condition of all the samples is reducing (anoxic, <1) with exception of Agadem[1] which is Anoxic (Pr/Ph ratio>1).

35αβ/34αβ is a parameter used for depositional condition by peters et al. 2005, values greater than one (>1.0) indicate anoxic depositional condition often seen in hypersaline environments. From the results obtained indicate that all the samples are in reducing conditions (<1) with exception of Agadem[1] (>1) oxidizing and this is in conformity with the results of pr/ph.

Degree of waxiness also used to assess depositional condition with values lessthan one (<1) is reducing and greaterthan one (>1) is oxidizing and this revealed that all the samples have value greater than one (>1) which are oxidizing with exception of Agadem[2] (<1) which is reducing.

CONCLUSION

Biomarkers investigate in the crude oil samples with Gas Chromatography Mass Spectrometry. Revealed that the crude oils in Agadem oil field Niger republic are related to the crude oil in the Oredo oil field Nigeria or Crude oil migrated from one location to another.

The overall biomarker distributions indicate geochemical similarities between the studied Agadem and Oredo crude oils, although additional oil–source-rock correlation and a larger sample set are required to establish a definitive genetic relationship.

Geochemical/geophysical investigation should be undertaken in the Nguru/Gaidam and Hadejia/Jama'are basins because crude oil migrate from one location to another (Azubike A.N.*et al*. 2026).

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