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The Distributions and Geochemical Significance of Triaromatic Steroids and Aromatic Dinosteroids in Crude Oils from Niger Delta Basin, Nigeria

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Abstract

The crude oils from the Northern and offshore Niger Delta basin, Nigeria have been characterized by gas chromatography-mass spectrometry (GC-MS) in terms of their origins, depositional environments and thermal maturity based on the distribution of triaromatic steroids and aromatic dinosteroids. The oil samples from ADL and MJI oilfields were characterized by higher abundance of C_{26} 20R + C_{27} 20S TAS, C_{28} 20S and C_{28} 20R triaromatic steroids while OKN, MJO and WZB oil samples were characterized by the predominance of C_{26} 20R + C_{27} 20S TAS peak. Among the compounds identified in m/z 245 mass chromatograms, C_{21}methyltriaromatic steroids, C_{22}methyltriaromatic steroids, C_{27}, 4-methyltriaromatic steroid, C_{27}, 3-Methyltriaromatic steroid + C_{28}, 3,24-Dimethyltriaromatic steroid and C_{27}, 4-methyltriaromatic steroid + C_{29}, 4-methyl-, 24-ethyltriaromatic steroid were the dominant compounds in the oil samples from ADL and MJI oilfields while the oil samples from OKN, MJO and WZB oilfields were characterized high abundance of all the compounds identified in m/z 245 mass chromatograms of the aromatic fractions of the oils. The crude oils were found to be formed from mixed origin (terrestrial and marine) but with significant contribution of dinoflagellates to the organic matter and deposited in freshwater-brackish/saline lacustrine environment. The oil samples were found to have early oil window maturity status based on the distributions and abundance of triaromatic steroids in the crude oils and this was further supported by well-established maturity parameters based on the saturate and aromatic biomarkers. This study showed that the abundance and distribution of triaromatic steroids and triaromaticdinosteroids can be used to assess the origin, depositional environments and thermal maturity of crude oils in the Niger DeltaBasin.

Keywords: Triaromatic steroids, Aromatic dinosteroids, crude oils, Niger Delta.

Introduction

Biological markers, or ‘‘molecular fossils”, which can be identifiedin extracts of ancient sediments and in crude oils, are routinely used to infer organicfacies, depositional environment andthermalhistoryofthehostrockor, in the case of petroleum, the source

rock(s). Particular classes of molecular fossils in petroleum have found increasing application as age diagnostic markers (Peters et al., 2005). Steranes with 27, 28 and 29 carbons and conventional side chains are important biomarkers for eukaryotic life. Furthermore, those with unconventional side chains offer opportunities for making more specific genetic links between families of organisms and mature sediments and oils (Moldowan et al.,1991).

Triaromatic steroids (TAS) may originate by aromatization and loss of a methyl group ($–CH_3$) from monoaromatic steroids (Rioloand Albrecht, 1985; Riolo et al., 1985; Peters et al., 2005). The C_{26}, C_{27}, C_{28} triaromatic steroids potentially retain genetic information about petroleum and source rocks similar to C_{27}, C_{28} and C_{29} regular steranes. 2005). The cross plot of C_{26}/C_{28} 20S versus C_{27}/C_{28} 20R triaromatic steroid ratios have been used to distinguish petroleum systems (Picha and Peters, 1998; Peters et al., 2005). Zhang et al. (2000, 2002) and Mi et al. (2007) reported relatively higher abundances of C_{26} 20S, C_{26} 20R + C_{27} 20S and C_{27} 20R TAS in oils derived from Cambrian source rocks, whereas C_{28} 20S and C_{28} 20R TAS are relatively abundant in oils which originated from Middle–Upper Ordovician carbonate source rocks in the Lunnan oil field, Tarim Basin. Also, triaromatic steroids have been successfully applied to thermal maturity assessment of crude oils and source rocks (Xiangchun et al., 2011; Asif and Fazeelat, 2012).

Triaromaticdinosteroids are important molecular fossil groups derived from dinosterols, compounds known to be the almost exclusive, widely occurring natural products of dinoflagellates (Robinson et al., 1984; Moldowan et al., 1996; Moldowan and Talyzina, 1998). The highest concentrations of these compounds are typically found in strata deposited since the beginning of the Mesozoic. However, Moldowan and Talyzina (1998) concluded that dinoflagellate ancestors may date back to the Early Cambrian on the basis of biomarker evidence. Zhang et al. (2002) reported the wide occurrence of 24-norcholestane, dinosteranesand

triaromaticdinosteroids with relatively high abundance in extracts from organic rich sediments in Cambrian and Precambrian (Sinian) rocks of the Tarim Basin. Biogeochemical evidence for dinoflagellate ancestors were reported in the Early Cambrian (Withers, 1987) and molecular evidence has provided a link of cyst-forming dinoflagellates with pre-Triassic ancestors (Moldowanand Talyzina, 1998). These studies suggest that planktonic algae suchas dinoflagellates and diatoms may have originated earlier than the Mesozoic.

However, there is limited reports on triaromatic steroids in Niger Delta crude oils while aromatic dinosteroids have been not reported or studied in Niger Delta crude oils. This study is conducted to investigate the distributions and geochemical significance of aromatic steroids and aromatic dinosteroids in Niger Delta source rocks.

Geological and Stratigraphic Setting

Niger delta is a sedimentary basin situated in the re-entrant of the Gulf of Guinea, West Africa. The sub-aerial portion of the Niger Delta covers approximately 75,000 km^2 and stretches about 200 km from apex to mouth. The total sedimentary prism encompasses 140000 km^2, with a maximum stratigraphic thickness of about 12 km (Whiteman, 1982). The stratigraphy of the thick sedimentary sequence is divided into three lithostratigraphic units, namely the Akata, Agbada and Benin Formations (Short and Stauble,1967).

The uppermost unit, the Benin Formation which ranges from Oligocene to recent in age, comprises continental/fluviatile sands, gravels, and backswamp deposits up to 2500 m thick. These are underlain by the Agbada Formation of paralic, brackish to marine, coastal and fluvio-marine deposits. These are mainly interbedded sandstones and shale with minor lignite organized into coarsening upward 'offlap' cycles. Underlying this unit is the Akata Formation, ranging in age from Paleocene to Miocene consists of mainly of overpressure shales deposited under fully marineconditions.-

The depobelts are partitioned into 6-7east-west bound blocks corresponding to discrete periods of the deltas evolutionary history starting from the oldest in the north, northern delta to theyoungest, offshore in the south (Doust and Omatsola, 1990). It is believed that each depobelt constitutes a more or less autonomous unit with respect to sedimentation, structural deformation and hydrocarbon generation and accumulation (Evamy et al., 1978). Available source rocks in the basinexist mainly in the lower parts of the paralic sequence (Agbada Formation) and uppermost strata of the continuous marine shale (Akata Formation; Evamyet al., 1978; Ekweozor and Daukoru, 1994). The hydrocarbon habitat of the Niger Delta is mostly the sandstone reservoir of the Agbada Formation where oil and gas are usually trapped in rollover anticlines associated with growthfaults.

Materials andMethods

Samples

Forty-one crude oil samples from five wells in five fields were collected and analyzed.

Fractionation andAnalysis

The crude oils were separated into saturated and aromatic hydrocarbon fractions using silica gel/alumina chromatography columns eluted with n-hexane and dichloromethane:n-hexane (2:1, v:v), respectively (Li et al., 2012). The GC-MS analyses of the saturate and aromatic fractions were performed on an agilent 5975i gas chromatography (GC) equipped with an HP-5MS (5% phenylmethylpolysiloxane) fused silica capillary column (60m x 0.25mm i.d., x 0.25µm film thickness) coupled to an agilent 5975i mass spectrometry (MS). The GC operating conditions are as follows: the oven temperature was held isothermally at 80˚C for 1 min, ramped to 310˚C at 3˚C/min and held isothermal for 16 min (Li et al., 2012). Helium was used as the carrier gas with constant flow rate of 1.2 mL/min. The MS was operated in the electron impact (EI) mode at 70eV, an ion source temperature of 250 ^{o}C and injector temperature of 285^{o}C. The identification and elution order of fluorene and its derivativeswere

determined by comparison of their mass spectra and relative retention times in the corresponding mass chromatograms with those reported in literature (Zhang et al., 2000, 2002; Wang et al., 2008; Li et al., 2012).

Results andDiscussion

Distribution characteristics of Triaromatic Steroids and Aromatic Dinosteroids in Crude Oils from Niger DeltaBasin

The m/z 231 and 245 mass chromatograms showing the distributions of triaromaticsteroids (TAS) and aromatic dinosteroids in the oil samples are shown in Figure 1. The peak identities are shown in Table 1. The crude oils from ADL and MJI oilfields are characterized by higher abundance of C_{26} 20R + C_{27} 20S, C_{28} 20S and C_{28}20R triaromatic steroids while C_{26} 20S occur as least (Fig. 1). This pattern of distribution has been reported in a freshwater lacustrine crude oils from LinnanSubsag, Shandong Province, China (Xiangchun et al., 2011) and crude oils from Ordovician reservoirs from the Tahe oil field, Tarimbasin, China (Li et al., 2012). OKN, MJO and WZB oil samples are characterized by the predominance of C_{26} 20R + C_{27} 20S TASpeakswhileC_{28}20SandC_{28}20R TAS and C_{26} 20S occurred relatively low (Fig. 1). Crude oils and source rocks from saline and brackish lacustrine environments have been reported to contain low abundance of C_{28} TAS (Xiangchun et al., 2011). Also, Cambrian and Lower Ordovician source rocks have been shown to be characterized by lower C_{28} 20S and C_{28} 20R TAS and higher C_{26} 20S, C_{27} 20R and C_{26} 20R + C_{27} 20S TAS peaks, which is similar to those reported in the literature (Zhang et al., 2002; Mi et al., 2007; Li et al., 2012). There are appreciable quantities of C_{20} and C_{21}triaromatic steroids in all the oil samples studied in this work (Fig. 1). Among the methyltriaromatic steroids, dimethyltriaromatic steroids, aromatic dinosteroids and C_{29}, 3-Methyl-, 24-ethyltriaromatic steroids identified in m/z 245 mass chromatograms, C_{21}methyltriaromatic steroids, C_{22}methyltriaromatic steroids, C_{27}, 4-methyltriaromatic steroid, C_{27}, 3-Methyltriaromatic steroid + C_{28},3,24-

Dimethyltriaromatic steroid and C_{27}, 4-methyltriaromatic steroid + C_{29}, 4-methyl-, 24-ethyltriaromatic steroid are the dominant compounds in the oil samples from ADL and MJI oilfields while one of the peaks of aromatic dinosteroids occurs as the least (Fig. 2). The samples from OKN, MJO and WZB oilfields are characterized by high abundance of all the compounds identified in the m/z 245 mass chromatograms of the aromatic fractions of the crude oils (Fig. 2). The significant amounts of aromatic dinosteroids observed in the oil samples indicates significant contributions of dinoflagellates into the organic matter that formed the oils (Li et al., 2012; Zhang et al., 2002; Wang et al.,2008).

Geochemical Significance of Triaromatic Steroids and Aromatic Dinosteroids in Crude Oils from Niger DeltaBasin.

The geochemical parameters computed from triaromatic steroids, aromatic dinosteroids and other geochemical parameters are shown in Table 2. The geochemical parameters are used determine the origin and maturity status of the Niger Delta crude oils.Occurrences of aromatic steroids are influenced by multiple factors and thus can be used as indicator of different source inputs and depositional environments. For example, organic matter formed in fresh water environment is abundant with C_{28}-TAS while in saline and brackish water environments it is abundant with C_{26}-TAS (Xiangchun et al., 2011). The C_{26}/C_{28} – 20S TAS and C_{27}/C_{28}- 20R TAS ratios for the rock samples range from 0.21 to 0.50 and 0.43 to 0.84, respectively (Table 2). The low values of C_{26}/C_{28} – 20S TAS recorded in some oil samples indicate oils formed from a freshwater environment while higher values recorded in some samples indicate a lake environment of brackish-saline water (Xiangchun et al., 2011; Li et al., 2012). These results show that the crude oils studied are formed from source rocks of mixed origin (terrestrial and marine) deposited in freshwater-brackish/saline lacustrine environments. The cross plots of C_{26}/C_{28} – 20S TAS versus C_{27}/C_{28}- 20R TAS showedthat

the oil samples from the same field received similar organic material (Fig. 3). The triaromaticdinosteroids are assumed to originate from dinosterol and related sterols, which characterize modern marine dinoflagellates (Moldowan and Talyzina, 1998; Peters et al., 2005). This association suggests that triaromaticdinosteroids are useful biomarkers for improving the recognition of ancient dinoflagellates. The triaromaticdinosteroid hydrocarbon index (TDSI) could be used to reflect the contribution of organic matter from dinoflagellates in the source rocks and crude oils. This parameter has been used to indicate the contribution of dinoflagellates to the oils and source rocks of the Tarim Basin, NW China (Zhang et al., 2000, Li et al. 2012) and Paleogene lacustrine sediments from Bohai Bay Basin, China (Wang et al., 2008). The TDSI values for the rock samples range from 0.52 to 0.71 (Table 2). These values indicate significant contributions of dinoflagellates to the organic matter that formed the source rocks. Progressively more evidence has suggested thatdinoflagellates or theirancestors

appeared during the Early Cambrian (about 520 Ma, Moldowan and Talyzina, 1998) or even Precambrian (Summons et al., 1992; Moldowan et al., 2000; Zhang et al., 2002). In this study, the presence of aromatized dinosteroids with extremely high relative concentrations indicates that dinoflagellates or their ancestors lived during the Cambrian and Early Ordovician in the seas of Niger Delta.

Ratios of C_{26}-TAS 20S/ (20S+20R) and C_{28}-TAS 20S/(20S+20R) are mostly used to evaluate thermal maturity (Xiangchun et al., 2011; Asif and Fazeelat, 2012). In the crude oils studied, theratiosarewithintherangeof0.22to 0.28 and 0.52 to 0.59 respectively (Table 2), suggesting early mature characteristics. The values also vary over a small range, indicating similar maturity status for the oils. The Methylphenanthrene index (MPI-1) and 20S/(20S+20R) C_{29}steranes for the rock samples range from 0.69 to 0.96 and 0.28 to 0.47, respectively (Table 2), supporting that the oils are within oil window (Seifert and Moldowan,1981; Radke, 1988) already inferred fromthe

from the triaromatic steroids based maturity parameters. These findings are consistent with the previous report on maturity status of Niger Delta crude oils (Sonibare et al., 2008; Faboya et al, 2015).

4.0 Conclusion

The crude oils from the Northern and offshore Niger Delta basin, Nigeria have been characterized by gas chromatography-mass spectrometry (GC-MS) in terms of their origins, depositional environments and thermal maturity based on the distribution of triaromatic steroids and aromatic dinosteroids. The oil samples from ADL and MJI oilfields were characterized by higher abundance of C_{26} 20R + C_{27} 20S TAS, C_{28} 20S and C_{28} 20R triaromatic steroids while OKN, MJO and WZB oil samples were characterized by the predominance of C_{26} 20R + C_{27} 20STAS peak. Among the compounds identified in m/z 245 mass chromatograms, C_{21}methyltriaromatic steroids, C_{22}methyltriaromatic steroids, C_{27}, 4-methyltriaromatic steroid, C_{27}, 3-Methyltriaromatic steroid + C_{28}, 3,24-Dimethyltriaromatic steroid and C_{27}, 4-methyltriaromatic steroid + C_{29}, 4-methyl-, 24-ethyltriaromatic steroid were the dominant compounds in theoil samples from ADL and MJI oilfields while the oil samples from OKN, MJO and WZB oilfields were characterized high abundance of all the compounds identified in m/z 245 mass chromatograms of the aromatic fractions of the oils. The crude oils were found to be formed from mixed origin (terrestrial and marine) but with significant contribution of dinoflagellates to the organic matter and deposited in freshwater-brackish/saline lacustrine environment. The oil samples were found to have early oil window maturity status based on the distributions and abundance of triaromatic steroids in the crude oils and this was further supported by well-established maturity parameters based on the saturate and aromatic biomarkers.

This study showed that the abundance and distribution oftriaromatic steroids and triaromaticdinosteroids can be used to assess the origin, depositional environmentsand

thermal maturity of crude oilsin the Niger DeltaBasin.

References

Asif, M. and T. Fazeelat (2012). Petroleum geochemistry of the Potwar Basin, Pakistan: II – Oil classification based on heterocyclic and polycyclic aromatic hydrocarbons. Applied Geochemistry 27: 1655–1665.

Doust, H., and E. Omatsola (1990).Niger Delta divergent/passive margin basins. AAPG Bull. Mem.45:201–238

Ekweozor C. M. and E.M. Daukoru (1994).Northern delta depobelt portion of Akata-Agbada petroleum system, Niger Delta, Nigeria. In: AAPG Memoir, vol 60. American Association of petroleum Geologists, Tulsa, pp 599–614

Evamy, B. D., Haremboure, J., Kamerling, P., Knaap, W. A.,Molloy, F. A., and Rowlands, P.
H. (1978).Hydrocarbon habitat of Tertiary Niger Delta.AAPG Bull.62:277–298

Faboya, O. L., Sonibare, O. O., Liao, Z., Ekundayo, O., and Y. Tian(2015).Oil-source Rock Correlation and Distributions of Pyrrolic Nitrogen Compounds in Oils from the Niger Delta, Nigeria.*Petroleum Science and Technology*33:1253–1266

Li, M., Wang, T.G., Lillis, P.G., Wang, C. and S. Shi (2012b).The significance of 24-norcholestanes, triaromatic steroids and dinosteroids in oils and Cambrian-Ordovician source rocks from the cratonic region of the Tarim Basin, NW China.Applied Geochemistry 27, 1643– 1654.

Mi, J., Zhang, S., Chen, J., Tang,L. and Z. He (2007). The distribution of the oil derived from Cambrian source rocks in Lunna area, TheTarim Basin, China. Chin. Sci. Bull. 52(Suppl. I), 133–140.

Moldowan, J.M. and N.M. Talyzina (1998). Biogeochemical evidence for dinoflagellate ancestors in the

Early Cambrian.Science 281, 168–1170.

Moldowan, J.M., Dahl, J., Jacobson, S.R., Huizinga, B.J., Fago,F.J., Shetty, R., Watt, D.S., and K.E. Peters (1996). Chemostratigraphic reconstruction of biofacies: molecular evidence linking cyst-forming dinoflagellates with pre-Triassic ancestors. Geology 24, 159–162

Moldowan, J.M., Lee, C.Y., Watt, D.S.,Jeganathan, A., Slougui, N. and E.J. Gallegos, (1991). Analysis and occurrence of C26steranes in petroleum and source rocks.GeochimicaetCosmochimi caActa 55, 1065–1081.

Peters, K.E., Walters, C.C. and J.M. Moldowan (2005). The Biomarker Guide, second ed. Cambridge University Press.

Picha, F.K. and K.E. Peters (1998).Biomarker oil-to-source rock correlation in the Western Carpathians and their foreland, Czech Republic.Petrol.Geosci. 4, 289–302.

Radke, M. (1988).Application of aromatic compounds as maturity indicators in source rocks and crude oils. Marine and Petroleum Geology 5, 224–236.

Riolo, J. and P. Albrecht (1985). Novel rearranged ring C monoaromatic steroid hydrocarbons in sediments and petroleums. Tetrahedron Lett. 26,2701–2704.

Riolo, J., Ludwig, B. and P. Albrecht (1985). Synthesis of ring C monoaromatic steroihydrocarbonsoccurring in geological samples.Tetrahedron Lett.26, 2607–2700 Robinson, N., Eglinton, G. and S.C. Brassell (1984).Dinoflagellate origin for sedimentary 4a-methylsteroids and 5a- stanols. Nature 308,439–441.

Seifert, W.K. and J.M. Moldowan (1981).Palaeoreconstruction by Biological markers.*GeochimicaetCosmochimicaActa*45:783-794

Short, K. C., and A. J. Stauble (1967). Outline of geology of Niger Delta. AAPG 51:761-779.

Sonibare,O.,Alimi,H.,Jarvie,D.,and O.A. Ehinola (2008). Origin and occurrence ofcrude oil in the

Niger Delta, Nigeria. J. Pet. Sci. Eng.61:99–107

Summons, R.E., Thomas, J., Maxwell, J.R. and C.J. Boreham, C.J. (1992).Secular andenvironmental constraints on the occurrence of dinosterane in sediments.Geochim.Cosmochim.Acta 56:2437–2444.

Wang, G., Wang, T.-G., Simoneit, B.R.T., Chen, Z., Zhang, L. and J. Xu (2008a). The distribution of molecular fossils derived from dinoflagellates in Paleogene lacustrine sediments (Bohai Bay Basin, China). Org. Geochem. 39: 1512–1521.

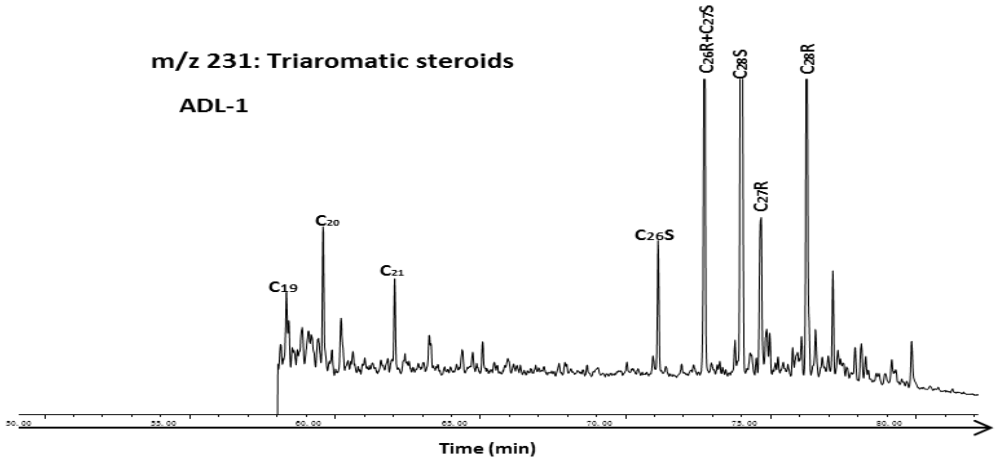
Whiteman, A. (1982). Nigeria: Its Petroleum Geology, Resources and Potentials, vol. 1 and 2. Pub. Graham and Trontman Ltd., 394pp

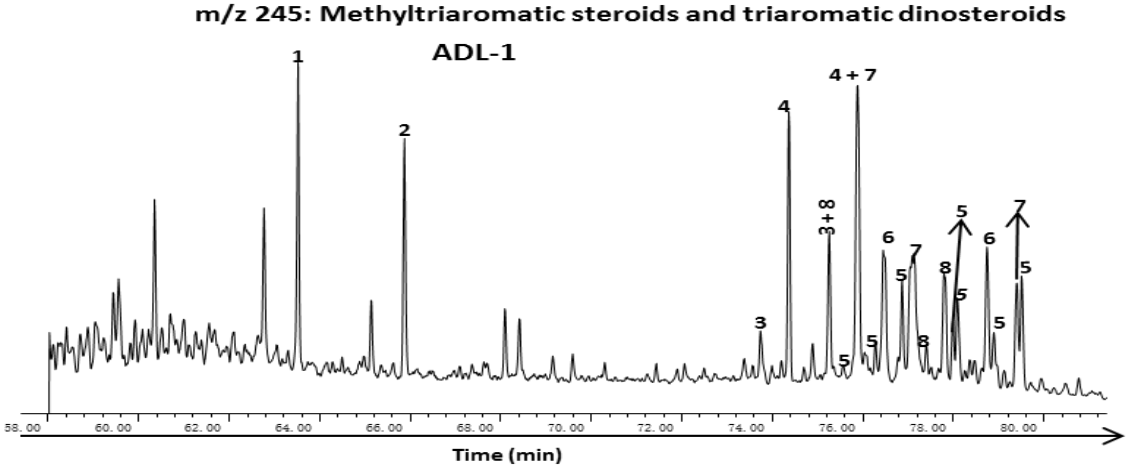
Withers, N. (1987).Dinoflagellates sterols. In: Taylor, F.J.R. (Ed.). The Biology of Dinoflagellates. Blackwell Scientific, Oxford, pp. 316–359.

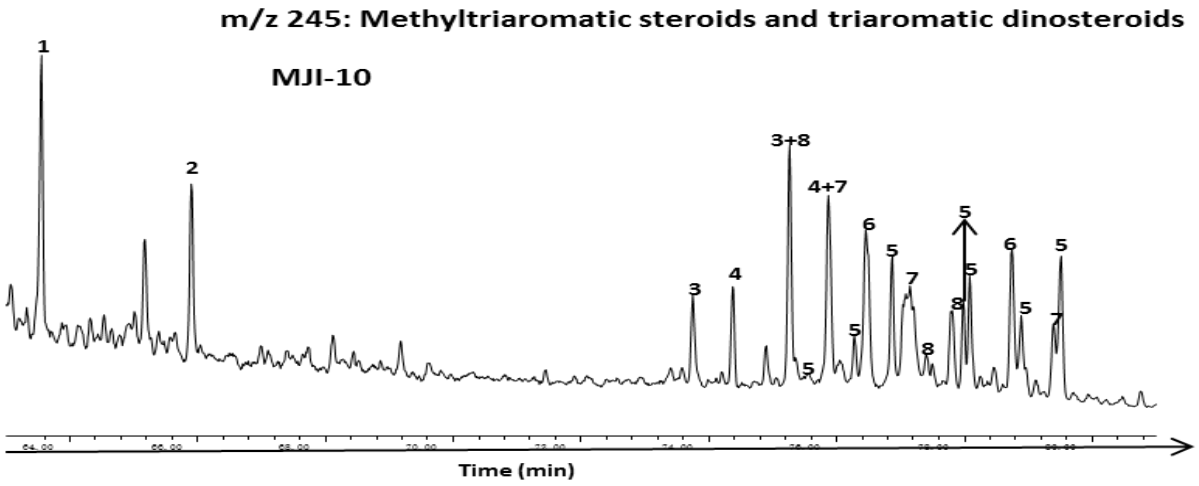
Xiangchun, C., Zuozhen, H., Xiaofei, S. and Y. Chengpeng, (2011). Geochemical characteristics of aromatic hydrocarbons in crude oils from the LinnanSubsag, Shandong Province, China. *Chinese Journal of Geochemistry* 30:132–137

Zhang, S., Moldowan, J.M., Li, M., Bian, L., Zhang, B., Wang, F., He, Z. and D. Wang (2002). Theabnormal distribution of molecular fossils in the pre-Cambrian and Cambrian: its biological significance. Sci. China D (Earth Sci.) 45:193–199.

Zhang, S., Wang, F. and B. Zhang (2000).Middle–upper Ordovician source rock geochemistry of the Tarim Basin.Acta Petrol.Sin. 21: 23–28 (in Chinese with English abstract).


m/z 231: Triaromatic steroids
ADL-1
C19
C20
C21
C26S
C26R+C27S
C28S
C27R
C28R
Time (min)


m/z 245: Methyltriaromatic steroids and triaromatic dinosteroids
ADL-1
1
2
3
4
4 + 7
3+8
5
6
7
8
58.00
60.00
62.00
64.00
66.00
68.00
70.00
72.00
74.00
76.00
78.00
80.00
Time (min)


m/z 245: Methyltriaromatic steroids and triaromatic dinosteroids
MJI-10
Time (min)

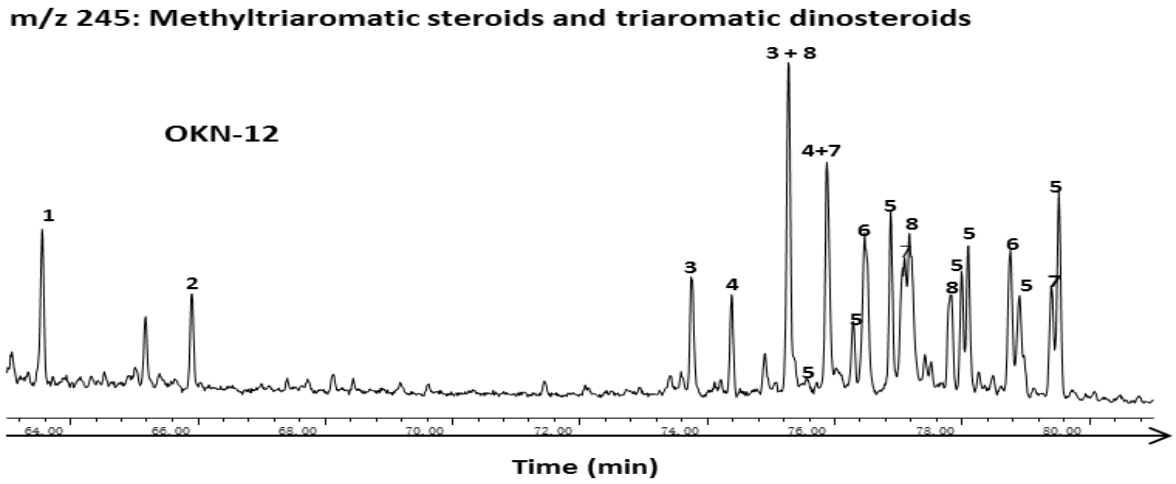

m/z 245: Methyltriaromatic steroids and triaromatic dinosteroids
OKN-12
Time (min)

Fig. 2: m/z 245 Mass chromatograms showing the distributions of methyltriaromatic steroids and aromatic dinosteroids in the crude

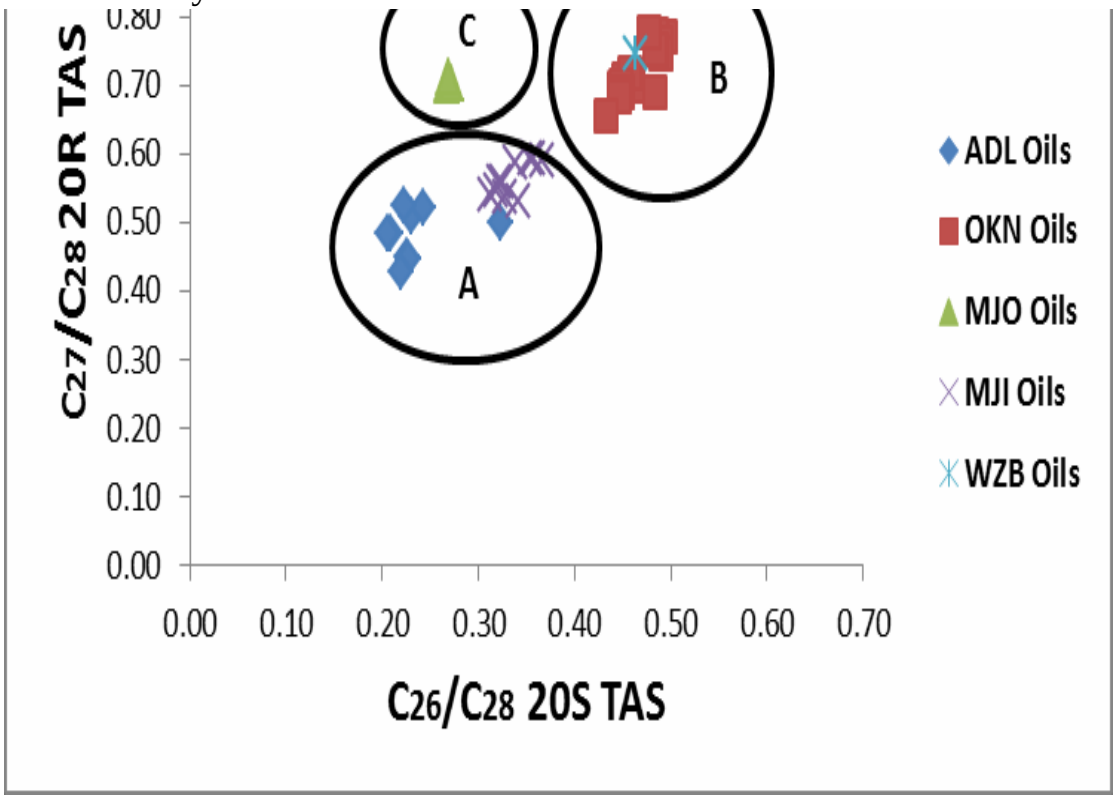


Fig. 1: m/z 231 Mass chromatograms showing the distributions of triaromatic steroids in the crude oils from the Niger Delta.

I Oil samples.

Table 1: The peak identities of the compounds identified in m/z 245 mass Chromatograms of aromatic fractions of Niger Delta rock samples.

PEAK NUMBER	COMPOUND
1	C_{21}Methyltriaromatic steroid
2	C_{22}Methyltriaromatic steroid
3	C_{27},3-Methyltriaromatic steroid
4	C_{27},4-Methyltriaromatic steroid
3+8	C_{27},3-Methyltriaromatic steroid+C_{28},3,24-Dimethyltriaromatic steroid
5	C_{29}Triaromatic dinoflagellatessterane
4+7	C_{27},4-Methyltriaromatic steroid+C_{29},4-Methyl-, 24-Ehytriaromatic steroid
6	C_{29},3-Methyl-, 24-Ethyltriaromatic steroid
7	C_{29},4-Methyl-,24-Ethyltriaromatic steroid
8	C_{28},3,24-Dimethyltriaromatic steroid

Table 2a: Source and thermal maturity parameters computed from triaromatic steroids, aromaticdinosteroids and related compounds in Niger Delta crudeoils

Sample	Depth(m)	C_{27}/C_{28} 20R TAS	C_{26}/C_{28} 20S TAS	TDSI	20S/(20S+20R) C_{26} TAS	20S/(20S+20R) C_{28} TAS	20S/20S+20R C_{29}	MPI^{-1}
ADL1	2602-2607	0.48	0.21	0.59	0.23	0.55	0.41	0.73
ADL2	2602-2607	0.48	0.21	0.57	0.23	0.56	0.40	0.71
ADL3	2702-2704	0.50	0.32	0.57	0.23	0.52	0.40	0.69
ADL4	2718-2720	0.51	0.23	0.52	0.22	0.59	0.44	0.73
ADL5	2759-2763	0.52	0.24	0.58	0.25	0.55	0.43	0.70
ADL6	2766-2770	0.45	0.23	0.58	0.24	0.55	0.45	0.78
ADL7	2905-2908	0.52	0.22	0.56	0.23	0.54	0.45	0.79
ADL8	2964-2967	0.45	0.23	0.58	0.24	0.56	0.44	0.82
ADL9	3064-3052	0.43	0.22	0.59	0.24	0.54	0.47	0.84
OKN1	1749-1750	0.71	0.45	0.65	0.28	0.55	0.36	0.95
OKN2	1892-1895	0.77	0.49	0.68	0.27	0.53	0.40	0.91
OKN3	1905-1907	0.77	0.48	0.68	0.27	0.54	0.40	0.91
OKN4	1952-1955	0.69	0.45	0.65	0.27	0.54	0.33	0.93
OKN5	2050-2059	0.76	0.49	0.68	0.27	0.53	0.41	0.90
OKN6	2369-2555	0.75	0.49	0.68	0.27	0.52	0.39	0.95
OKN7	2377-2672	0.75	0.49	0.68	0.27	0.53	0.43	0.90
OKN8	2469-2782	0.75	0.48	0.67	0.27	0.53	0.39	0.89
OKN9	2485-2793	0.78	0.48	0.68	0.27	0.54	0.41	0.91

OKN10	2489-2491	0.70	0.46	0.66	0.27	0.54	0.36	0.76
OKN11	2521-2523	0.72	0.46	0.66	0.27	0.55	0.33	0.70

Table 2b: Source and thermal maturity parameters computed from triaromatic steroids, aromaticdinosteroids and related compounds in Niger Delta crudeoils

Sample	Depth(m)	C_{27}/C_{28} 20R TAS	C_{26}/C_{28} 20S TAS	TDSI	20S/(20S+20R) C_{26} TAS	20S/(20S+20R) C_{28} TAS	20S/20S+20R C_{29}	MPI^{-1}
OKN12	2530-2537	0.70	0.45	0.65	0.27	0.54	0.37	0.76
OKN13	2566-2568	0.69	0.45	0.64	0.28	0.55	0.35	0.94
OKN14	2677-2683	0.68	0.45	0.62	0.28	0.54	0.41	0.62
OKN15	3148-3154	0.69	0.48	0.62	0.28	0.54	0.38	0.65
OKN16	3593-3605	0.66	0.43	0.61	0.27	0.53	0.41	0.70
MJO1	2207-2216	0.70	0.44	0.69	0.27	0.52	0.45	0.77
MJO2	2070-2081	0.70	0.44	0.69	0.27	0.53	0.46	0.77
MJO3	2091-2104	0.70	0.45	0.68	0.27	0.53	0.45	0.78
MJO4	2096-2101	0.71	0.44	0.68	0.27	0.53	0.45	0.78
MJI1	1607-1611	0.59	0.35	0.64	0.26	0.55	0.28	0.76
MJI2	1777-1779	0.56	0.32	0.63	0.26	0.56	0.40	0.84
MJI3	1795-1797	0.56	0.32	0.63	0.26	0.55	0.36	0.83
MJI4	1920-1921	0.55	0.32	0.64	0.26	0.55	0.37	0.96
MJI5	1936-2342	0.59	0.36	0.64	0.26	0.55	0.35	0.78
MJI6	1944-1947	0.54	0.33	0.64	0.26	0.54	0.34	0.82
MJI7	1948-1950	0.54	0.31	0.62	0.26	0.56	0.39	0.86
MJI8	1979-2398	0.59	0.34	0.63	0.26	0.55	0.36	0.82
MJI9	2442-2444	0.53	0.34	0.62	0.26	0.55	0.38	0.83
MJI10	3030-3036	0.59	0.37	0.62	0.27	0.53	0.38	0.83
WZB1	1610-2647	0.84	0.50	0.71	0.24	0.52	0.42	0.86
WZB2	1811-1957	0.75	0.46	0.69	0.26	0.52	0.37	0.86

C_{26}/C_{28} 20S TAS = triaromatic steroids ratio.
C_{27}/C_{28} 20R TAS = triaromatic steroids ratio
TDSI = Triaromaticdinosteroids/(triaromaticdinosteroids + 3-methyl-24-ethyl triaromatic steroids) index
C_{26} TAS S/(S+R) = C_{26}triaromatic steroids maturity parameters
C_{28} TAS S/(S+R) = C_{28}triaromatic steroids maturity parameters
MPI-1 = methylphenanthrene index 1
20S/(20S+20R) C_{29} = C_{29}steranes maturity parameters.