

Organic Geochemical Evaluation of the Middle Devonian to Late Carboniferous Source Rocks, South East Murzuq Basin, SW Libya

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Abstract— Ninety-four rock samples were taken from the Middle to Late Devonian Awaynat Wanin, Early Carboniferous Marar, Late Carboniferous Assedjefar formations. The cuttings of Assedjefar Marar and Awaynat Wanin Formations collected from two wells, in the A1-163 oil field, located in the Murzuq Basin. Rock-Eval Pyrolysis, Total Organic Carbon (TOC) and molecular biomarker (via the use of chromatography-mass spectrometry, GC-MS) as geochemical parameters were applied to find out the types of kerogen, depositional conditions and level of organic matter maturity for representative samples. Such Formations are poor to excellent quantity of organic matter. Results of TOC related with remaining generation potential (S₂) and hydrogen index (HI) data showed that the organic matter attributed to Type II/III and Type III kerogen (gas and oil-prone organic matter), as well connected to S₁ parameter indicated indigenous hydrocarbon exist. Ratios data of individual hydrocarbons, n-alkanes, isoprenoids and biomarkers parameters of Triterpanes and steranes indicate non-marine with marine organic matter deposited under non-marine conditions for Awaynat Wanin samples while Marar and Assedjefar Formations deposited in non-marine to deltaic conditions. The maturity data from T_{max}, spore colour index and biomarker related parameters based on terpanes, steranes, and low molecular-weight hydrocarbons indicate the studied rocks are ranged from immature to mature.

Key Words— Awaynat Wanin Formation, Middle to Late Devonian, Kerogen, Biomarker, Rock Eval, Murzuq Basin

I. INTRODUCTION

In southwestern Libya, the Murzuq Basin is the great production oil and gas province in this region, with a zone of roughly 60000 km² (Fig. 1). It extends southward into Niger. Despite the geochemical studies about geological petroleum system of Murzuq Basin were presented great information. Murzuq Basin has six of the larger twenty nine oil fields in Libya and it has the second reserves after those of Sirte Basin (Hallett and Clark-Lowes, 2016). However, more significant can be obtained from organic geochemical evaluation by biomarkers of saturated and aromatic hydrocarbons in particular of the depositional environment of the source rock, Organic Matter type and level of thermal maturity. Over the recent decades, the origin of organic matter in sedimentary rocks and petroleum has taken extreme attention. The data within the organic matter in source rock and crude oil has been effectively used for the understanding of depositional conditions of environments and calculation of the type and thermal maturity of this organic matter (e.g. Peters and Moldowan, 1993; Philp, 2007). An important of published investigation was carried out over the last period based on the use of contemporary geochemical technique and determined valued data around the organic contribution and the depositional environment. In the Devonian and Carboniferous Formations, the T_{max} showed that most of the samples are located inside the mature region. Besides this, Aromatic hydrocarbon ratios revealed two levels of thermal maturity and the hot shale member displayed high aromatic content, revealed stage of reasonable thermal maturity whereas rest intervals showed low aromatic hydrocarbon indicated marginal thermal maturity (Aboglila et al 2018). In 2020, Albaghdady et al published in valued manuscript that the Devonian Awaynat Wanin Formation presented TOC data varied from good to excellent for oil generation and kerogen type II, involved with II/III type. In addition, the T_{max} values ranged between 435 and 454°C. The key level of hydrocarbon generation has been touched. A normal alkane, distribution isotope isoprenoids and stable carbon of oil samples from the Murzuq Basin established that the crude oils derived from marine organic matter with trending to distinguished increase of waxy organic matter lacustrine sources. The hopane, tricyclic terpane and sterane distributions of the oils are inconsistent and confirming alterations in the source of their

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structure organic matter sediments (Aboglila et al 2020a). Nevertheless, the hot shale facies at the base of the Silurian Tanezzuft Formation has recognized as the principal source rock for Murzuq Basin, there are other organic-rich formations, characterized by high TOC content, suggested as good source hydrocarbon potential with a large range of maturity degrees between source extractions, based on Ro% values (Aboglila et al 2020b). In this study, geochemical evaluation of organic matter type, thermal maturity was established for samples derived from the Middle Devonian to Late Carboniferous age. This assessment is also suggested several hydrocarbon sources existed.

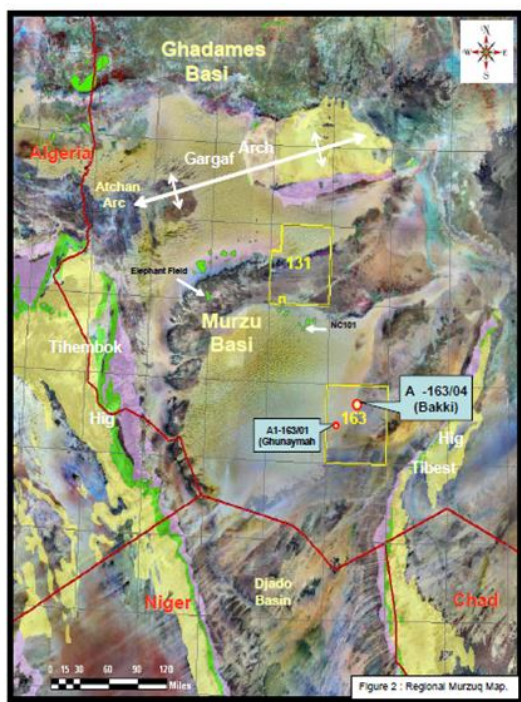


Fig. 1. Location map of Murzuq Basin and study area

II. EXPERIMENTAL METHODS

Ninety- nine samples from two wells located in the well A1-163, South eastern part of Murzuq Basin, representing the Middle to Late Devonian Awaynat Wanin, Early Carboniferous Marar, and Late Carboniferous Assedjefar formations. The samples were examined by using Rock-Eval pyrolysis to investigate potential hydrocarbon generative of the organic matter. The Rock-Eval analyze was used to get parameters. Crushed samples (100 mg) were pyrolysis in a helium atmosphere at 325°C for 3 min, following by temperature programmed pyrolysis at 25°C/min from 300 to 650°C. Use A flame ionization detector (FID) to screen rate hydrocarbons (Tissot and Welte, 1984). A first peak (S1 mg HC/g) was showed volatilization of free hydrocarbons during isothermal pyrolysis at 300°C. The second peak (S2 mg HC/g) as hydrocarbons generated by thermal cracking of kerogen in hydrocarbon crack at 300 to 550°C. A third peak (S3)

represents the amount of Carbon dioxide by mg produced from one gram of rock through pyrolysis at temperature between 300°C and 390°C and recording using an IR detector. The Tmax represents the temperature equivalent to the maximum number of hydrocarbons generated from the kerogen cracking. The quantity of organic matter or total organic carbon (TOC) was determined basing a LECO carbon analyzer for each sample. Samples to be analysed for vitrine reflectance are ground to small granules and polished using three finer grades of corundum paper to reduce scratches in the surfaces. Reflectance measurements of the polished blocks are made under oil immersion at 546 nm using a Zeiss Universal Photo microscope II equipped with a HP 9000 series computer system.

Nine samples were selected for more detailed organic geochemical analysis. For extraction of the source rocks, an amount of about 40 g crushed sample was placed in a thimble capped with glass wool and extracted in a Tecator Soxtec HT-System using dichloromethane and methanol (93:7). The samples were boiled for 1 hour and then rinsed for 2 hours. The extraction of sample was moved to flask to remove solvent, using a Buchi rotary evaporator. Asphaltene as well removed from the extracts by precipitation with n-pentane by ultrasonic bath for 3 min. filtration used to maltene, evaporating the n-pentane solution by rotary evaporation, and then moved to a pre-weighted glass vial. The gas chromatograph (GC) was used to analyze the saturate fractions. A DANI 8510 Gas Chromatograph coupled with flame ionization detector (GC/FID) equipped with an FID detector and OV1 (25m) column. An Injection of extraction used a Helium gas as a carrier. The temperature was programmed from 80 to 300°C at 4°C/min and held isothermal for 20 min. The carrier gas was helium and the temperature program run from 40°C to 290°C at a rate of 40°C/min. Final hold time is 10 mins. The Gas Chromatography - Mass Spectrometry (GC-MS) use to analyses the biomarkers. An Autospec Ultima system interfaced to a Hewlett Packard 5890 gas chromatograph and equipped a fused silica SE54 capillary column (40 m x 0.22 mm i.d.) directly into the ion source. The oven was initially maintained at 45°C for 1.5 min, subsequent temperatures were programmed from 45 to 150°C at 35°C/min and held isothermal for 14 min. The injector and detector temperatures were kept at 300°C. The oven column was connected directly to the ion source through a transfer line functioned at 300°C; the electronic impact ion source was operated at 70 eV. Statistics were acquired in a designated ion monitoring (SIM) mode and processed with using the Chemstation software.

III. RESULTS AND DISCUSSION

Variations of organic geochemical analyses applied to determine the type of kerogen, depositional conditions and thermal maturity of extractions of samples, collected from the A1-163 field-Murzuq Basin. Based on these analyses, the results of lithology description, Rock-Eval Pyrolysis, Total

Organic Carbon and molecular biomarker (using GC-MS), have been shown to discuss geochemical characteristics of each formation.

Lithology of studied formations

The lithology of representative samples for Assedjefar Marar and Awaynat Wanin Formations (studied formations) show varied physical features for instance color, texture, and mud content. The samples of Assedjefar Formation demonstrate texture of Medium dark to grey shale with red-brown trace Mudstone. The lithology of the Marar Formation gradient from dark-grey shale with multicolor mudstone to dark-grey shale with low to minor mudstone and sandstone. Dark-grey shale with low mudstone to mostly multicolor shale with minor mudstone and sandstone described in samples of Awaynat Wanin Formation. The results of lithological analysis in agreement with published monographs by Aboglila, at el (2018) and Albaghady at el., (2020).

Source Rock Generation Potential

The TOC data is one of several parameters have been used to investigate organic matter richness. The TOC percentage of studied samples illustrate indigenous hydrocarbon and quite varied values (Fig. 1). The Awaynat Wanin formation is a high average of TOC content, ranging from 1.1% to 4.37% with good potential hydrocarbon yields to excellent. The Marar Formation samples showed TOC data ringed from 1.3 to 4.63%, with mainly good to excellent. The TOC values from samples of Assedjefar Formation range from 1.76 to 4.32 %. Next parameter of Rock Eval is S2 (HC/g rock) that can be used to evaluate the generative potential of rock samples (Peters, 1986; Bordenave, 1993). The S2 value more than 4.0 mg HC/g rock are commonly found in common hydrocarbon source rocks (Bordenave, 1993). In all studied samples, the amount of hydrocarbon yield (S2) rage from 2.31 to 12.52 with an exception of one sample from the Marar Formation which has S2 value of 1.16. The majority of S2 values indicate that the generative potential the most rock samples are very from good to excellent. A plot of TOC versus total generative potential shows different generative potential organic matter richness and/or might quite respectable mark of source rocks in particularly the Awaynat Wanin formation which displayed dominance in S1 and generative potential organic matter (Fig. 2& 3).

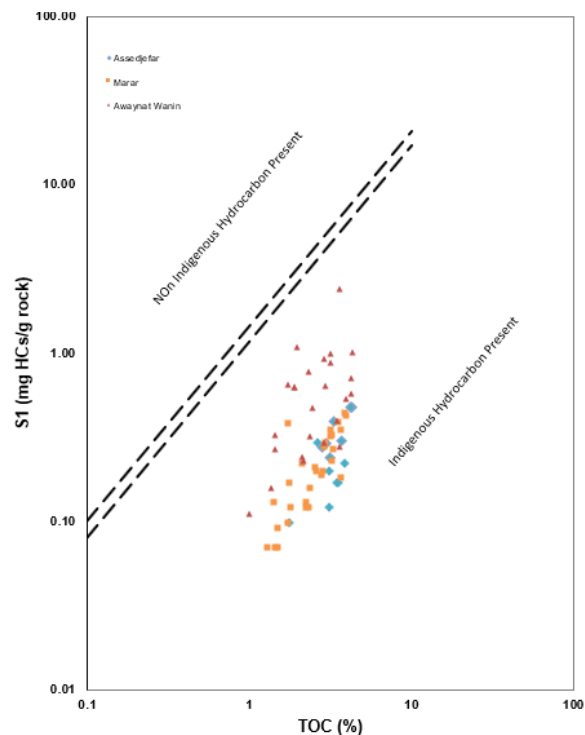


Fig. 2. Plot of S1 versus TOC, showing indigenous hydrocarbons in all of studied samples (Hunt, 1996).

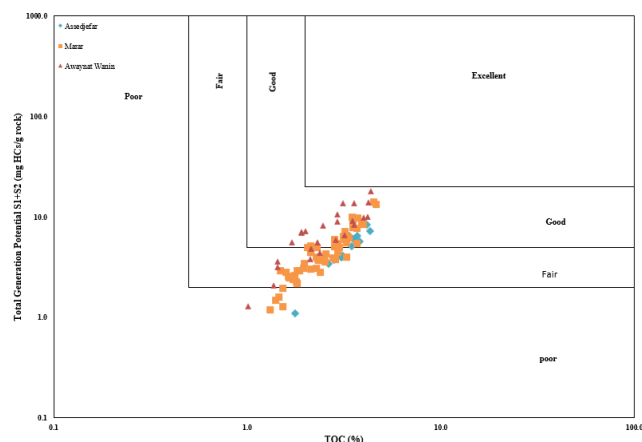


Fig.3. Plot of TOC versus total hydrocarbon generating potential of the studied source rocks

Type of Organic Matter

Hydrogen index (HI) and oxygen index (OI), are widely used as parameters to describe the type of organic matter (Tissot and Welte, 1984; Bordenave, 1993 , Cornford et al., 1998). The type of kerogen in a potential source rock determines the nature and number of hydrocarbons that it can produce from studied cuttings. In the well A 163-04, the samples from the Awaynat Wanin Formation showed values of HI, range among 143 to 315 mg HC/g TOC and OI values between 25 to 282. These statistics indicate to II/III kerogen types as the main component of the organic matter besides

mainly fair potential for generation of oil with some good samples and good for gas. The Marar and Assedjefar Formations are offered HI values, ranging from 59 to 202 and OI from 22 to 84, representing to type of kerogen II and III (Fig. 4 & 5). This description is in consistence with several studies published through last decade (Aboglila, at el 2018 and Albaghdady at el 2020).

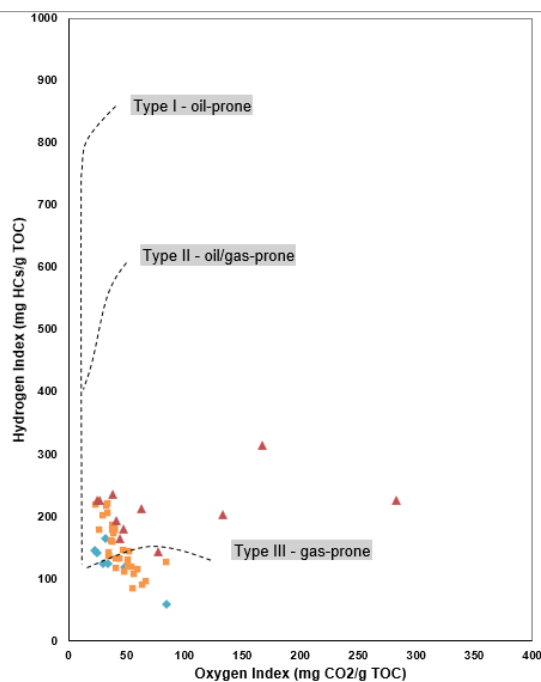


Fig. 4. Plot of Hydrogen Index against Oxygen Index the samples from A1 163 03

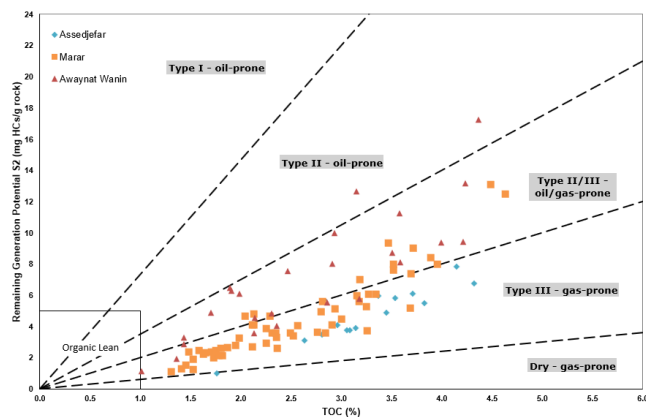


Fig. 5. Plot of HI vs. TOC of the source rock samples

Thermal maturity

Tmax is the most widely used thermal maturity parameters to determine type of kerogen (Tissot and Welte, 1984). This parameter has been used to estimate maturity level of the organic matter. Data of selected samples from Assedjefar Marar and Awaynat Wanin Formations show quite diverse

values. The maturity determined by Tmax, showed that majority of the samples lie between the immature to mature score of hydrocarbon generation > 430. Devonian Awaynat Wanin is the maximum value of Tmax ranging from 431 to 442. The Tmax values fell within range (431-440°C), showed that majority of these rocks are within the sector of hydrocarbon generation. S1/ TOC ranged from 0.04 to 0.67, which indicates that oil phi The thermal maturity of organic matter classified according to hydrogen index (HI) and Tmax values. The data of HI and Tmax values established that the analyzed samples contain organic matter is graded from immature to mature with a reasonable amount of oil-prone with a potential to generate, mainly Awaynat Wanin Formation as older rock and closer to part of basin shale (Silurian Tanezzuft Fm) as it is extremely discussed in published articles (Aboglila, at el 2018 and Albaghdady at el 2020). The thermal maturity was also estimated based on a data of plot of Tmax versus production index (Fig 5). Vitrinite Reflectance data which is the most commonly used to indicate the level thermal maturity of organic matter, showed that the most the studied samples have entered the oil generation window with values range from 0.40 to 0.84. Spore colour indices of selected samples range between 4.5 to 5.5 supporting the vitrinite reflectance values.

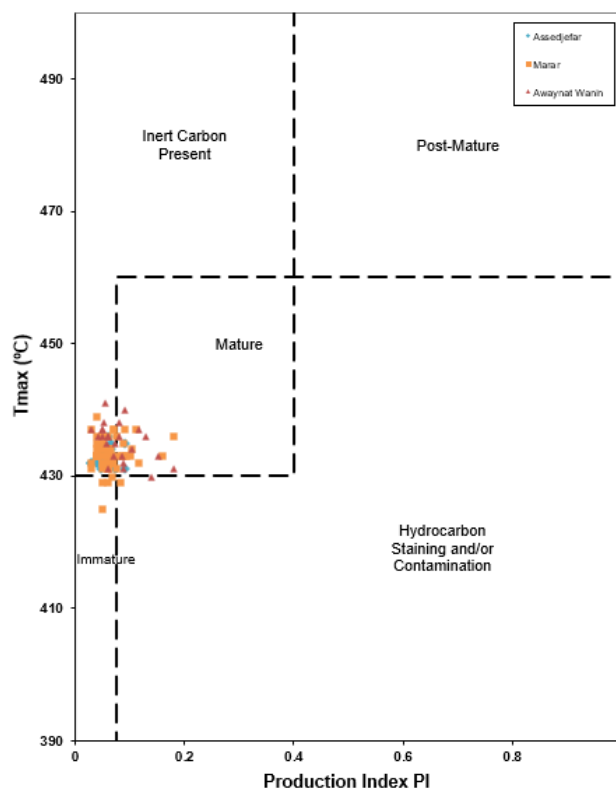


Fig. 6. Production Index (PI) versus Tmax viewing the level of thermal maturity of the source rock samples.

Organic Matter Input and Depositional Environments

Biomarkers are complex structure components, known in organic matter of petroleum and rock extraction, derived from biological molecular precursors, such as chlorophyll, sterols, and hopanoids (Peters and Moldowan, 1993). Mackenzie (1984) defined biomarkers as organic compounds revealed in the source rock and crude oil as basic skeleton offers an certain link with recognized natural precursors. The biomarkers formed by thermal reactions, there rates are controlled by subsurface temperature and length of exposed time. The use of biomarkers in petroleum exploration has increased significantly due to development of gas chromatography-mass spectrometry (GC-MS), which is now used routinely for separating and identifying compounds in complex mixtures such as crude oils and rock extracts. Biomarker analyses can also aid in understanding and identifying the processes of transformation of organic matter after deposition (Philp, 1985). The distribution of n-alkanes in crude oils and source rocks may reflect the organic matter source (Volkmann, 1988) and in rock samples from this study range from C_{13} – C_{35} with maxima between nC_{16} – nC_{18} (Fig. 7) The abundance of high molecular n-alkanes relative to the lower molecular weight n-alkanes (nC_{27}/nC_{17} ratios), suggests a high contribution, of terrigenous organic matter. The nC_{27} indicates higher plant input and the nC_{17} shows a contribution from algae (Hunt, 1996; Tissot and Welte, 1984). The pristane/phytane ratios in all of the samples studied range from 1.85 to 3.18 and may suggest terrigenous organic matter deposited in a non-marine environment (Hunt, 1996). A plot of Pr/nC_{17} versus Ph/nC_{18} has been used to specify type of organic matter (Fig. 8). The distribution of the samples on this plot suggested non-marine and/or mixed depositional environment for the source rock.

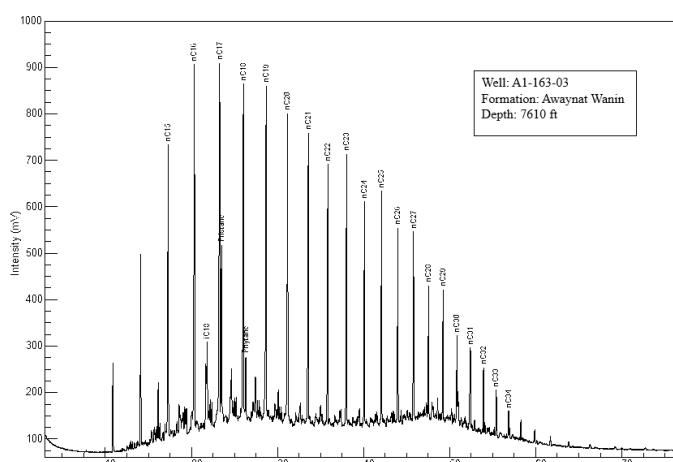
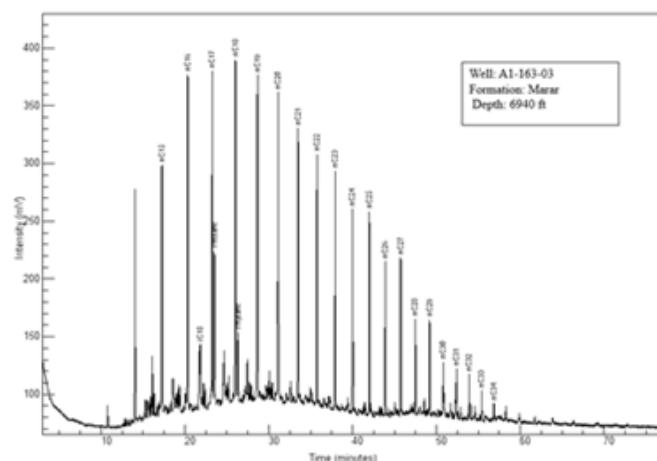
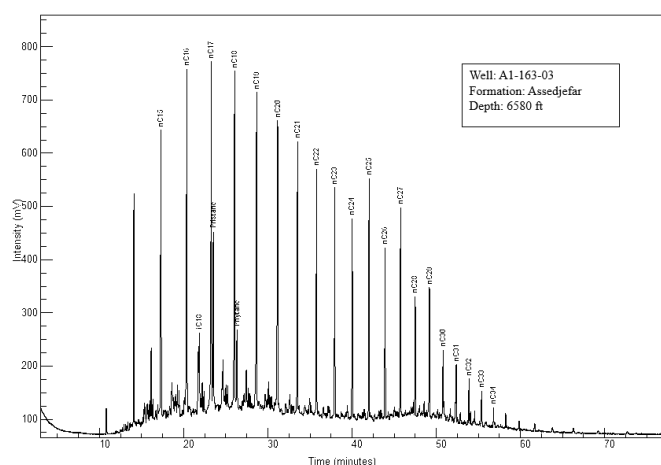


Fig. 7. GC trace for extracts of source rocks and show n-alkane distribution in the samples.

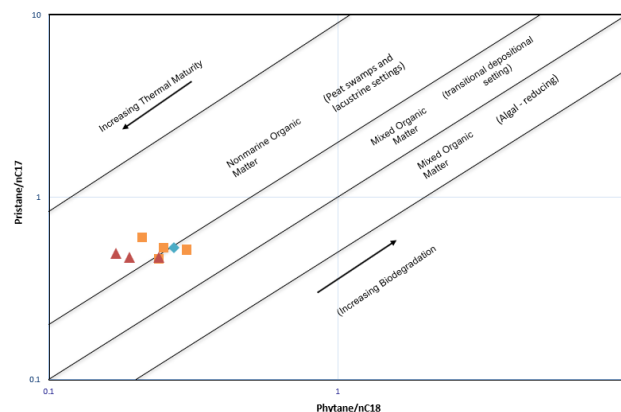


Fig. 8. pristane/ nC_{17} versus phytane/ nC_{18} of the selected samples (Shanmugan, 1985).

The illustrations commonly have similar biomarker distributions based on the m/z 191 and 217 mass chromatograms as revealed in Figures 8 and 9. Biomarker peaks identifications are listed in Table 1 & 2. Hopanes are biomarkers of pentacyclic triterpane biomarkers derived mainly from hopanoids structures in bacteria (Ourisson et al.,

1984). The C_{29} and C_{30} $17\alpha(H)$ -hopanes, the dominant triterpanes in the samples of this study (Fig. 8), are used to indicate depositional environments (Waples and Machihara, 1990). Organic matter derived from organic-rich carbonates described by Zumberge, 1984; Connan et al., 1986; Price et al., 1987, evaporites (Connan et al., 1986) and may contains high relative concentrations of C_{29} $17\alpha(H)$ -hopane. Ratios of C_{29}/C_{30} hopanes between 0.64 and 0.78 in the Awaynat Wanin Formation are consistent with the clay-bearing character for the samples in the study. The samples from Marar and Assedjefar Formations are having ratios from 0.72 to 0.91 which may indicate organic-rich carbonates. Gammacerane / $C_{31}R$ hopane ratios range from 0.02 to 0.31 in the most samples of Awaynat Wanin and Assedjefar Formations may show less salinity of these samples. The presence of gammacerane in the Marar Formation may indicates salinity and water column stratification in the source rock depositional environment (Sinninghe Damsté et al., 1995). The higher abundance of C_{24} tetracyclic terpanes in the studied samples may result from the impact of non-marine organic matter. An organic matter contains richness of the C_{24} tetracyclic terpane within contribution of terrestrial were known (Philp and Gilbert, 1986). Clark and Philp (1989) reported high abundance of the C_{24} tetracyclic terpane as indicative of carbonate and evaporite depositional environments. Therefore, the low abundance of C_{24} tetracyclic terpanes in this study does not support a characteristic for high input of terrigenous organic matter or non-marine depositional environments.

The regular steranes is commonly used to investigate the source of organic matter in the crude oils and source rocks. Organic matter derived essentially from marine phytoplankton is dominated by C_{27} steranes while high abundance of C_{29} steranes reflects a high contribution from higher plant organic matter and high abundance of C_{28} steranes may suggest a contribution by lacustrine algae (Huang and Meinschein, 1979; Philp, 1985; Waples and Machihara, 1990). In this study, the relative abundance of C_{27} , C_{28} and C_{29} steranes is $C_{29} > C_{27} > C_{28}$ (Fig. 10) and the ratio of C_{27}/C_{29} steranes from studied samples ranges from 0.44 to 0.90, may point to an input of non-marine source organic matter. The ratios of diasteranes/steranes are commonly used to distinguish crude oil was derived from carbonate versus clastic source rocks (Mello et al., 1988). The diasterane/ $C_{27}R$ sterane ratios indicate hydrocarbons are generated from source rocks containing an richness of mud leading to clay catalyzed rearrangement reactions (Peakman et al., 1989), whereas low ratios indicate an oxic and clay poor carbonate (Peters and Moldowan, 1993). High concentrations of diasteranes reflected in ratios of C_{27} diasterane/ $C_{27}R$ sterane (0.76 to 1.65).

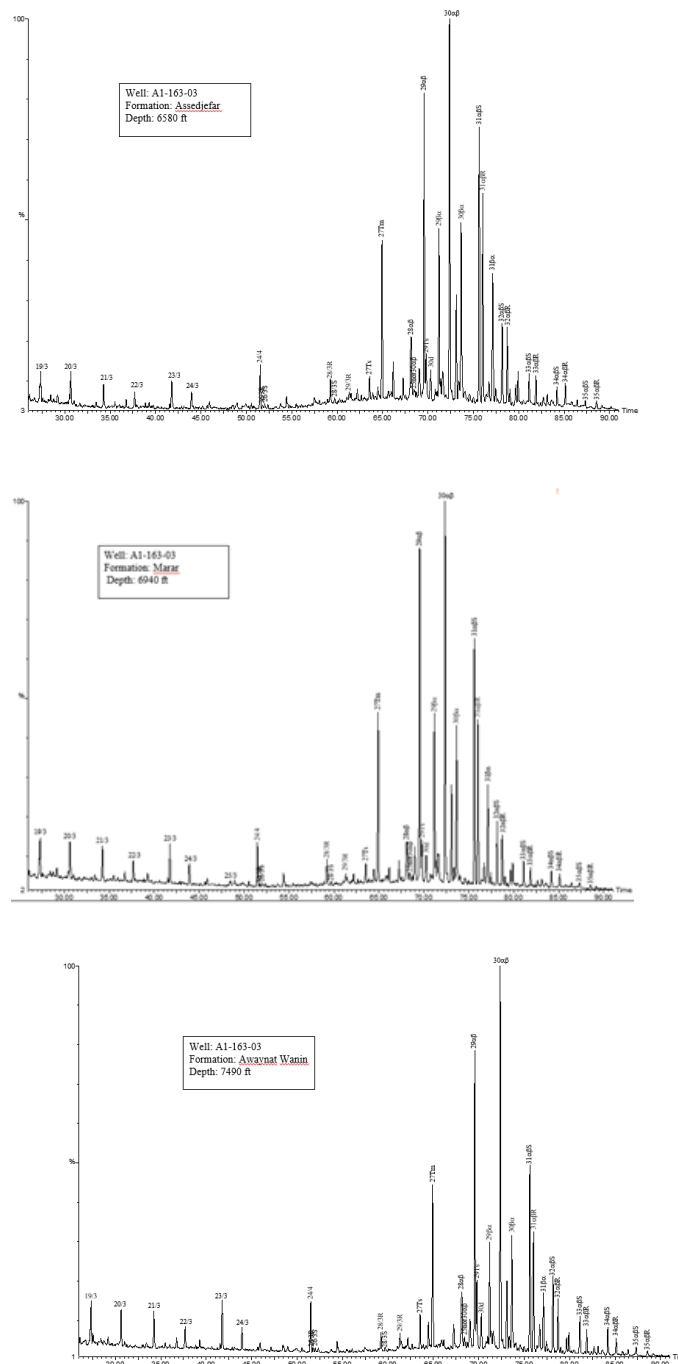


Fig. 9. GC-MS are showing the distribution of terpanes (m/z 191)

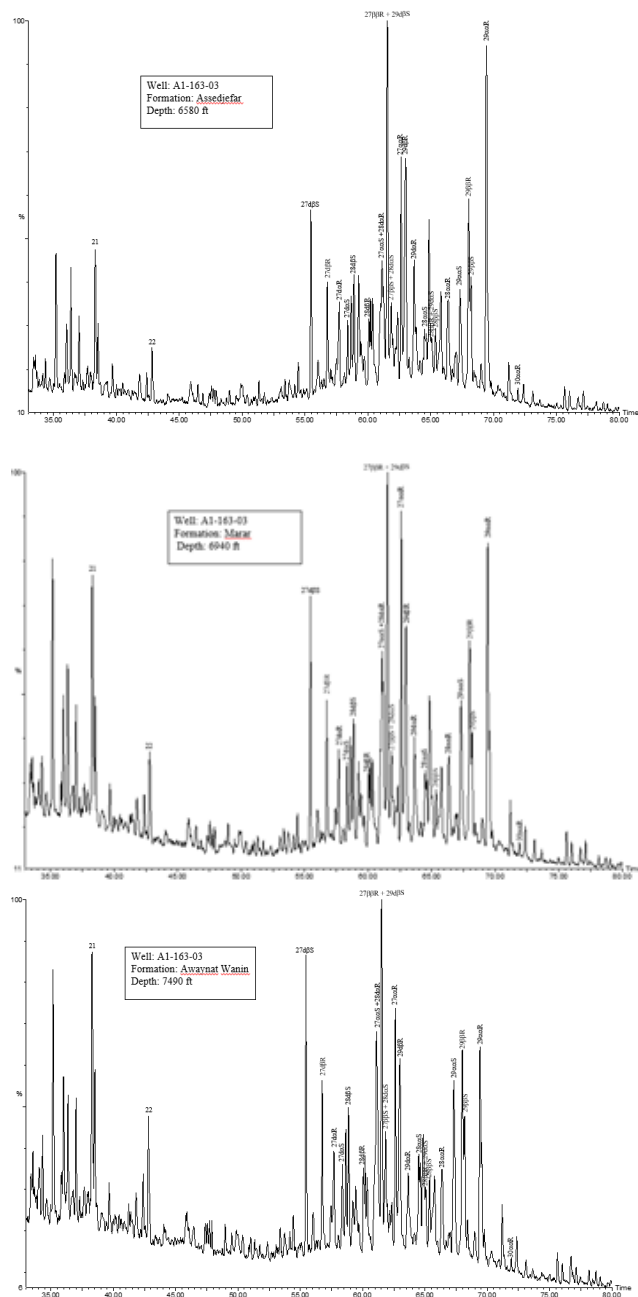


Fig. 10. GC-MS chromatograms are show distribution of steranes (m/z 217).

The biomarker data also support this level of maturation. The samples exhibit CPI (carbon preference index) values of about 1.14 to 1.38 which indicate lower maturity (Simoneit, 1978). The hopane isomerization at C-22 $22S/(22S+22R)$, is a widely practical biomarker maturity parameters and accounts the relative abundance of the more stable 22S isomer compared to

the biologically-derived 22R stereochemistry (e.g. Kolaczowska et al., 1990). Generally, the ratio rises from 0 to about 0.60 during maturation (Seifert and Moldowan et al., 1986). The hopane isomers show range between 0.50 to 0.54 were considered as having barely entered the oil generation window, while ratios in range 0.57 to 0.62 indicate that the main phase of generation has been reached (Peters et al. 2005). The ratios of the samples in this study range from 0.49 to 0.62. The values of the samples from Awaynat Wanin and Marar Formations indicate that the main phase of generation has been reached.

The $Ts/(Ts+Tm)$ ratios are generally low and this is indication of lower maturity level. This parameter is commonly used for evaluating of thermal maturity level, even though it can be affected by the source of organic matter (Seifert and Moldowan, 1978) and must be used with caution as a thermal maturity indicator. The moretane/ C_{30} hopane ratios are low in all samples and range from 0.10 to 0.47. Moretanes are less stable than hopanes, and therefore its concentration decrease more rapidly than regular hopanes with increasing the level of thermal maturity (Peters and Moldowan, 1993). Moretane/hopane ratios, like the $22S/(22S+22R)$ ratios for homohopanes, are mainly useful as an indicator of thermal maturity (Grantham, 1986). This ratio ranges from around 0.80 in immature source rock to values of less than 0.15 in higher mature level and could be less than 0.05 in oils (Mackenzie et al., 1980; Seifert and Moldowan, 1980). Tricyclic terpanes are thought to be derived primarily from algae and bacteria (Aquino Neto et al., 1983). The tricyclics to hopanes ratio have been known as decent parameter to investigate a thermal maturity of oils and rock extraction. A high level of maturity, tricyclics are released from kerogen at higher rates than $17\alpha(H)$ -hopanes due to their higher thermal stability (Peters et al., 1990). Generally, in this study the abundance of tricyclic terpanes are low. The ratios of the C_{23} tricyclic to C_{30} hopane range from 0.01 to 0.13 and generally these ratios are indicating the maturity level of the samples. The ratios of C_{24}/C_{23} tricyclic tropain range from 0.36 to 0.70. With increasing maturity there was decrease in the abundance of the C_{23} tricyclic compounds relative to the C_{21} and C_{24} tricyclics (Cassani et al., 1988). The most commonly used sterane maturity parameter is the proportion of 20R and 20S epimers of the $\alpha\alpha$ steranes expressed as $20S/(20S+20R)$. The biologically produced form is exclusively $\alpha\alpha$ -20R, but with increasing maturity the proportion of 20S increases at the expense of 20R from 0 to about 0.5. Equilibrium between the two forms is reached approximately between 0.52 and 0.55. Once equilibrium is reached, no further variations in maturity recorded (Seifert and Moldowan, 1986; Waples and Machihara, 1990). Also the $\beta\beta/(\beta\beta+\alpha\alpha)$ ratio for regular steranes has been widely used as a maturity parameter. This ratio increases from 0 to about 0.7 with equilibrium value between 0.67 and 0.71 (Seifert and Moldowan, 1986). These ratios should be used with caution due to the influence of some factors such as heat rate, clay minerals existence, nature source material, and depositional environment (Philp, 2007). The $20S/(20S+20R)$ ratios in this study range from 0.16 to

0.51, and $\beta\beta/(\beta\beta+\alpha\alpha)$ ratio range from 0.29 to 0.55. The sterane ratios indicate that the equilibrium values have not been reached for these. These values for the steranes ratios suggest that these samples are lower maturity. Huang et al. (1991) suggested that values 0.25 for C_{29} sterane $20S/(20S+20R)$ ratio as a margin between immature to low maturity while a value of 0.42 was considered as boundary between low maturity and maturity.

Table 1. Peak identifications of tricyclic, tetracyclic and pentacyclic triterpanes.

27Ts	18 α trisnorhopane (T_s)
27Tm	17 α trisnorhopane (T_m)
28 $\alpha\beta$	Bisnorhopane
25nor30 $\alpha\beta$	norhopane
29 $\alpha\beta$	$\alpha\beta$ norhopane
29Ts	norhopane
29 $\beta\alpha$	$\beta\alpha$ norhopane
30 $\alpha\beta$	$\alpha\beta$ hopane
30O	Oleanane
30 $\beta\alpha$	$\beta\alpha$ hopane
31 $\alpha\beta$ S	22S $\alpha\beta$ homohopane
31 $\alpha\beta$ R	22R $\alpha\beta$ homohopane
30G	gammacerane
31 $\beta\alpha$	$\beta\alpha$ homohopane
32 $\alpha\beta$ S	22S $\alpha\beta$ bishomohopane
32 $\alpha\beta$ R	22R $\alpha\beta$ bishomohopane
33 $\alpha\beta$ S	22S $\alpha\beta$ trishomohopane
33 $\alpha\beta$ R	22R $\alpha\beta$ trishomohopane
34 $\alpha\beta$ S	22S $\alpha\beta$ tetrakishomohopane
34 $\alpha\beta$ R	22R $\alpha\beta$ tetrakishomohopane
35 $\alpha\beta$ S	22S $\alpha\beta$ pentakishomohopane
35 $\alpha\beta$ R	22R $\alpha\beta$ pentakishomohopane
23/3	Tricyclic terpene
24/3	Tricyclic terpene
25/3	Tricyclic terpene (17R, 17S)
24/4	Tetracyclic terpene
26/3	Tricyclic terpene (17R, 17S)
21/3	Tricyclic terpene
22/3	Tricyclic terpene
25nor28	25,28,30-trisnorhopane/moretane
30d	Diahopane

Table 2. Peak identifications of steranes and diasteranes

21 α	5 α sterane 22 α 5 α sterane
27d β S	20S $\beta\alpha$ diacholestane
27d β R	20R $\beta\alpha$ diacholestane

27d α S	20S $\alpha\beta$ diacholestane
27d α R	20R $\alpha\beta$ diacholestane
28d β S	20S $\beta\alpha$ 24-methyl-diacholestane
28d β R	20R $\beta\alpha$ 24-methyl-diacholestane
28d α R	20R $\alpha\beta$ 24-methyl-diacholestane
27 $\alpha\alpha$ S	+ 20S $\alpha\alpha\alpha$ cholestane
29d β S	20S $\beta\alpha$ 24-ethyl-diacholestane
27 $\beta\beta$ R	+ 20R $\alpha\beta\beta$ cholestane
27 $\beta\beta$ S	20S $\alpha\beta\beta$ cholestane
28 α S	+ 20S $\alpha\beta$ 24-methyl-diacholestane
27 $\alpha\alpha$ R	20R $\alpha\alpha\alpha$ cholestane
29d β R	20R $\beta\alpha$ 24-ethyl-diacholestane
29d α R	20R $\alpha\beta$ 24-ethyl-diacholestane
28 $\alpha\alpha$ S	20S $\alpha\alpha\alpha$ 24-methyl-cholestane
28 $\beta\beta$ R	20R $\alpha\beta\beta$ 24-methyl-cholestane
29d α S	+ 20S $\alpha\beta$ 24-ethyl-diacholestane
28 $\beta\beta$ S	20S $\alpha\beta\beta$ 24-methyl-cholestane
28 $\alpha\alpha$ R	20R $\alpha\alpha\alpha$ 24-methyl-cholestane
29 $\alpha\alpha$ S	20S $\alpha\alpha\alpha$ 24-ethyl-cholestane
29 $\beta\beta$ R	20R $\alpha\beta\beta$ 24-ethyl-cholestane
29 $\beta\beta$ S	20S $\alpha\beta\beta$ 24-ethyl-cholestane
29 $\alpha\alpha$ R	20R $\alpha\alpha\alpha$ 24-ethyl-cholestane
M30 $\alpha\alpha$	$\alpha\alpha$ 4-methyl-24-ethyl-cholestane
M30D	$\alpha\alpha$ 4,23,24-trimethyl-cholestane
30 $\alpha\alpha$ S	20S $\alpha\alpha\alpha$ 24-propyl-cholestane
30 $\beta\beta$ R	20R $\alpha\beta\beta$ 24-propyl-cholestane
30 $\beta\beta$ S	20S $\alpha\beta\beta$ 24-propyl-cholestane
	30 $\alpha\alpha$ R 20R $\alpha\alpha\alpha$ 24-propyl-cholestane

VI. CONCLUSION

The total organic carbon values are wide-ranging from good to excellent for two studied wells. The kerogen types are II, II/III as well III existed. The Awaynat Wanin formation is a high overall average of TOC content. Organic matter type is generally consistent with non-marine characteristics. The thermal maturity of the studied rocks indicated range of level maturities between early oil generations to mid-oil generation based on rock Eval parameters and biomarkers values. The data confirmed that the investigated rocks in this search is part of the oil source rocks for Murzuq Basin as they showed organic-rich sediments in the Devonian and Carboniferous strata of the Paleozoic Era.

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