

Specific Geochemical Parameters and Oil: Source Rock Correlations of Some Oilfields in the North Western Desert, Egypt

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Abstract: Different analytical techniques, including liquid chromatographic separation, gas chromatography and gas chromatography-mass spectrometry were used to characterize the crude oil and extract samples of the source rocks. The samples were collected from different oilfields in North Western Desert Egypt namely: Meleiha, Misaada and Qarun oilfields. In the present work, the mentioned parameters have been used to essentially discuss the relation between the produced oils and their potential source rocks to confirm the indigenous sources for the petroleum generation of the studied oilfields. The results showed that the studied oil samples of Misaada and Qarun oilfields are well correlated with each other, where they are similar in their maturation and source depositional environments and slightly correlated with Meleiha oil. The correlation between source rocks and crude oils show that there is a good correlation between the extract samples of Kharita and Khatatba formations and crude oils from Qarun and Misaada oilfields. While the extract of Bahariya source rocks and Meleiha oil show slight correlation. These evidences indicate that Kharita and Khatatba source rocks seem to act as sources and reservoirs for oil generation in the Qarun and Misaada oilfields.

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1. Introduction:

The geochemical characteristics of oils are of great interest for petroleum geology. Chemical fingerprinting is the application of chemistry to identify the sources of complex environmental pollutants, including petroleum. This practice has advanced into a science where the original sources of complex mixtures (e.g. crude oil) can often be identified by the relative abundance of some major individual compounds (e.g. n-alkanes) forming a chemical pattern by ratios of specific constituents or by identifying source-specific compounds or markers (e.g. triterpanes) in the environmental sample being investigated. (Peters *et al.*, 2005).

Geochemical correlations of oils and the source rocks extracts are based on the ability to recognize distinct physical and chemical similarities, or differences, between the hydrocarbons in a reservoir and the extractable bitumen plus the residue in the original source rock (Williams, 1974). Oil-source rock correlations are more difficult than oil-oil correlations, due to many problems in their sampling, analyses and/or interpreting the available data. Such interpretations must be confirmed by different parameters, e.g. gross composition of oil and source rock extracts, biomarkers analyses, environmental analysis.....etc. Many parameters for oil-source correlations as, saturates (%), saturates/aromatics, C_{max} , $C_{21}+C_{22}/C_{28}+C_{29}$, carbon preference index (CPI), pristane/phytane, pristane/n- C_{17} and

pristane+n- C_{17} /phytane+n- C_{18} ratios were discussed by Welte *et al.* (1975); Alexander *et al.* (1981); Pool and Claypool (1984); Leythaeuser *et al.* (1987) and Philip *et al.* (1989). These parameters depend mostly on the preburial environments of the living organisms, the depositional environments of the organic matter and the diagenetic processes in the source rocks.

Geologic Setting

The Western Desert of Egypt covers an area of 700,000 square kilometers and comprises almost two thirds of the whole area of Egypt (EGPC, 1992). The North Western Desert represents an important part of the unstable shelf of Northern Africa. It has been subjected to different tectonic regimes since the Paleozoic times, which were able to form the construction of many basins, sub-basins, ridges, troughs and platforms. These structural features encourage both Egyptian and foreign oil companies to establish condensed exploration works in this region. The geographic locations of the selected studied oilfields are shown in (Fig. 1). The Western Desert still has a significant hydrocarbon potential as some oil and gas discoveries indicate (Dolson *et al.*, 2001). There are few available literatures concerning the geochemical characterization of crude oils from the Western Desert of Egypt (Taher *et al.*, 1988; Zein El-Din *et al.*, 1990, Halim *et al.*, 1996), and few deal

with the distribution of biomarkers (EL Nady, 1998; Mostafa *et al.*, 1998; El- Gayar *et al.*, 2002).

Metwalli, and Abd El-Hady (1975) stated that Umbarka Field produces a waxy oil of 44° API, from the Aptian clastics. The Alamein Dolomite acts as a sealing rock for the oil accumulated in this Aptian clastics in that field. They also added that the variation of crude oil-gravities, in the Western Desert, reflects different stages of oil migration and accumulation as well as different oil source rocks in the same and different ages. Zein El Din *et al.* (1990) divided the oils from the North Western Desert into two main groups: The first includes oils from Shushan-Matruh basins, which are thought to be derived from source rocks of terrestrial origin, while the second includes oils of marine origin from Abu Gharadig and Gindi basins. Matbouly (1993) reported that the Jurassic oil in the north Western Desert is derived from terrigenous organic matter. Mostafa *et al.* (1998) recognized four oil types in the north Western Desert. Oils from Shushan and Matruh basins are characterized by terrestrial waxes inputs, while oils from Abu Gharadig Basin are generated from marine siliciclastic source rocks, and those from Alamein Basin seem to be derived from mixed marine/terrigenous sources. Sharaf and El Nady (2003) recognized that the oils from Alam El Bueib and Bahariya reservoirs are genetically related, multisourced from Khatatba and Alam El Bueib source rocks with minor contribution from Kohla source rocks. El Nady *et al.* (2003) classified the crude oils of the Meleiha oil field into two classes namely, paraffinic and deltaic oils, originated from marine and terrigenous sources, respectively. El Nady (2009) reported that the oils from Khatatba and Alam El Bueib formations are mature, derived from source

rocks containing marine and terrestrial organic matter, respectively. Also, recognized that the source environments and maturity of the oil from Khatatba reservoir is similar to that of the Khatatba source rock extract. The oil from the Alam El Bueib reservoir differs from the extracts of the Alam El Bueib and Kharita formations. El Nady and Harb (2010) revealed close genetic relationship and remarkable similarities in the origin and maturation of the oils and extracts of the Khatatba and Alam El Bueib source rocks of some oilfields in the North Western Desert.

Objectives

The objectives of this work is to utilize biomarkers characteristics together with bulk geochemical parameters to identify and characterize the crude oils and to assess the respective depositional environments and maturation. Also, the authors attempt to assess the correlation between the crude oil samples and the potential source rocks to confirm the indigenous sources for the petroleum generation of some oilfields of the North Western Desert This target was made through out the study in detail of the analytical results for three crude oil samples collected from three oilfields in the North Western Desert (Fig. 1) namely: Meleiha, Misaada and Qarun oilfields, as well as, three extract samples from Baharia, Kharita and Khtataba formations ranging in age from Upper Cretaceous to Middle Jurassic. (Fig. 2), represent the potential source rocks of the studied oilfields. The geologic informations of the crude oils and their reservoirs are summarized in Table (1). The Egyptian General Petroleum Corporation kindly supplied these samples.

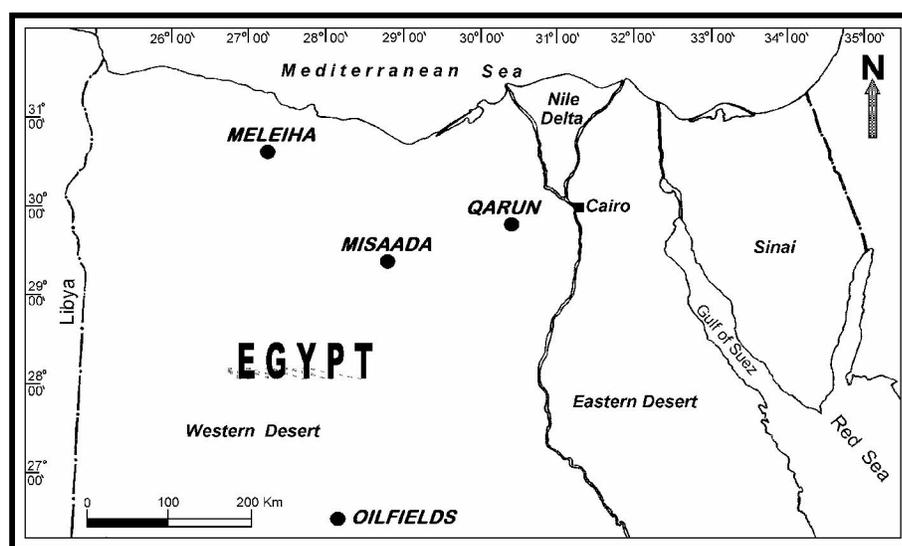


Fig. (1): Location map of the studied oilfields in North Western Desert, Egypt

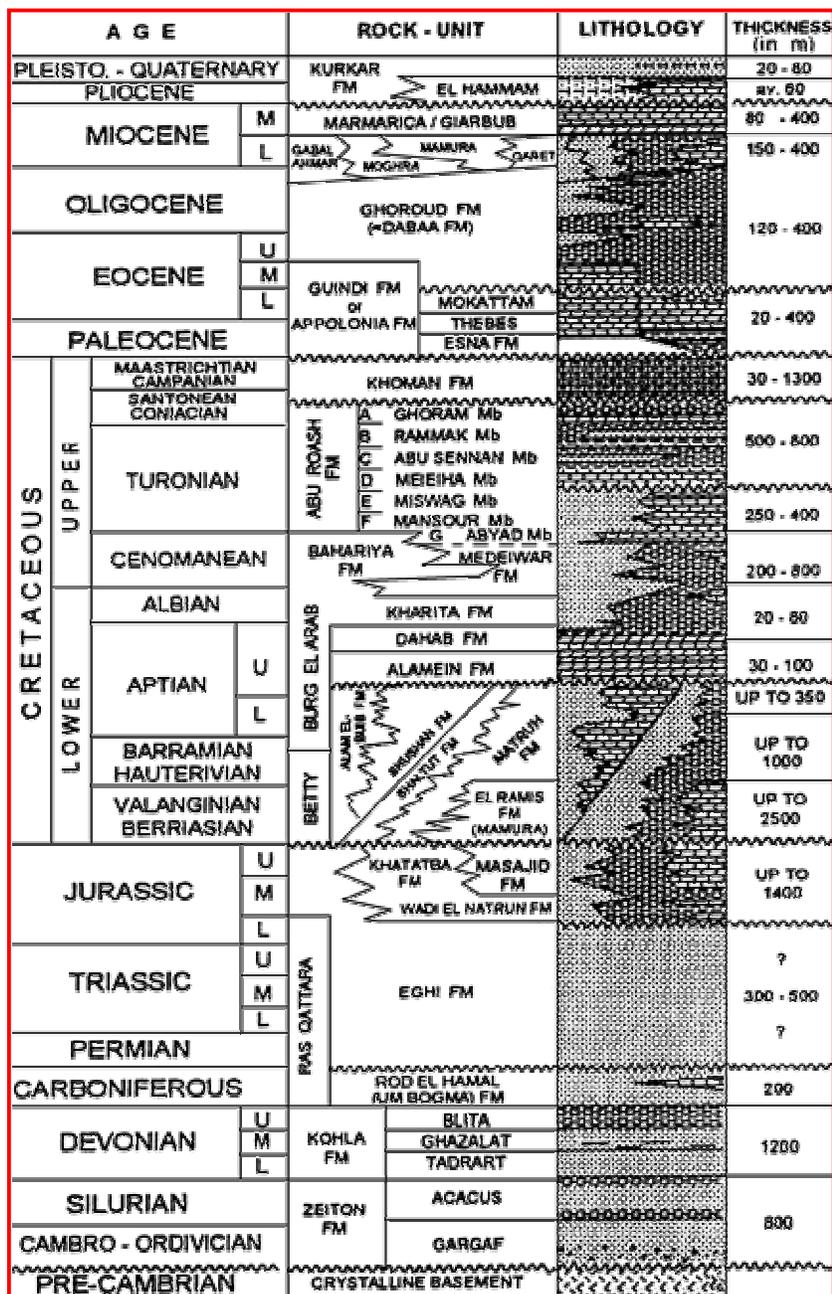


Fig. (2): Generalized stratigraphic column of the North Western Desert, Egypt (Schumberger, 1995)

Techniques

1. About 200g of rock samples were powdered to 250-mesh size and then extracted with chloroform by using soxhlet extractor.
2. The crude oils and extract samples were separated into saturates, aromatics and resins by column chromatography. The column was packed with 1:1 (by weight) alumina overlying silica gel such that the weight of the sample (asphaltenes free) was about 2% of the combined weight of the packed materials. Successive elution with n-heptane,

toluene and chloroform yielded saturates, aromatics and resins component fractions, respectively. The obtained fractions were freed from solvents by evaporation. The results are expressed as weight percent to the whole oils or extracts.

3. The saturate fractions of oils and extracts were analyzed by gas chromatography using (Perkin Elmer Instrument Model 8700) provided with a flame ionization detector (FID). Oven temperature was programmed for 100 to 320°C at 5°C/min. Gas chromatography-mass spectrometry used a 50m x

0.25mm fused silica capillary column of bonded SE 54 installed with a finnigan MAT TSQ-70 combined gas chromatography/quadrupole mass spectrometer. The column oven was programmed from 100 to 310°C at 4°C/min.

These analyses were carried out in the laboratories of the Egyptian Petroleum Research Institute.

3. Results and Discussion

Specific geochemical parameters

The specific geochemical parameters have been assessed by the aid of gas chromatography and gas chromatographic-mass spectrometric analyses of the saturated fractions. The parameters include normal paraffins, carbon preference index (CPI), pristane/phytane ratios, isoprenoids/n-alkanes ratio (pr/n-C₁₇ and ph/n-C₁₈), as well as triterpanes and steranes (Table 1 - Figs. 3 and 5).

N-Paraffins

The mode distribution of n-paraffins is used to shed light on the genetic origin of oils (Tissot and

Welte, 1984). It is known that the amorphous sapropelic organic matter characterized by maximum peak concentrations of C₁₅-C₂₅, reflects marine organic sources (Waples, 1985). Further more, the organic matters which were derived from remains of higher vascular plants (terrestrial) are characterized by maximum concentrations of n-paraffins at n-C₂₅-C₂₉ (Hunt, 1979; Tissot and Welte, 1984).

The GC/FID chromatogram of the Meleiha crude oil sample is characterized by a monotonically decreasing homologous series of heavy normal alkanes (n-C₂₅ to n-C₃₀) and display odd carbon preference at n-C₁₅ (Fig. 3A). These data reflect mature oils, originated mainly from non-marine origin mainly terrestrial organic matters, deposited under slightly oxidizing environment (Hunt, 1996) and slightly mixed with inputs from marine source.

The mode of distribution of n-paraffins in the crude oils of Misaada and Qarun oilfields (Fig. 3B and C) show that the maximum abundance is at n-C₁₅ to n-C₂₅ reflecting marine origin.

Table (1): Geologic informations and geochemical analysis of the studied crude oil samples from oilfields in the North Western Desert, Egypt

	Oilfields		
	Meleiha	Misaada	Qarun
Depth(ft)	9563	11169	17786
Reservoirs	Bahariya Fm.	Kharita Fm.	Khatatba Fm
Age	Up. Cretaceous	L. Cretaceous	M. Jurassic
Lithology	Sandstone	Sandstone	Sandstone
Pristane/phytane	03.00	00.63	02.00
Pristane/n-C ₁₇	00.40	00.28	00.10
Phytane/n-C ₁₈	00.18	00.47	00.10
CPI	01.04	00.94	01.02
C ₂₇ Steranes (%)	16.30	20.77	20.60
C ₂₈ Steranes (%)	37.40	39.30	40.43
C ₂₉ Steranes (%)	46.30	39.90	38.80
Homohopane index ^a	00.00	00.12	00.72
Diasteranes index ^b	00.27	00.10	00.14
Gammacerane index ^c	00.00	00.15	00.24
C ₂₉ 20S/20S+20R ^d	00.56	00.50	00.66
C ₂₉ /C ₃₀ ^e	00.57	01.30	00.22
Steranes/hopanes ^f	06.00	07.50	06.00
Ts/Tm^g	00.00	01.00	00.70

CPI: $\sum_{\text{odd}} / \sum_{\text{even}}$ carbon numbers,

a; Homohopane index: $(C_{35} \text{ homohopane S} + R) / (C_{31} + C_{32} + C_{33} + C_{34} + C_{35} \text{ homohopanes S} + R)$.

b: Diasteranes index: $(C_{27} \text{ diasteranes S} + R) / [(C_{27} \text{ diasteranes} + R) + C_{29} \text{ steranes S} + R]$.

c: Gammacerane index: $\text{gammacerane} / (\text{gammacerane} + C_{30} \text{ hopane})$.

d: C₂₉ 20S/20S+20R steranes ratios

e: C₂₉/C₃₀: C₂₉ norhopane/C₃₀ hopane,

f: Steranes/hopanes ratio.

g: Ts/Tm: Trisnorhopanes/Trisnorhopanes ratios.

Carbon Preference Index

Carbon preference index obtained from the distribution of n-alkanes is affected by both source and maturity of crude oils (Tissot and Welte, 1984). The CPI values of the studied crude oils, which are calculated according to Waples formula (1985), are listed in Table (1). It is clear that the oil samples have CPI values close to unity, ranging from (0.94 to 1.04) these values indicate mature crude oils.

Pristane/Phytane

Pristane/phytane ratios seem to be useful as correlation parameters, because it is believed to be sensitive to diagenetic conditions. Pr/ph ratios substantially below unity could be taken as indicator of highly reducing depositional environments. Very high pr/ph ratios (more than 3) are associated with terrestrial sediments. Pr/ph ratios ranging between 1 and 3 reflect oxidizing depositional environments (Hunt, 1996). In the present work pr/ph ratio of the oil sample from Meleiha oilfield is 3.0 (Table 1) indicating oxidizing depositional environment of the crude oil. On the other hand, the crude oils from Qarun and Misaada oil fields have pr/ph ratios of 0.63 and 2.00 respectively reflecting that these crude oils were deposited under transitional (reducing–oxidizing) environments. These results indicate good correlation between crude oils from Qarun and Misaada oilfields, with slight correlation to crude oil from Meleiha oilfield.

Isoprenoids/n-alkanes

Waples (1985) stated that by increasing maturity, n-alkanes are generated faster than isoprenoids, in contrast to biodegradation. Accordingly Isoprenoids/n-alkanes (Pr/n-C₁₇ and ph/n-C₁₈) ratios obtained from gas chromatography provide valuable informations on biodegradation, maturation and diagenetic conditions. Pr/n-C₁₇ and ph/n-C₁₈ ratios of the studied crude oils are given in Table (1) and Fig (3). It is clear that the crude oil samples of Qarun and Misaada oilfields have Pr/n-C₁₇ and ph/n-C₁₈ ratios 0.28, 0.47 and 0.1, 0.1, respectively reflecting mostly mature and originated mainly from marine organic sources, deposited under reducing environment (Fig. 4). The crude oil of Meleiha oilfield has Pr/n-C₁₇ and ph/n-C₁₈ of 0.40 and 0.28 indicating mixed organic sources Fig. (4).

Steranes

The steranes distribution of crude oils are given in Table (1), represented in Fig.(5) and peaks identification in Table (2). Meleiha crude oil (Fig. 5A) is characterized by low predominance of C₂₇ steranes (20S and 20R 16.3 %, (peaks D and E) and slightly high abundance of C₂₈ and C₂₉ (20S and 20R

37.40 and 46.30, respectively, (peaks I to P), indicating that the Meleiha oil is believed to be generated from both marine shales and carbonates enriched in marine algae with more contribution from terrestrial organic sources, deposited under saline conditions and oxic setting (Peters and Moldowan, 1993). Furthermore, the distributions of regular steranes C₂₉, C₂₇ and C₂₈ on the ternary diagram (Fig. 6) reveal also that the Meleiha oil is derived mainly from terrestrial organic sources.

The high concentrations of C₂₇ diasteranes (20S) peak (A) and C₂₈, C₂₉ diasteranes (20S and 20R, peaks B, C and G, in case of Meleiha oil, indicate input of marine organic source with more contribution from terrestrial organics (Waples and Machihara, 1992). The high diasteranes concentration compared to regular steranes suggest a clay rich source rock, because the clay is required to catalyze the steroids transformation to diasteranes (Peters and Moldowan, 1991)

Misaada and Qarun oils are characterized by slightly lower predominance of C₂₇ steranes (20S and 20R, peaks D, E, F 20.77% and 20.60%, respectively) and higher abundance of C₂₈ and C₂₉ steranes (20S and 20R 39.30, 39.90% and 40.43, 38.90%, respectively, (peaks I to P) indicating inputs from marine organic sources (Waples and Machihara, 1992). Moreover, the distributions of regular steranes C₂₉, C₂₇ and C₂₈ on the ternary diagram (Fig. 6) reveal also more contribution from marine organic sources.

The diasteranes concentrations compared to regular steranes is low, suggesting a clay rich source rock. The low concentrations of C₂₇ diasteranes (20S) peak (A) and C₂₈, C₂₉ diasteranes (20S and 20R, peaks B,C and G, Fig. 5B, C) indicate marine organic source (Waples and Machihara, 1992). Also, the presence of C₃₀ steranes indicates a marine depositional influence (Moldowan *et al.*, 1985).

Tricyclic Terpanes

Terpanes biomarkers distributions derived from the m/z 191 mass chromatograms are shown in Figure (7) and peaks identification are given in Table 2. The results show that the C₂₁-C₂₅ tricyclic terpanes of Meleiha oil (A-E, Fig. 7A) appear to be the largest components which may support that the oil of Meleiha oilfield is more mature and sourced mainly from marine carbonate source rocks. At the same time the C₂₃, C₂₄ and C₂₅ tricyclic terpanes peaks C, D and E are generally of lower values compared with C₂₂ indicating that the oil has some inputs from terrestrial organic materials (Hunt, 1996). This confirms the conclusion of steranes biomarkers. The unusual low amounts of C₃₀ extended hopanes seem to be associated with mixed organic sources

(Moldowan *et al.*, 1985). This phenomenon can be displayed by the low ratio of C_{29}/C_{30} extended hopanes and Ts/Tm ratio (Jones and Philip, 1990; Hunt, 1996).

On the other hand, The C_{30} hopanes are the largest components in the series $C_{27}-C_{34}$ in oil samples from Misaada and Qarun oilfields (Fig. 7B and C). This indicates that the organic materials in

these oils were originated mainly from saline and hypersaline environments (Ten Haven *et al.*, 1988; Peters and Moldowan, 1993). The extended hopanes are available as paleoenvironmental indicator (Waples and Machihara, 1992). The unusual large amounts of C_{30} hopanes seem to be associated with marine sources (Moldowan *et al.*, 1985).

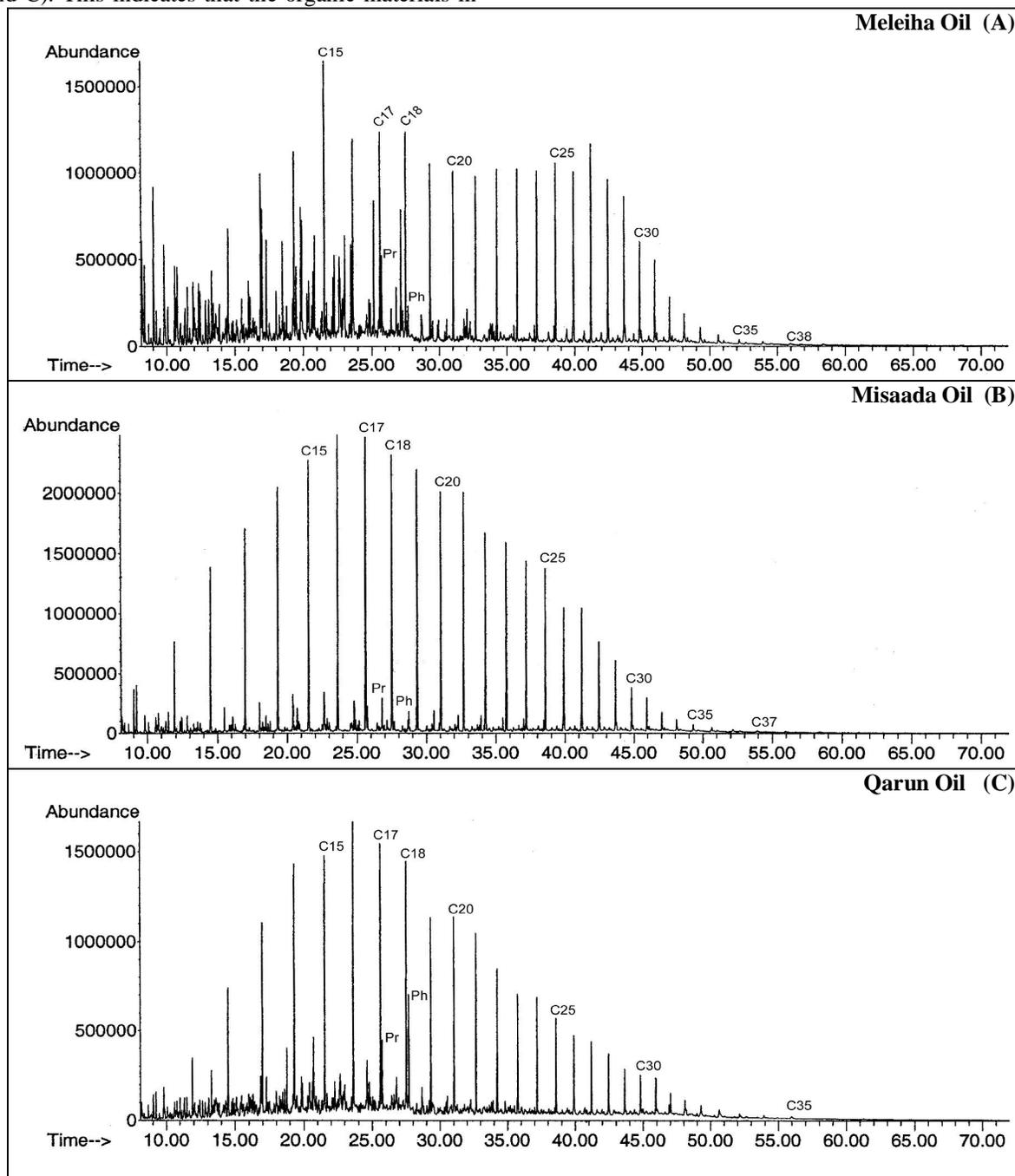


Fig. (3): Gas chromatograms of the saturated hydrocarbons of the studied oil samples

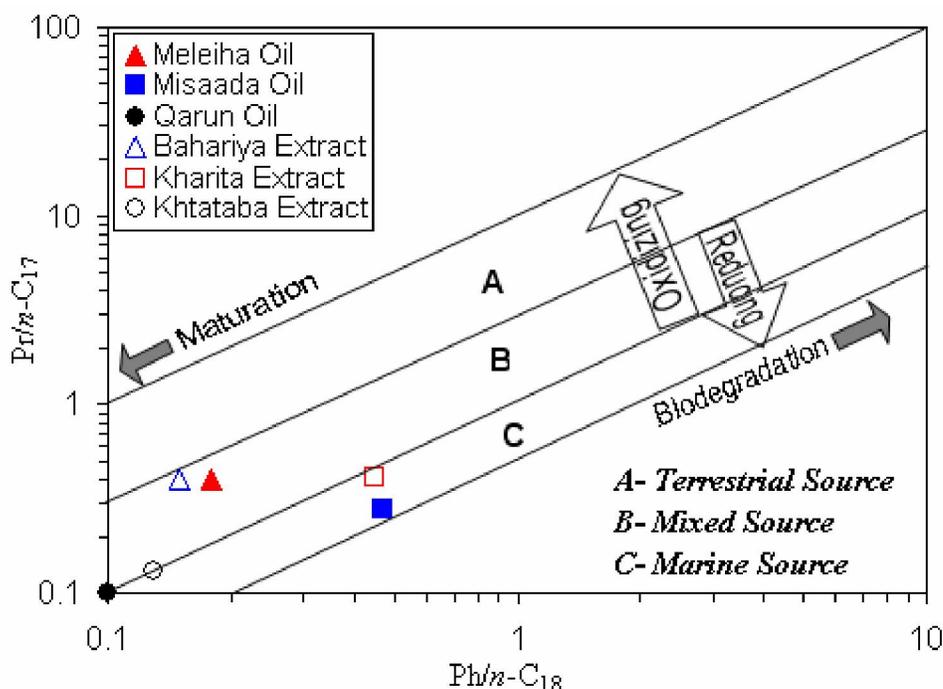


Fig. (4): Plot of $Pr/n-C_{17}$ versus $Ph/n-C_{18}$ (Shanmugam, 1985, modified by Peters et al., 2000), showing oil: source rock correlation of the studied oilfields.

The ratio of Trisnorhopane/Trisnorneohopane (Ts/Tm) is considered as a facies and depositional environmental parameter of the relevant source rocks. Ts/Tm (1.0) in case of Qarun oil and (0.7) in case of Misaada oil (Table 1) reveal marine organic facies of depositional environment. It is also considered as a maturation parameter due to the greater thermal stability of Ts than its counterpart Tm . The ratio of C_{29}/C_{30} hopanes 0.22 and 1.30 again confirm marine organic facies of depositional environment. Ts/Tm and C_{29}/C_{30} hopanes ratios for the crude oils are generally consistent with the pristane/phytane and isoprenoids/n-alkanes ratios (Table 1, Fig. 4). The low concentrations of C_{29} norhopane in crude samples (Fig. 7B and C, peak M) confirms that these samples were generated from organic materials rich in carbonates and evaporites (Connan *et al.*, 1986).

Because gammacerane is resistant to biodegradation, it tends to be present in a variety of source rocks and oils (Hunt, 1996), but its proportion relative to other triterpanes is particularly high in samples from hypersaline depositional settings (Moldowan *et al.*, 1985; Brassel *et al.*, 1988; Huang,

2000), therefore the presence of gammacerane (peak R) in oils of Misaada and Qarun oilfields support the interpretation of an anoxic, reducing hypersaline environment.

The distribution of homohopanes 22R+22S in crude oils can be used as an indicator of the associated organic matter type, as it can also be used to evaluate the oxic/anoxic conditions of source during and immediately after deposition of the source sediments (Peters and Moldowan, 1991). The studied crude oils have low concentrations of $C_{31}-C_{34}$ homohopanes (20S and 20R) (peaks Q, S to U Fig. 7B and C, Table 2) which are more significant to hypersaline marine oils. The homohopane indices values 0.12 and 0.72 confirm this conclusion.

Bisnorhopanes

Bisnorhopanes are types of pentacyclic triterpanes present in significant concentrations in oil. Bisnorhopanes are observed in Guatemalan evaporites (Connan *et al.*, 1986) and frequency reported in other biogenic siliceous rocks of the circum-Pacific region (Katz and Elrod, 1983). It is believed that sediments containing large amounts of bisnorhopane were deposited under anoxic conditions

(Mello *et al.*, 1988). The crude oils of Misaada oilfield has relatively higher amounts of C₂₈ bisnorhopane (peak L) Fig. (7) indicating more anoxic environment than Qarun and Meleiha oils).

Moretanes

Moretanes are abundant in organic materials of marine origin (Connan *et al.*, 1986; Mann *et al.*,

1987). Figure (7) shows that moretanes (peak P) in Misaada and Qarun oils are clearly detectable, indicating marine origin. On the other hand the poorly detectable moretanes in meleiha oil indicates inputs of terrestrial organic matter.

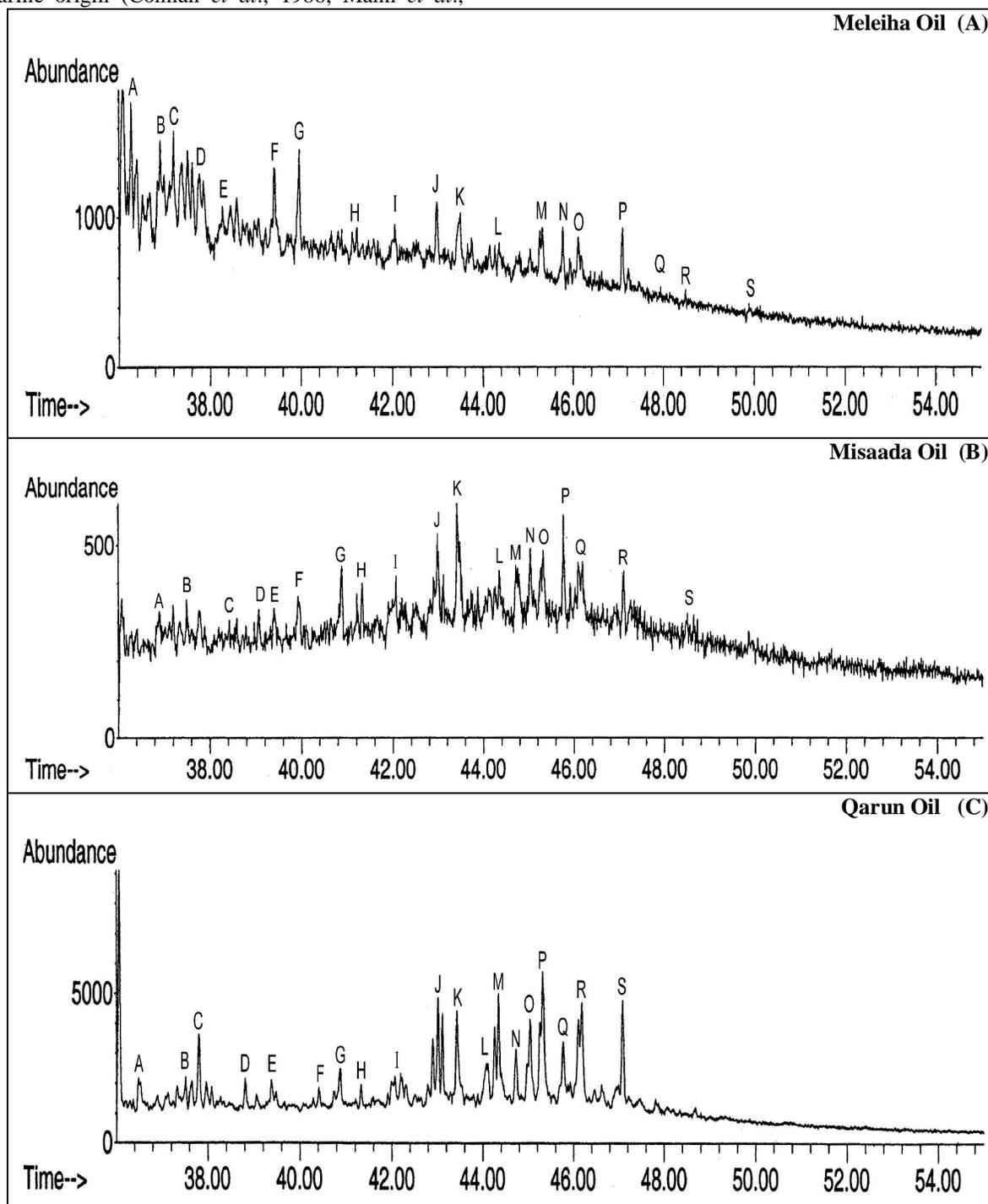


Fig. (5): M/Z 217 steranes in the saturated fractions of the studied oil samples.

Maturation

The maturation of crude oils is controlled by specific geochemical parameters as Carbon preference index (CPI), isoprenoids/n-alkanes ratio (Pr/n-C₁₇ and Ph/n-C₁₈), the diasteranes index and C₂₉ 20S/20S+20R steranes ratio. The CPI values of the studied crude oil samples are close to unity ranging from 0.94 to 1.04 (Table 1) indicating that the studied samples are of high maturity levels (Waples 1985). The isoprenoids/n-alkanes ratios (Pr/n-C₁₇ and Ph/n-C₁₈) ranging from 0.10 to 0.40 and 0.10 to 0.47,

respectively, reflect both the high maturation levels of these crude oils and slight or no biodegradation effects (Fig. 4). Peters and Moldowan (1993); Petersen *et al.*, (2000) recognized that the maturity level of oils increase with increasing of diasteranes index (> 0.1), and C₂₉ 20S/20S+20R (> 0.5). The studied oils have diasteranes index range from 0.10 to 0.27 and C₂₉ 20S/20S+20R from 0.56 to 0.66 (Table 1). These data confirm that the oils are characterized by high maturity levels.

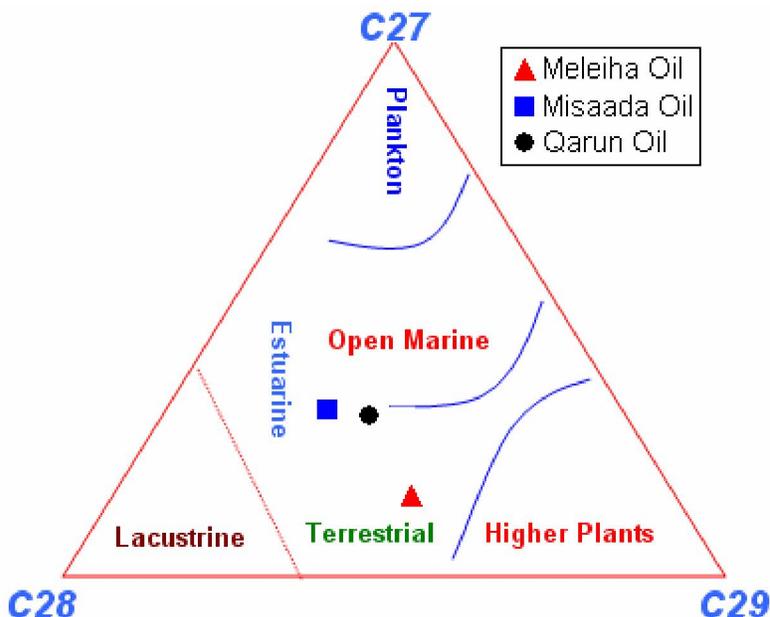
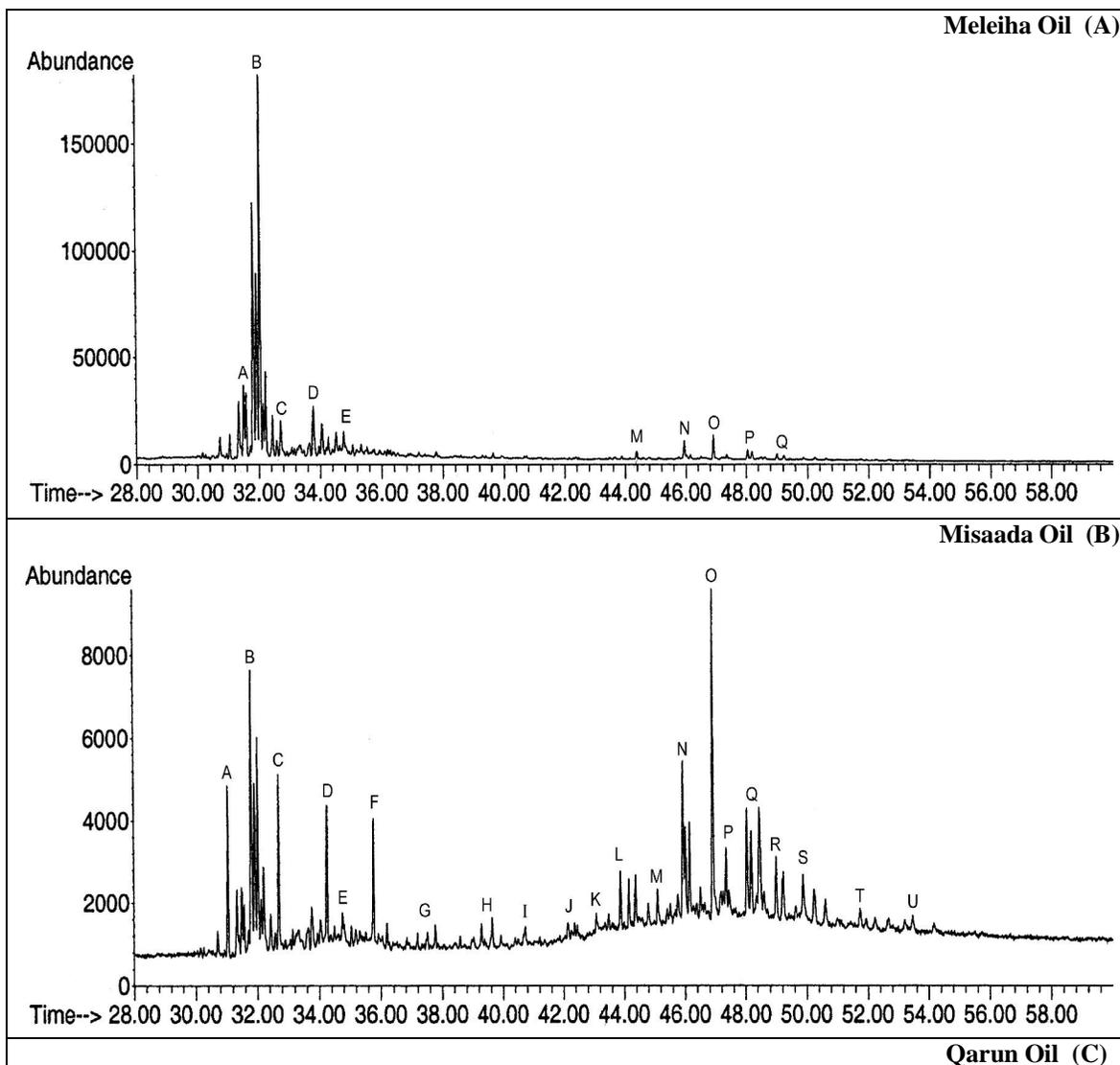


Fig. (6): Distribution of C₂₇, C₂₈ and C₂₉ regular steranes (Huang and Meinschein, 1979), showing organic facies of the studied oils.

Table (2): Peaks Identification of triterpanes (*m/z*191) and steranes (*m/z* 217) mass fragmentograms.

Triterpanes		Steranes	
Peaks	Compounds Name	Peaks	Compounds Name
A	C ₂₁ Tricyclic terpane	A	C ₂₇ Diasterane (20S)
B	C ₂₂ Tricyclic terpane	B	C ₂₈ Diasterane (20S)
C	C ₂₃ Tricyclic terpane	C	C ₂₈ Diasterane (20R)
D	C ₂₄ Tricyclic terpane	D	C ₂₇ Sterane (20S)
E	C ₂₅ Tricyclic terpane	E	C ₂₇ Sterane (20R)
F	(22R)	F	C ₂₉ Diasterane (20R)
G	C ₂₄ Tricyclic terpane	G	C ₂₉ Diasterane (20S)
H	C ₂₈ Tricyclic terpane	H	C ₂₈ Sterane (20S)
I	(22R)	I	C ₂₈ Sterane (20R)
J	C ₂₈ Tricyclic terpane	J	C ₂₈ Sterane (20S)
K	(22S)	K	C ₂₈ Sterane (20R)
L	C ₂₈ Tricyclic terpane	L	C ₂₉ Sterane (20S)
M	(22S)	M	C ₂₉ Sterane (20R)
N	C ₂₇ Trisnorhopane (Ts)	N	C ₂₉ Sterane (20S)
O	C ₂₇ Trisnorneohopane	O	C ₂₉ Sterane (20R)
P	(Tm)	P	C ₃₀ Steranes (20R)
Q	C ₂₈ Bisonorhopans	Q	

R	C ₂₉ Norhopanes	R	C ₃₀ Steranes (20S)
S	C ₂₉ Normoretane	S	C ₃₀ Steranes (20R)
T	C ₃₀ Hopane		
U	C ₂₉ Moretane		
	C ₃₁ Homohopane (22R)		
	C ₃₀ Gammacerance		
	C ₃₂ Homohopane (22R)		
	C ₃₃ Homohopane (22R)		
	C ₃₄ Homohopane (22S)		



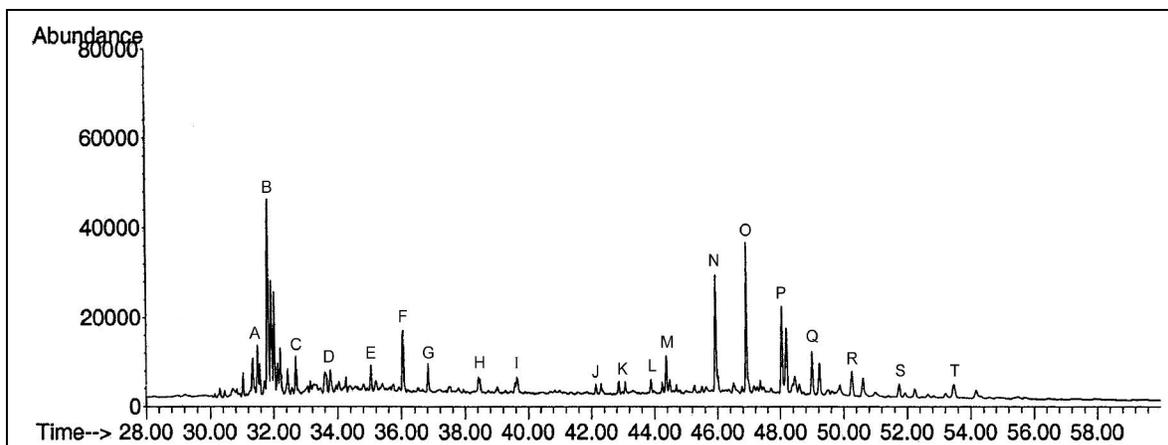


Fig. (7): M/Z 191 terpenes in the saturated hydrocarbons of the studied oil samples

Oil: Source Rocks Correlation

Gross Composition of Oils and Source Rock Extracts

Crude oils and source rock extracts of the studied samples in case of Misaada and Khatatba fields show remarkable similarities in the gross chemical composition, as both have high percent of saturated hydrocarbon contents, exceeding the aromatic and NSO compounds. However, the oil samples have higher saturates percent (69.56 and 72.15 %) than the extract samples where it is 50.82 and 64.59% respectively, revealing that the crude oils appear to be slightly more mature than the extracts. On the other hand, the gross compositions of Meleiha oil and extract of Bahariya source rocks have saturates less than 50% (13.45) and aromatics 22.15% indicating mixed organic sources.

n- alkanes Characteristics

The carbon distribution of crude oils and source rock extracts (Fig. 8) and their normalized composition percent are shown in Table (4). The clear similarities in the molecular distribution between Qarun and Misaada oils and Khatatba and Kharita extracts indicate genetic relationships. On the other hand, Meleiha oil and Bahariya source rocks extract seem to be similar and have other genetic origin.

The Shanmugam plot (1985; Fig. 4) of isoprenoid/n-alkanes ratios supports the previous finding, that oils and extracts of Qarun and Misaada oilfields and extracts of Khatatba and Kharita source rocks are genetically related as they are sourced from marine organic sources and deposited under reducing conditions. The oil and extract samples show degrees of maturation.

Meleiha oil and extract of Bahariya source rocks are genetically related and seem to be sourced from mixed organic sources deposited under transitional conditions (oxidizing – reducing) and of high maturation rate.

Correlation Assessment

The degrees of the correlation between crude oils and the extracted samples have been determined by studying the correlation scores for both oils and extracts. Eight correlation parameters have been studied for this purpose, including saturates (%), saturates/aromatics ratio, C_{max} , $C_{21}+C_{22}/C_{28}+C_{29}$, CPI, pristane/phytane, pristane/n-C₁₇ and pristane+n-C₁₇/phytane+n-C₁₈, (Table 3). The score points, which have been allotted to these different mentioned parameters according to Alexander *et al.*, (1981) are 5 score points for each saturates/aromatics ratios and CPI, 10 points for each pristane/n-C₁₇ and carbon maximum (C_{max}), 15 points for each saturates (%), $C_{21}+C_{22}/C_{28}+C_{29}$ and pristane/phytane ratio, and 25 points to pristane+n-C₁₇/phytane+n-C₁₈. This is depending on their powers, which reflect the genetic relations between oils and potential source rocks (Welte *et al.*, 1975; Alexander *et al.*, 1981).

Based on the above correlation parameters, an overall correlation score was obtained for each oil and extract by summing up the contribution from each parameter. The ratio of correlation parameter to the total parameters (parameter match) has been also considered in evaluating the correlation rate. The samples showing a score 50 points and 5/8-parameter match or more, indicate good correlation. Samples with a score 40-50 points and 4/8-parameter match are considered as not correlated (Alexander *et al.*, 1981).

We prefer to suggest and use a more logic modified correlation rate as shown in the following table:

Score points	Parameter match	Significance
< 50	< 4/8	Not correlated
50	4/8	Slightly correlated
> 50 < 100	> 4/8 < 8/8	correlated
100	8/8	Completely correlated

From the results we conclude that the crude oil from Meleiha oilfield has score point equal to 50 and parameter match 4/8 (Table 5) indicating slightly correlated oil. While the crude oils from Qarun and Misaada oilfields have score points of 80 and 100 and parameters matches 6/8 and 8/8, respectively reflecting correlated and completely correlated oils respectively. On the other hand, the extract sample of Bahariya source rock also is slightly correlated where it has score point 50 and 4/8 parameters match. The extracts of Kharita and Khatatba source rocks having score points of 55 and 60 and parameters match 5/8 and 6/8, respectively indicate correlated extracts.

Therefore, comparing the studied source rocks extracts and the corresponding crude oils it is clear that there is a correlation between the extract samples of Kharita and Khatatba source rocks and crude oils from Qarun and Misaada oilfields. While each of the extract of Bahariya source rocks and Meleiha oil show slight correlation and differ from the other samples. These evidences indicate that Kharita and Khatatba source rocks seem to act as a source and reservoirs for oil generation in the Qarun and Misaada oilfields, while the oil generation of Meleiha

oilfield seems to be migrated from Bahariya source rocks.

Conclusions

Biomarker analyses of crude oils Meleiha, Misaada and Qarun oilfields in the North Western Desert suggest the following:

1. Meleiha oil seems to be sourced from mixed organic sources deposited under transitional conditions.
2. The crude oils of Qarun and Misaada oilfields are genetically related and are sourced from marine organic sources and deposited under reducing conditions.
3. Oil: source correlation reflect a good correlation between the extract samples of Kharita and Khatatba source rocks and crude oils from Meleiha and Qarun oilfields
4. The extract of Bahariya source rock show slight correlation with Meleiha oil and differ from the other oil samples.

These evidences indicate that Kharita and Khatatba source rocks seem to act as sources and reservoirs for oil generation in the Qarun and Misaada oilfields. while, the oil generation of Meleiha oilfield seems to be migrated from Bahariya source rocks.

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Table (3): Geochemical parameters of oils and: source rocks extracts of the studied oilfields.

Samples	Sat %	Arom %	Saturates/ Aromatics	NSO %	Cmax	C ₂₁ +C ₂₂ / C ₂₈ +C ₂₉	CPI	Pr/p h	Pr/ n-C ₁₇	Ph/ n-C ₁₈	Pr+n-C ₁₇ / ph+n-C ₁₈
<i>OILS</i>											
Meleiha	28.58	15.50	1.84	55.92	15	1.10	1.04	3.00	0.40	0.18	1.17
Misaada	69.56	15.23	5.11	15.12	16	2.3	1.02	2.00	0.10	0.10	1.08
Qarun	72.15	18.45	3.91	9.40	16	1.1	0.94	0.63	0.28	0.47	0.90
<i>EXTRACTS</i>											
Bahariya Fm	13.45	22.15	0.64	64.40	15	2.84	2.00	1.41	0.41	0.45	3.33
Kharita Fm.	64.59	30.12	2.14	05.29	16	3.33	0.92	0.42	0.40	0.15	2.84
Khatatba Fm	50.82	22.50	2.26	26.68	16	3.50	0.95	0.60	0.13	0.13	3.50

NSO%: (Asphaltenes + resins) percent; Pr/Ph: Pristane/ Phytane ratio. Pr/n-C₁₇: Pristane/normal alkane ratio. Ph/n-C₁₈: Phytane/ normal alkane ratio. CPI: Carbon preference index = Odd carbon atom/ Even carbon atom.

Table (4): Carbon Number distribution of n-alkanes in the saturated hydrocarbons fractions of crude oils and extract samples of the studied oilfields.

Carbon Number	Meleiha Oil	Qarun Oil	Misaada Oil	Bahariya Extract	Kharita Extract	Khatatba Extract
C ₁₀	1.6	0.5	1.0	1.7	1.5	0.62
C ₁₁	1.0	0.9	1.8	1.1	1.7	0.93
C ₁₂	1.8	2	3.2	1.5	3.3	2.1
C ₁₃	2.7	3.0	4.0	2.2	3.9	3.9
C ₁₄	3.1	3.9	4.8	3.2	4.7	4.7
C ₁₅	4.5	4.0	5.4	4.1	5.1	5.1
C ₁₆	3.3	4.5	5.9	3.1	5.8	5.8
C ₁₇	3.4	4.2	5.8	3.0	5.2	5.2
C ₁₈	3.4	3.9	5.5	2.5	4.9	4.9
C ₁₉	2.9	3.5	5.2	2.2	4.6	4.6
C ₂₀	2.7	3.1	4.8	2.5	4.2	4.2
C ₂₁	2.7	3.0	4.8	2.6	4.2	4.2
C ₂₂	2.8	2.3	3.9	2.4	3.5	3.5
C ₂₃	2.8	1.9	3.8	2.6	3.6	3.6
C ₂₄	2.8	1.8	3.4	2.5	3.4	3.4
C ₂₅	2.9	1.5	3.2	2.7	3.1	3.1
C ₂₆	2.7	1.3	2.5	2.5	2.4	2.4
C ₂₇	3.2	1.2	2.5	3.1	2.5	2.5
C ₂₈	2.6	1.0	1.8	2.4	1.8	1.8
C ₂₉	2.4	1.0	1.9	2.0	1.8	1.8
C ₃₀	1.6	0.7	0.9	1.4	1.2	1.2
C ₃₁	1.3	0.6	0.7	1.2	1.0	1.0
C ₃₂	0.8	0.4	0.4	0.6	0.6	0.6
C ₃₃	0.5	0.3	0.3	0.4	0.5	0.5
C ₃₄	0.3	0.2	0.2	0.2	0.3	0.3
C ₃₅	0.2	0.1	0.1	0.1	0.2	0.10

Table (5): Oils: source rocks correlation of the studied oilfields in the North Western Desert, Egypt

Samples	Sat % >50	Sat/Arom >2.00	C _{max} <22	C ₂₁ +C ₂₂ / C ₂₈ +C ₂₉ >2.00	CPI 1.0+0.1	Pr/ ph 2.0+0.6	Pr/ n-C ₁₇ 0.7+0.6	Pr+n-C ₁₇ / ph+n-C ₁₈ 1.2+0.6	Score + =5 0=Nil	*P.M	**C. R
<i>OILS</i>											
Meleiha	0	0	++	0	+	0	++	+++++	50	4/8	Slightly correlated
Misaada	+++	+	++	+++	+	+++	++	+++++	100	8/8	completely correlated
Qarun	+++	+	++	0	+	0	++	+++++	70	6/8	Correlated
<i>EXTRACTS</i>											
Bahariya	0	0	++	+++	0	+++	++	0	50	4/8	Slightly correlated
Kharita	+++	+	++	+++	+	0	++	0	55	5/8	correlated
Khatatba	+++	+	++	+++	+	0	++	0	60	6/8	Correlated

*P. M: Parameters matching rate are: > 4/8: not correlated 4/8: Slightly correlated < 5/8: correlated
8/8: completely correlated

** C. R: Correlation Ratings are: < 50: not correlated 50: slightly correlated > 50 <: 100 correlated
100: completely correlated

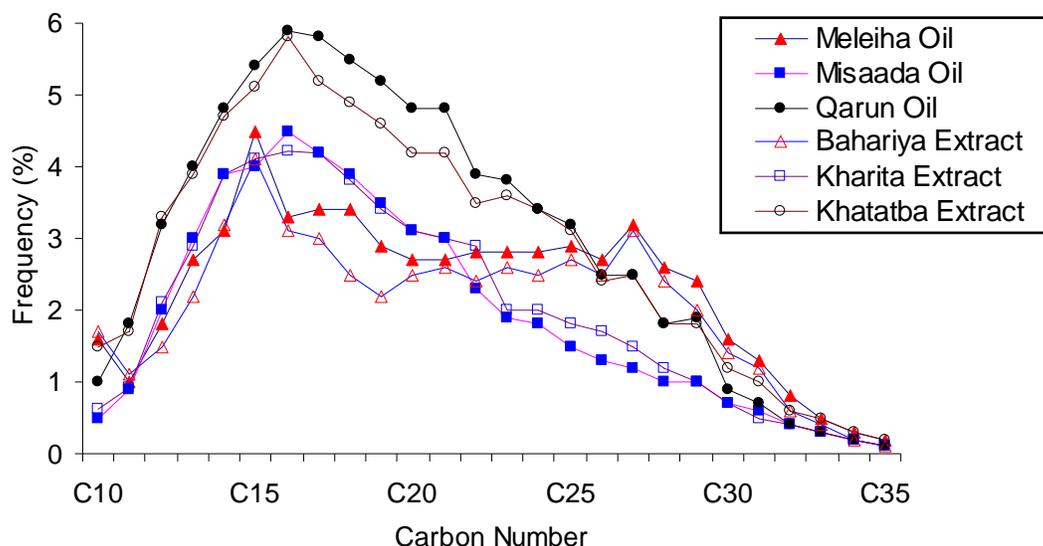


Fig (8). oil: source rock carbon distributions in the studied crude oil and extract samples

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