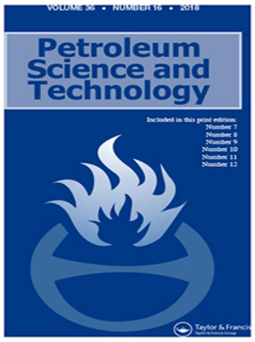

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Evaluation of possible source rocks and extracts characteristics from Safir-1x well, North Western Desert, Egypt

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ABSTRACTS

The pyrolysis and vitrinite reflectance estimations for fifteen shale rock tests and additionally, geochemical burial history, and gas chromatography – mass spectrometry parameters were talked about to explore the hydrocarbon generation and maturation level and time, type of hydrocarbon produced of rock units of Safir-1x well. The results assign that the Bahariya Formation is poor to great source rock to create oil and gas, with a lower thermal maturation degree than the Khatatba and Alam El Bueib formation. Alam El Bueib is viewed as good to excellent source rock for oil and gas age, having marginally high level of thermal maturation at oil window at around 40 million years. Khatatba formation achieved the oil and gas generation window at about 80 and 50 million years separately and considered excellent source rock.

The molecular gas chromatography and mass spectrometry parameters demonstrated that the extracts of source rocks reflected that the Bahariya and Alam El Bueib extracts have a mixed sources formed under transitional conditions at low grad of thermal maturation. Khatatba source rock extracts originated from marine sources formed under reducing conditions at high grade of maturation.

KEYWORDS

Egypt; extracts; Safir-1x well; source rock; thermal maturation; Western Desert

1. Introduction

The Western Desert of Egypt considered as a superb potential oil and gas, it is the second biggest hydrocarbon creating region after the Gulf of Suez. The North Western Desert is a critical segment of the unstable shelf of the Northern Africa.

It has been subjected to various tectonic events since the Paleozoic times, which made numerous basins, sub-basins, ridges, troughs and platforms (EGPC 1992). The main maker around there was Khalda Petroleum Company and the first revelation was Salam-3x well took after by Safir-1x, and Safir N-1 in 1986. Safir-1x well (Figure 1) is described by high collections of oil and gas, which deliver more than 33% of the oil production from the Western Desert of Egypt (EGPC 1992).

Many authors among them, Taher, Said, and El-Azhary (1988), Abdel-Aziz and Hassan (1998), Khaled (1999), Sharaf et al. (1999), Waly, Allard, and Abdel-Razek (2001), El-Gayar et al. (2002), El Nady and Sharaf (2004), El Nady and Ghanem (2011), El Nady (2012- 2015), El Nady and Harb (2015), El Nady et al. (2016a, b), El Nady and El Nagaar (2016) and El Nady and Hakimi 2016) considered the hydrocarbon generation and source rock capability of the northern Western Desert of Egypt. This paper completed to assess the possibilities of source rock by the Rock-Eval pyrolysis method utilized shale rock

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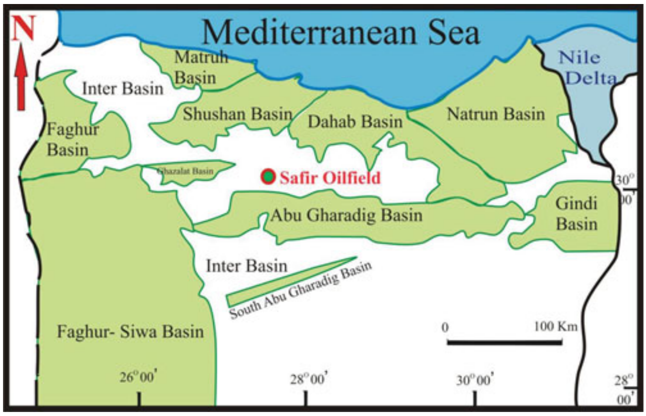

Figure 1. Location map of the studied area.

samples from the succession of Khatatba, Alam El Bueib and Baharyia formations in addition to burial history modeling to assess the thermal maturation degree in the Safir-1x well.

The biomarker characteristics as related to extracts created from Khatatba, Alam El Bueib and Baharyia source rocks from Safir-1 well, were utilized to close the states of depositional environments.

2. Sampling and methods

1. Source rock potential was assessed by estimating the measure of hydrocarbons produced of fifteen chosen shale rock samples by Rock-Eval pyrolysis procedure from Bahariya, Alam El Bueib and Khatatba formations of Safir – 1x well.
2. Burial history modeling to decide source rocks maturation stage and timing.
3. Gas chromatographic investigation of the saturated hydrocarbon fractions of the samples were finished utilizing a Perkin Elmer Instrument Model 8700 (Waltham, MA) provided with a flame ionization detector (FID). Oven temperature was customized for 100°C to 320°C at 3°C/min and last time 20 min. The SPB-1 capillary column was 60 m long. utilized Nitrogen as bearer gas; the ideal flow rate was 6 ml/min.

3. Results and discussions

3.1. Baharyia formation

Baharyia Formation This formation comprises chiefly of sandstones with a few intercalations of shales, limestones and minor dolomites. It kept under fluvial to shallow marine condition. Table (1) demonstrates that the organic contents of the samples differs from poor to fair (Table 1). The production index PI = (S1/S1+S2) of these rocks (Table 1), show that the shale rocks of this formation have a low to medium source rock for generating potential (Figure 2a). As per the connection amongst TOC and S1, it has indigenous hydrocarbons with no contamination (Figure 2b). The gas chromatogram of the saturated hydrocarbons fractions extracted from Safir-1 well demonstrates that it contains moderate amount of heavy n-alkanes (C25-C30) (Figure 3a-a) with odd carbon preference, showing immature sample with contribution of marine organic matter. with preference index (CPI) of 1.42 (Table 1). The isoprenoid pristane/phytane proportion of 0.33 demonstrate that source rock kept under hypersaline conditions, due to phytane from halophilic microorganisms (ten Haven et al., 1987; 1988).

The isoprenoids/n-alkanes (Pristane/n-C17 and Phytane/n-C18) ratios indicate a slightly mature sample of mixed organic source, deposited under transitional environment (Figure 3b)

The ion fragmentograms (triterpanes m/z 191, Figure 3a-b) show low abundance of moretanes in the extracts indicate a slightly limited input of terrestrial organic matter. By increasing maturity moretanes

Table 1. Rock-Eval pyrolysis data, vitrinite reflectance data and GC and GC/MS data of saturated hydrocarbons from extracts of the shale rock samples of the studied formations from Safir -1x well.

Formations	Depth (m)	TOC	S1	S2	HI	OI	Tmax	PI	Ro%	Pr/Ph	Pr/n-c17	Ph/n-c18	CPI	C35/C34 H	Ts/ Tm	GI	HPI
Bahariya	2489	0.44	0.05	0.89	202	129	425	0.05	0.20	0.33	0.70	0.52	1.42	0.50	0.54	0.23	0.11
Bahariya	2500	0.64	0.17	0.91	142	144	428	0.16	0.45								
Bahariya	2520	0.84	0.12	1.32	157	101	428	0.08	0.55								
Bahariya	2550	0.91	0.17	1.48	163	132	430	0.10	0.55								
Bahariya	2580	0.98	0.49	1.88	192	113	425	0.21	0.56								
Alam El Bb	2600	1.15	1.90	5.04	438	117	436	0.27	0.51	0.65	0.49	0.34	1.03	0.49	0.72	0.56	0.57
Alam El Bb	2620	1.54	0.95	5.03	326	146	438	0.16	0.61								
Alam El Bb	2640	1.89	0.96	5.15	272	189	440	0.16	0.62								
Alam El Bb	2700	2.18	1.04	5.67	260	208	437	0.15	0.65								
Alam El Bb	2720	2.40	2..00	5.87	373	198	440	0.19	0.66								
Khatatba	2740	3.71	1.11	5.81	157	183	437	0.16	0.68	0.97	0.37	0.56	1.00	0.52	0.80	0.48	0.32
Khatatba	2760	3.60	1.10	5.74	160	189	435	0.16	0.62								
Khatatba	2780	3.68	1.88	6.11	166	180	458	0.46	0.71								
Khatatba	2800	4.01	1.78	7.45	186	199	441	0.19	1.10								
Khatatba	3100	4.20	2.37	8.38	152	149	455	0.22	1.12								

Note: Alam El Bb: Alam El Bueib Formation S1: mg HC/g rock; S2: mg CO2/g rock; HI: hydrogen index (mg HC/g TOC);
OI: oxygen index (mg CO2/g TOC); PI: Productivity index (S1/ (S1+S2)); Pr/Ph: (Pristane/Phytane); Pr/n-c17: (Pristane/n-C17);
Ph/n-c18: (Phytane/n-C18); CPI: Carbon preference index = (Odd carbon atom/Even carbon atom); C35/C34 H: C35/C34 homohopanes
Ts/Tm: Trisnorhopanes/Trisnorneohopanes ratio; GI: Gammacerane index = gammacerane/(gammacerane + C30hopane);
HPI: Homohopane index = (C35 homohopane S+R)/(C32+C33+C34+C35 homohopanes S+R).

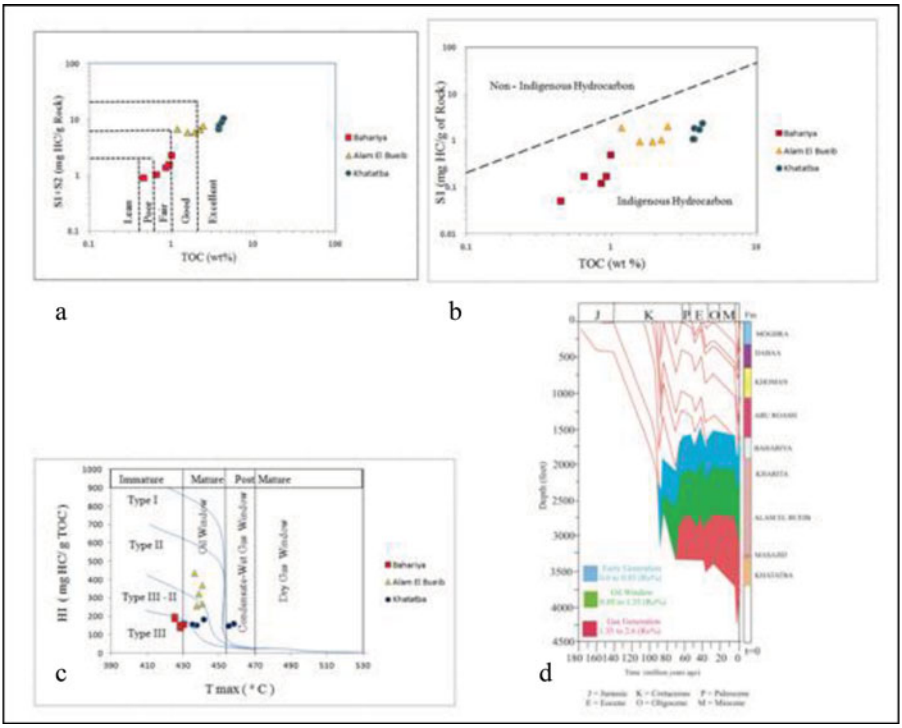

Figure 2. (a) Relation between TOC (wt%) and potential production (S1+S2), (b) Relation between TOC (wt %) and S1 (mg Hc/g of rock), (c) Relation between Tmax (°C) and HI (mg HC / g TOC), (d) Burial history modelling of well Safir-1x.

become less stable; this led to their low concentrations (Brassel et al. 1988). alternatively, the hydrocarbons of the extracts is characterized by slightly high C30 hopane (Figure 3a-b, Table 1) suggesting that the hydrocarbons derived from carbonaceous source rocks organic matters (Hunt 1996). The relative abundance of high gammacerane demonstrates that this formation was gotten from source rocks kept in hypersaline condition, this high figure show stratified water section during source sedimentation (Sinninghe Damste et al. 1995). The C35/C34 homohopanes, Ts/Tm proportions, homohopane and gammacerane indices (Table 1) show mixed organic matter preserved under transitional conditions (Figure 3a-a).

3.2. Alam el bueib formation

This formation comprises principally of sandstones and shales with a few dolomites intercalations. These lithofacies uncovers that this formation was kept under a fluvio-deltaic environment. The shale section of the formation contains TOC values (Table 1) demonstrate a good source rock.

The pyrolysis-derived “S1” and “S2” values of the samples (Table 1) indicate good to excellent generating potential. These samples have high production index of 0.15 to 0.27 (Table 1) which also indicates that the shale rocks of the formation have a very good generating potential (Figure 2a). The formation hydrocarbons are indigenous with no contamination (Figure 2b).

The gas chromatogram of the saturated hydrocarbon fractions of source rock is represented in Fig. (3a-c). This value demonstrate moderate n-alkanes with slightly even and odd carbon preference varies from n-C15 to n-C35, where the CPI value approach unity (Table 1). The pristane/phytane ratios are 0.65 (Table 1) suggesting mixed organic sources deposited under suboxic conditions (Petres and Moldowan 1993). The Pristane/n-C17 and Phytane/n-C18 ratios (Table 1) are reflecting that the extracts of source rocks were derivative from mixed organic sources, deposited under transitional environment (Figure 3b).

The m/z 191 framentograms (Figure 3a-d) show slightly low abundance of tricyclic terpanes reflecting low salinity of depositional environments. The slightly high amount of C28 bisnorohopanes is suggesting input from algae or sulfur- oxidizing bacteria. Furthermore, high C30 hopane is signifying marine organic matters with slightly contribution of terrigenous sources. The presence of C30 moretane suggest

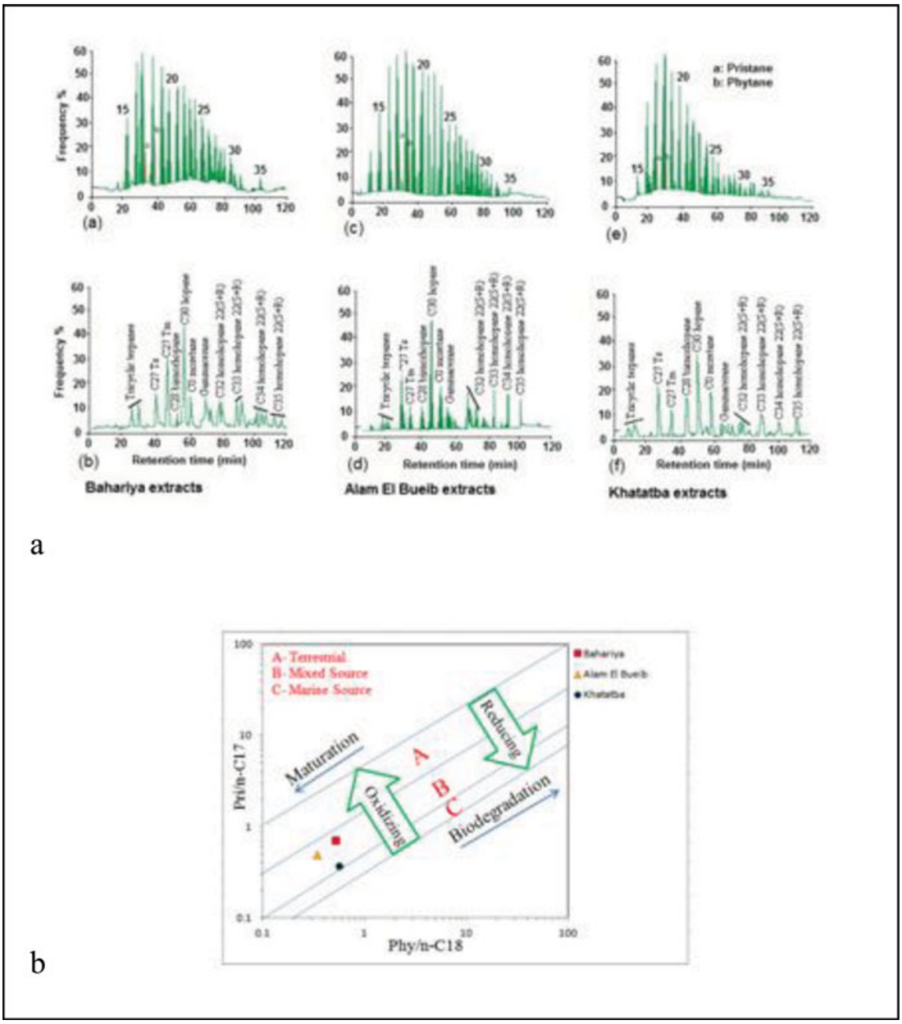

Figure 3. (a) Gas chromatography and Mass spectrometry of the selected samples, (b), Phytane/ n-C18 versus Pristane/ n-C17.

normal salinity marine carbonate source rocks. The C35/C34 homohopanes, and Ts/Tm ratios are 0.49 and 0.72 (Table 1). These high ratios propose that the Alam El Bueib source rock extract generated mainly from calcareous rocks (Mello et al. 1988). The homohopanes (C32-C35) is high as preserved as shown in (Figure 3a-c) indicating strongly reducing anoxic depositional environment. The homohopane index value is 0.57 (Table 1) is significantly among the hypersaline lacustrine. Low concentration of gammacerance (Figure 3a-d), with high gammacerance index value is 0.56 (Table 1), suggest hypersaline marine oil, deposited in reducing environments.

3.3. Khatatba formation

This formation consists of shales intercalated with sandstones and minor limestones, deposited under shallow marine environment. The organic content (TOC) (Table 1) indicate an excellent source rock (Peters and Cassa 1994). The pyrolysis derived S1 and S2 values of Khatatba Formation samples (Table 1) indicate excellent generating potential. The PI of these rocks (Table 1) indicates a high source rock potential (Figure 2a). This Formation has indigenous hydrocarbons with no contamination (Figure 2b).

The gas chromatogram of the saturated hydrocarbons (Figure 3a-e) shows that it contains low amount of heavy n-alkanes, and display no even or odd carbon preference with carbon preference index (CPI) value of 1.00 (Table 1) indicates also a mature sample. This value is undependable to mention the origin of organic matter; whereas the maturity increases the CPI values approach unity (Hunt 1996). The pristane/phytane ratio of this formation (0.97) suggest a slightly reducing depositional environment. The isoprenoids/n-alkanes ratios (Pristane/n-C17 and Phytane/n-C18, Table 1) are 0.37 and 0.56, respectively suggest that marine organic matters, mainly algae, deposited under reducing conditions (Figure 3b).

The triterpanes m/z 191 (Figure 3a-f) shows relatively low concentration from tricyclic terpanes reflecting low salinity of depositional environments (Huang 2000). The faintly high value of C28 bisnorohopanes reflect input from algae or sulfur-oxidizing bacteria (Schoell et al. 1992). conversely, the extracts have slightly high C30 hopane suggeste marine organic matters with a little input from terrigenous sources (Hunt 1996). Furthermore, high C30 moretane indicates normal salinity marine carbonate source rocks. The C35/C34 homohopanes, Ts/Tm ratios are 0.52 and 0.80, respectively (Table 1). These ratios indicate that the extracts generated mainly from calcareous rocks (Mello et al.1988). The homohopanes distribution (C32-C35) is well preserved as shown in (Figure 3a-e) indicating strongly reducing anoxic depositional environment. Furthermore, the homohopane index (Table 1) indicate a hypersaline lacustrine environment (Andrew et al. 2001). Low concentration of gammacerance (Figure 3a-f), with gammacerance index value is 0.48 (Table 1). The data suggest that this formation was deposited in hypersaline marine environment, under reducing conditions (Peters and Moldowan 1993).

3.4. Kerogen types and maturation

Figure 2c shows a plot between Tmax and HI for the studied shale source rock intervals of Bahariya, Alam El-Bueib and Khatatba formations from Safir -1x well. It is reflecting that all formations contain mixed kerogen types II–III. which composed of mixed vitrinite-inertinite derived from land plants and preserved remains of algae (Peters and Cassa 1994). This kerogen type characterizes mixed environment contain mixture of continental and marginal marine organic matter which capable to generate oil and gas (Hunt 1996).

Tmax, and vitrinite reflectance (R_o %) measurements determined the maturity level of the source rocks (Waples 1994). Tmax of Baharyia source rocks ranged from 425 to 430°C, and the vitrinite reflectance (R_o %) ranged from 0.20% to 0.56% (Table 1) reflecting immature to marginally mature source rocks (Figure 2c) The Alam El Bueib and Khatatba source rocks have Tmax values ranging from 436 to 440°C, (R_o %) from 0.51 to 0.66% and from 435 to 455°C, Ro% from 0.62 to 1.12, respectively (Table 1), indicating mature source rocks and have capability of oil and gas generation (Figure 2c).

Burial history modeling of Safir x-1 well (Figure 2d) confirm the above result and give the timing of hydrocarbon generation and maturation of each formation, where Baharyia Formation begin to generate hydrocarbons from 10 million years at the early stage of generation while Alam El Bueib and Khatatba formations enter the oil window from 40 and 80 million years respectively, and Khatatba Formation begin to generate gas from 51 million years.

4. Conclusions

1. A Bahariya formation is considered as poor to good source rock for oil and gas generation and has a low level of thermal maturation.
2. The shale rock of Alam El-Bueib is considered as good to excelent source rock for oil and gas generation and has a medium level of thermal maturation.
3. The shale source rock of Khatatba formation achieved the oil and gas generating window and considered excellent source rock potential.
4. All formations have indigenous hydrocarbons with no contamination.
5. The atomic gas chromatography and ion mass spectrometry parameters demonstrated that the concentrates of Khatatba and Alam El Bueib source rocks are characterized by marine organic matter formed under high grad of thermal maturation. While Bahariya source rock has mixed organic sources formed under low grade of thermal maturation.

References

Abdel-Aziz, A. L., and Z. A. Hassan. 1998. Kenz field: A new play concept in Khalda concession. Paper presented at EGPC *14th Petrol. Explor. and Prod. Confer*, Cairo 1, 118–38.

EGPC (Egyptian General Petroleum Corporation). 1992. *Western Desert, Oil and Gas Fields (A Comprehensive Overview)*. Cairo, Egypt.

El Nady, M. M. 2012. The potentiality of source rocks in Hayat oilfield based on well data, North Western Desert, Egypt. *Journal of Energy Sources, Part A: Recovery, Utilization, and Environmental Effects* 34 (22):2023–30.

El Nady, M. M., and L. M. Sharaf. 2004. Contribution to the organo-geochemical characteristics of Paleozoic source rocks in the vicinity of Siwa Oasis, Western Desert, Egypt. *Ann. of Geol. Survey* 27:445–58.

El Nady, M. M., and M. Ghanem. 2011. Thickness variations, lithofacies changes and time of hydrocarbons generation in the Khalda West area, North Western Desert, Egypt. *Journal of Energy Source, Part A: Recovery, Utilization, and Environmental Effects* 33 (23):2218–29.

El Nady, M. M., and A. Y. El-Naggar. 2016. Petroleum Geochemistry of Crude Oils and Oil: Source Rock Correlation of Some Wells in the North Western Desert, Egypt. *Journal of Arabian Geoscience* 9 (13):1–8.

El Nady, M. M., and F. M. Harb. 2015. Source Rock Quality from Oil Biomarkers of Abu Gharadig Basin in the North Western Desert, Egypt. *Journal of Energy Sources, Part A: Recovery, Utilization, and Environmental Effects* 37 (23): 2514–23.

El Nady, M. M., and M. H. Hakimi. 2015. The petroleum generation modeling of prospective Jurassic-Cretacouse source rocks in Tut Oilfield, North Western Desert, Egypt: An integrated bulk pyrolysis and 1D- basin modeling. *Journal of Arabian Geoscience* 9 (6):1–14 (2016).

El Nady, M. M., F. M. Ramadan, E. A. Eysa, and N. M. Said. 2016b. The Potentiality of Hydrocarbon Generation of the Jurassic Source Rocks in Salam-3x well, North Western Desert, Egypt. *Egyptian Journal of Petroleum* 25 (1):97–105.

El Nady, M. M., N. S. Mohamed, and L. M. Sharaf. 2016a. Geochemical and biomarker characteristics of crude oils and source rock hydrocarbon extracts: An implication to their correlation, depositional environment and maturation in the Northern Western Desert, Egypt. *Egyptian Journal of Petroleum* 25 (1):263–68.

El-Gayar, M. S. H., A. E. Abdel-Fattah, and A. O. Barakat. 2002. Maturity dependent geochemical markers of crude petroleums from Egypt. *J. Petrol .Sci. and Techn* 20 (9 and 10):1057–70.

Haven ten, H. L., J. W. de Leeuw, J. Rullkötter, and J. S. Sinninghe Damste. 1987. Restricted utility of the pristane/phytane ratio as a paleoenvironmental indicator. *Nature*, 330:641–643.

Haven ten, H. L., J. W. de Leeuw, J. S. Sinninghe Domste, P. A. Schenck, S. E. M. Palmer, and J. E. Zumberge. 1988. Application of biological markers in the recognition of palaeohypersaline environments. In: Fleet, A. J., Kelts, K. and Talbot, M. R. (eds.), Lacustrine petroleum source rocks. *Geological Society Special Publication*, 40:123–130.

Huang, H. P. 2000. The nature and origin of petroleum in the Chaiwopu Sub-Basin (Junggar Basin), NW China. *J. Petrol. Geol.* 23:193–220.

Hunt, J. M. 1996. *Petroleum geochemistry and geology*. second edition. New York: W. H. Freeman and company.

Khaled, K. A. 1999. Cretaceous source rocks at Abu Gharadig oil and gas field. north Western Desert, Egypt. *J. Petrol. Geol.* 22 (24):377–95.

Mello, R. M., P. C. Gaglianone, S. C. Brassel, and J. R. Maxwell. 1988. Geochemical and biological marker assessment of depositional environments using Brazilian offshore oils. *Mar. Pet. Geol.* 5:205–23.

Peters, K., and M. Cassa. 1994. Applied source rock geochemistry. In *The Petroleum System from Sourc to Trap. AAPG Memoir*, ed. L. B. Magoon, W. G. Dow, vol. 60, 93–117. USA: AAPG bull.

Peters, K. E., and J. M. Moldowan. 1993. The Biomarker Guide. *Interpreting molecular fossils in petroleum and ancient sediments*. Englewood cliffs, NJ: Prentice hall. 363.

Schoell, M., M. A. Mc Caffrey, F. J. Fago, and J. M. Moldowan. 1992. Carbon isotopic compositions of 28, 30 bisnorhopanes and other biological markers in Monterey crude oil. *Geochimica et Cosmochimica Acta* 56:1391–99.

Sharaf, L. M., M. Ghanem, S. Hussein, and M. M. El-Nady. 1999. Contribution to petroleum source rocks and thermal maturation of Jurassic- Cretaceous sequence, south Matruh, north Western Desert, Egypt. *Bull. of Egyptian Society of Sedimentology* 7:71–83.

Sinninghe Damste, J. S., F. Kenig, M. P. Koopmans, J. Koster, S. Schouten, J. M. Hayes, and J. W. de Leeuw. 1995. Evidence for gammacerane as an indicator of water column stratification. *Geochimica et Cosmochimica Acta* 59:1895–900.

Taher, M., M. Said, and T. El-Azhary. 1988. Organic geochemical study in Meleiha area, Western Desert, Egypt. Proceeding of EGPC 9th Petrol. Explor. and Prod. Confer., Cairo, Egypt, 190–212.

Waly, M., A. Allard, and M. Abdel-Razek. 2001. Alamein basin hydrocarbon expulsion models. *Proceeding of the 5th Conference on Geochemistry* II:293–302.

Waples, D. W. 1994. Modeling of sedimentary basins and petroleum systems. In *The Petroleum System from Source to Trap. APPG Memoir*, ed. L. B. Magoon and W. G. Dow, vol. 60, 307–22. USA: AAPG bull.