AAPG Annual Convention
Salt Lake City, Utah
May 11-14, 2003

Alamein Basin Hydrocarbon Potentials, Northern Western Desert, Egypt

Younes, M. A. Geology Department, Faculty of Science, Moharrem Bek, Alexandria University, Alexandria, Egypt.
E-mail: mohamedyounes@hotmail.com

Abstract
Alamein basin is one of the giant basins in the northern Western Desert of Egypt that generated and expelled mature oil and gas accumulations. It is structurally bounded by Dabaa platform from north and Qattara platform to southwest. Crude oil samples from different pay zones of the Alamein, North Alamein, Yidma and Horus fields were used for organic geochemical analyses and stable carbon isotopic composition. The biomarker properties of these oils found no obvious variations among them. They characterized by high API gravities, low sulfur contents, oleanane index <10% and the canonical variable parameter is >0.47. These results show that all oil samples analyzed were derived from shale rocks dominated by terrestrial higher land plants input. The Rock-Eval pyrolysis data for the Jurassic-Cretaceous sequence revealed that the potential source rock in the Alamein basin is the dark shale sequence of the Middle Jurassic (Khatatba Formation). The maturation study of the Khatatba shales indicate that these rocks have mixed kerogen types II-III and have been entered the mid-mature stage of oil generation window at vitrinite reflectance measurements between 0.7-1.0 Ro%. These similarities in geologic occurrences and biomarker characteristics suggest the possibility that the hydrocarbon expulsion would have been initiated from deeply buried Jurassic source rocks during the Early Cenomanian time and trapped in the Pre-Laramide structures of Cretaceous formations throughout the extensional faults. The geochemical study of crude oils from Alamein basin defines a family of genetically related oils that were generated from thermally mature and organic-rich shales of Middle Jurassic age.

Lithostratigraphy and Structural Setting

The lithostratigraphic column in the northern part of the Western Desert contains the most of sedimentary section from Pre-Cambrian basement rocks to recent deposits. The thickness of sedimentary section measures about 14,000 feet. In general, the stratigraphic section consists mainly of alternating cycles of clastics and carbonates as a result of several successive transgressions and regressions of the sea. The lithostratigraphic column of the overlying series within the unstable shelf area of the north Western Desert subdivided into three sequences. First the Lower clastic unit from Cambrian to Cenomanian. Second, the Middle Carbonates from Turonian to Eocene and finally the Upper Clastic unit from Oligocene to Recent. Alamein basin is an elongated NE-SW and the major fault patterns include a primary NE-SW oriented trend and NW-SE oriented faults are also prominent, which are antithetic to the primary trend. The structural configuration development appears to have reached their maximum growth during the Late Cretaceous and have shown additional rejuvenation during the Tertiary (Waly et al., 2001).

The structure of Alamein area was defined as a large northeast-southwest plunging anticline constitutes the regional Qattara-Alamein structural ridge dissected by major fault system trending northeast-southwest directions. Within the Alamein structure itself these faults form a graben that cuts the crestal part of the structure into two blocks (Abdine, 1974). The structure of Qattara-Alamein ridge shows the same direction of the Syrian Arc folding system, which is the most prominent structural configuration of Alamein area consists of extensional faults which extended up into the Alam El-Bueib section, then the faulting ceased until very late Abu Roash to Khoman times. The faulting was then reactivated forming inversion structures which, were formed over the down thrown side of the reactivated old extensional faults.

Hydrocarbon Source Potential

The source rock potential and the hydrocarbon generation of the north Western Desert of Egypt were studied by many authors among them are, Metwalli and Abdel-Hadi (1973 and1975 a & b), Metwalli et al., (1979), Zein El-Din and El-Hamzy (1980), Parker (1982), Shahin and Shehab (1988), Taher et al., (1988), Zein El-Din et al. (1990), Abdel-Gawad et al., (1996), Douban (1996), Abdel-Moniem (1997), Khaled (1999), Metwalli et al., (1999), Dolson et al., (2000), Darwish et al., (2000) and Waly et al., (2001).

The hydrocarbon source potentials were applied on seventeen shale rock samples to the Jurassic-Cretaceous lithostratigraphic succession of the well Alamein 1-X to evaluate their organic richness, kerogen types, and the degree of thermal maturity in the Alamein basin of the north Western Desert.

1. Source Rock Richness

The results of Rock-Eval pyrolysis of the Jurassic-Cretaceous shale successions from the well Alamein-1X.. These results show that organic-rich intervals are present at two separate stratigraphic levels.

- **Cretaceous**

The Cretaceous shale rocks of the Kharita, Bahariya, Abu Roash and Khoman formations have low to medium source potential. Their TOC contents rang between 0.41-1.25 wt. %, and the pyrolysis yield S1+S2 rang between 0.8 and 4.1kg HC/ton rock and the productivity index of these rocks are generally less than unity.

- **Jurassic**

The Jurassic shale in the Khatatba Formation contain TOC reaches to 4.32 wt.%, the pyrolysis yield S1+S2 averages 6.1 kg HC/ton rock and the and the productivity index of these rocks are generally more than unity, therefore these shale source rocks are considered to have excellent source rock potential. The shale in the Yakout Formation have TOC average 2.1 wt.%, the pyrolysis yield S1+S2 average 4.2 kg HC/ton rock and the productivity index of these rocks are generally less than unity.

2. Organic Matter (Kerogen) Types

It is very important to determine the kerogen types due to the variation of the chemical structure of the different types of organic matters. The plotting of hydrogen index (HI) versus oxygen index (OI) on Van Krevelen diagram for the studied shale source rock intervals from well Alamein-1X shows that Jurassic-Cretaceous shales contain mixed kerogen types II-III. Rock-Eval pyrolysis results indicate that the kerogen is composed mainly of inertinite-vitrinitie materials with some predominance of structured lipid-rich vitrinite in Khoman and Abu Roash shales decreases downward in Jurassic formations. Structured lipid-rich vitrinite are mostly of terrigenous origin and have the potential to generate oil and gas deposits in an euxinic environment. (Tissot, 1984).

3. Source Rock Maturity

Thermal maturities were estimated from vitrinite reflectance measurements (Ro%) for the well Alamein-1X (Figure 2). These vitrinite reflectance data were plotted against depth in figure 6 to indicate the phases of hydrocarbon generation. Based on the maturity profile in the burial history curves of Alamein basin, the mid mature oil generation window is estimated to occur at 12,000 ft. Dark shale of the Khatatba Formation reached the oil generation window at vitrinite reflectance values of 0.7-1.0 Ro% at approximately 90 million years ago (Early Cenomanian). Maturation studies of source rocks indicate that hydrocarbon expulsion would have been initiated in the depocenters from Middle Jurassic Khatatba Formation source rock during Early Cenomanian and trapped in Pre-Laramide structures throughout the extensional faults.

Crude Oil Characteristics and Correlation

Taher et al., (1988) and Halim et al., (1996) used the biomarker properties and stable carbon isotopic composition of crude oils from different discoveries in the north Western Desert to assess the genetic relationship between hydrocarbon generation and their source rock depositional conditions. Six crude oil samples were recovered from the different pay zones of Aptian Alamein Dolomite and Cenomanian Bahariya and Abu Roash-G reservoirs of the Alamein, North Alamein, Yidma and Horus fields .

These crude oils have a low range of API gravities range between 34.5° and 36.8° and correspond to a low variation of sulfur content, which was found to be around unity. Liquid chromatograph data indicate a predominant composition of saturates >50%, with saturate/aromatic ratio around 2. The gas chromatograms of the whole crude oils recovered from Cretaceous reservoirs, which are very similar paraffinic and contain little branched or cyclic materials waxy n-alkanes (C_{25}-C_{31}) and moderately high pristine/phytane ratios (1.55 to 1.78) and CPI are generally >1 that are typical of terrestrially sourced oils (Moldowan et al., 1985). A plot of Pr/n-C_{17} versus Ph/n-C_{18} also indicates that the crude oils were derived from terrestrial and peat-coal environment (Shanmugam, 1985). The bulk geochemical characteristics of

crude oils suggest that they are derived from the same source rock of the same depositional conditions. The ratios of Ts/Tm and homohopane index C_{35}/C_{34} for the crude oils are generally <1 and the oleanane index was <10%. This suggests that the crude oils of Alamein basin may be derived from Mesozoic source rocks (Moldowan et al., 1994).

The regular sterane distribution of the Alamein crude oils further suggest their derivation from higher land plants input of terrestrial sources (Moldowan et al., 1985 and Zumberge, 1987). The ratio of 20S/(20S+20R) $C_{29}\alpha\alpha\alpha$ Cholestane was found to be >0.5, which indicates that the crude oils generated from Alamein basin were generated from thermally mature source rock (Seifert and Moldowan,1981; and Peter and Fowler, 2002).

Stable Carbon Isotopic Composition

Taher et al., (1988) and Zein El-Din et al., (1990) used the stable carbon isotope composition to the aromatics and saturates fractions of the Western Desert crude oils to characterize marine from terrestrial oil sources. Sofer (1984) distinguished the crude oils derived from marine and non-marine sources for crude oils from different areas of the world including Egypt depending on the stable carbon isotope δ^{13} C compositions to the saturate and aromatic fractions. He postulated the canonical variable parameter $(C.V)$ to distinguish the source of crude oils;

$$C.V = -2.53\delta^{13}C_{sat.} + 2.22\ \delta^{13}\ C_{arom.} - 11.65.$$

The plotting of the stable carbon isotopic composition to the saturate and aromatic hydrocarbon fractions of the studied crude oils from Alamein basin. The stable carbon isotope composition of the saturate fraction values range from (-26.9 to −26.0 ‰ PDB); while the stable carbon isotope composition of the aromatic fraction values has the range (-24.9 to −24.1 ‰ PDB). The figure reveals that the studied crude oils from Alamein basin were probably originated from source rocks dominated by the terrestrial organic matters. This conclusion is also supported from the calculated canonical variable parameter which was found to be >0.47 for all the studied crude oils characterize waxy oils of terrestrial sources. This is confirm with the results achieved by Zein El-Din et al., (1990) who concluded that the Western Desert crude oils are characterized by waxy nature, high maturity level and less negative carbon isotope values derived from terrestrial origin.

Inferred Oil to Source Rock Correlation

Attempts were made to correlate the Rock-Eval pyrolysis data of the shale source rock of Khatatba Formation to the biomarker characteristics of the cretaceous crude oils depending on the published results of Taher et al., (1988), Shahin and Shehab (1988) Zein El-Din et al., (1990) and Waly et al., (2001). They concluded that the Cretaceous crude oils of the north Western Desert fields are genetically related to a coaly facies source rock containing mainly terrestrial higher land plants input subjected to high stage of thermal maturation level. They concluded that the dark shale of the Middle Jurassic Khatatba Formation is the main source rock of oil generation in the northern part of the Western Desert. The biomarker properties of the Cretaceous crude oils of Alamein basin revealed no obvious variation among them characterized by high API gravities, low sulfur contents, oleanane index <10% and the canonical variable parameter is >0.47. The Rock-Eval pyrolysis data for the Jurassic-Cretaceous sequence revealed that the potential source rock in the Alamein basin is the dark shale sequence of the Middle Jurassic (Khatatba Formation). The maturation study of the Khatatba shales indicate that these rocks have mixed kerogen types II-III and have been entered the mid-mature stage of oil generation window at vitrinite reflectance measurements between 0.7-1.0 Ro% at approximately 90 million years ago (Early Cenomanian).

Conclusion

The biomarker properties and stable carbon isotopic composition of Cretaceous oils recovered from Alamein, North Alamein, Yidma and Horus fields found no obvious variations among them. These oils are paraffinic, contain little branched or cyclic materials waxy n-alkanes (C_{25}-C_{31}) and characterized by high API gravitiy, low sulfur content, oleanane index <10% and moderately high pristine/phytane ratio>1 and CPI >1 and the canonical variable parameter is >0.47. These results indicate that all oil samples were derived from shale rocks dominated by terrestrial higher land plants input. The Rock-Eval pyrolysis data for the Jurassic-Cretaceous sequence revealed that the potential source rock in the

Alamein basin is the dark shale rocks of the Middle Jurassic (Khatatba Formation). The maturation study of the Khatatba shales indicate that these rocks have mixed kerogen types II-III and have been entered the mid-mature stage of oil generation window at vitrinite reflectance measurements between 0.7-1.0 Ro% at approximately 90 million years ago (Early Cenomanian). These similarities in geologic occurrences and biomarker characteristics suggest the possibility that the hydrocarbon expulsion would have been initiated from deeply buried Jurassic source rocks during the Early Cenomanian time and trapped in the Pre-Laramide structures of Cretaceous formations throughout the extensional faults.

References

Abdel-Gawad, E. A., Philip, R. P. and Zein El-Din, M. Y. 1996. Evaluation of possible source rocks in Faghur-Siwa Basin, Western Desert, Egypt. Proceeding of the EGPC 13th Petroleum Exploration and Production Conference, Cairo. v.I, pp. 417-432.

Abdel-Moniem, M. 1997. Alamein Field; A leading oil field in the Western Desert, History and Future. Proceeding of the 3rd Conference on Geochemistry, V. II, pp. 33-46.

Abdine, A. S. 1974. Oil and gas discoveries in the North Western Desert of Egypt. International Report Western Desert Operating Petroleum Company, pp. 1-27.

Darwish, M., El-Azabi, M. H., Eid, A. A. and Moussa, S. 2000. Hydrocarbon Habitat of some Mesozoic sedimentary basins, Onshore West Nile Delta, Egypt. 5th Intern. Conf. Arab World (GAW), Cairo University (in press).

Dolson, J. C. Shann, M. V. Matbouly, S. Hammouda, H. and Rashed, R. 2000. Egypt in the next millenium: petroleum potential in offshore trends. Proceeding of the Mediterranean Offshore Conference, Alexandria, p.109-131.

Douban, A. F. 1996. Basin Analysis and hydrocarbon potentiality of Matruh Basin, North Western Desert, Egypt. Proceeding of the 3rdInt. Conf. Arab World (GAW), Cairo University, pp. 595-624.

Halim, M. A. Said, M. and El-Azhary, T. 1996. The geochemical characteristics of the Mesozoic and Tertiary hydrocarbons in the Western Desert and Nile delta Basins, Egypt: 13 th EGPC Petroleum Conference, Cairo.v.1, p.401-416.

Huang, W.Y. and Meinschein, W.G., 1979. Sterols and ecological indicators: Geochimica et Cosmochimica Acta, v. 43, p.739-745.

Lijmbach, G.W. 1975. On the origin of petroleum: Proceeding of the 9th World Petroleum Congress, Applied Science Publisher, London, v. 2, p.357-369.

Metwalli, M. H. and Abdel-Hady, Y. E. 1973. Tectonic analysis of the subsurface sedimentary succession in Alamein Field, Northern Western Desert, A. R. Egypt. Desert Inst. Bull., A. R. E., 23(2), pp. 271-284.

Metwalli, M. H. and Abdel-Hadi, Y. E. 1975 a. Petrographic characteristics of oil-bearing rocks in Alamein Oil Field; significance in source-reservoir relations in the Northern Western Desert, Egypt.AAPG Bulletin, 59(3), pp.510-523.

Metwalli, M. H. and Abdel-Hadi, Y. E. 1975 b. The significance of the variation of crude oil gravities of some oil fields in the Northern Western Desert, A. R. Egypt. 9th Arab Petroleum Congrss, Dubai, 113(B-3),pp.1-10.

Metwalli, M. H., Saad, M. K. and Ali, T. A. 1999. The Significance of porosity on the reservoir quality of the Upper Bahariya Clastics, Meleiha OilField area, North Western Desert, Egypt. Proceeding of the 4th Int. Conf. Arab World (GAW), Cairo University, pp. 924-935.

Moldowan, J.M., Seifert, W.K. and Gallegos, E. J., 1985. Relationship between petroleum composition and depositional environment of petroleum source rocks. AAPG Bulletin , 69, 1255-1268 .

Moldowan, J.M. Dahl, J. Huizinga, B. and Fago, F. 1994. The molecular fossil record of oleanane and its relation to angiosperms: Science, v. 265, p.768-771.

Parker, J. R. 1982. Hydrocarbon Habitat of the Western Desert, Egypt. 6th Exploration Seminar, Cairo.

Peters, K. E. and Fowler, M. G. 2002, Application of petroleum geochemistry to exploration and reservoir management. Organic Geochemistry, v. 33, pp. 5-36.

Seifert, W.K. and Moldowan, J.M. 1981. Paleoreconstruction by biological markers: Geochimica et Cosmochimica Acta, v.45, p.783-795.

Shahin, A.N. and Shehab, M.M.,1988. Undiscovered hydrocarbon reserves and their preservation time basin, Western Desert, Egypt. EGPC 9th Petroleum Exploration and Production Conference, Cairo.pp.134-163.

Shanmugam, G. 1985. Significance of coniferous rain forests and related oil, Gippsland Basin, Australia: AAPG Bulletin, v.69, p.1241-1254.

Sofer, Z., 1984. Stable carbon isotope compositions of crude oils: Applications to source depositional environments and petroleum alteration. AAPG Bulletin, 68, 31-49.

Taher, M., Said, M. and El-Azhary, T.1988. Organic geochemical study in Meleiha area, Western Desert, Egypt. EGPC 9th Petroleum Exploration and Production Conference, Cairo.pp.190-212.

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

Zein El-Din, M. Y., and El-Hamzy, A. A.1980. On the source rock potentialities of the Jurassic sediments, Western Desert, Egypt. 8th IGES Hannover Accepted Abstract. P. 106.

Zein El-Din, M. Y., Matbouly, S., Moussa, S. and Abdel-Khalek, M. 1990. Geochemistry and oil-oil correlation in the Western Desert, Egypt. EGPC 10th Petroleum Exploration and Production Conference, Cairo.

Zumberge, J. E., 1987. Terpenoid biomarker distributions in low maturity crude oils: Organic geochemistry, v. 11(6), pp. 479-496.

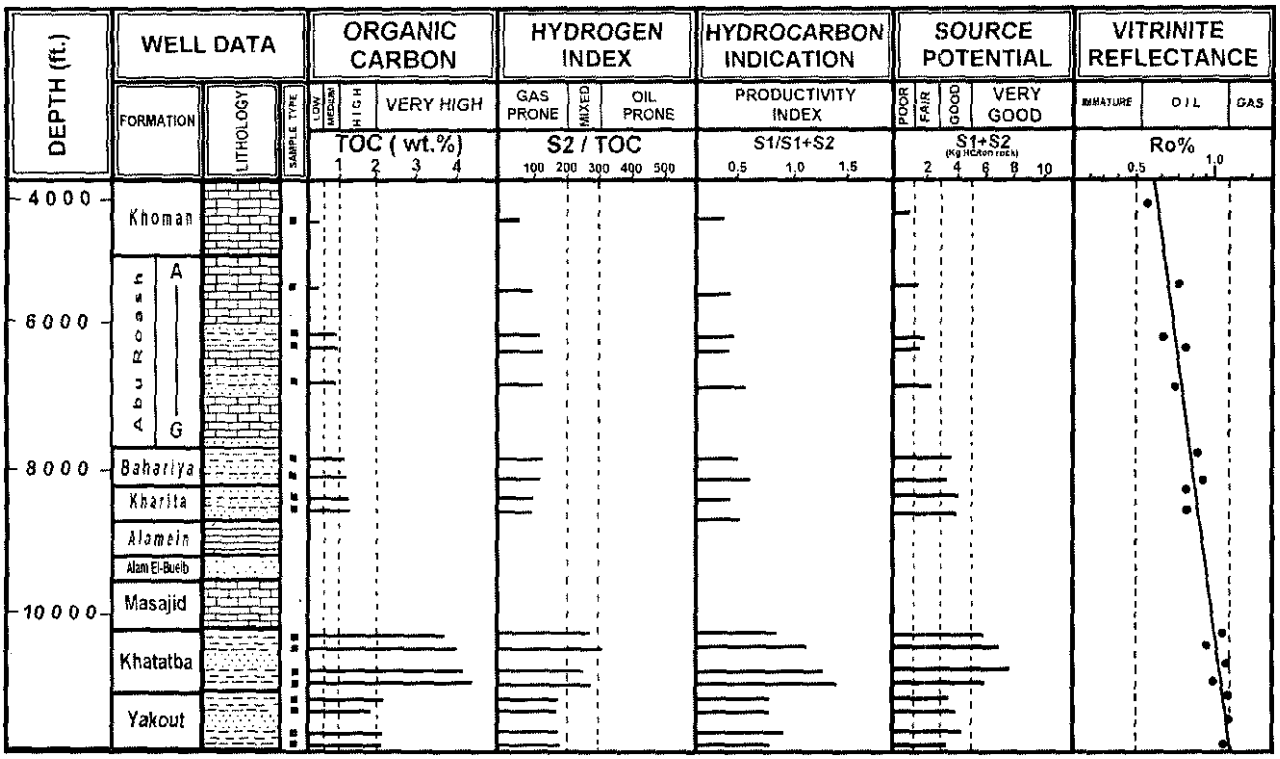

Figure 1: Idealized geochemical log to the weil Alamein-1X, showing Rock-Eval Pyrolysis data total organic carbon and virtinite reflectance measurements.

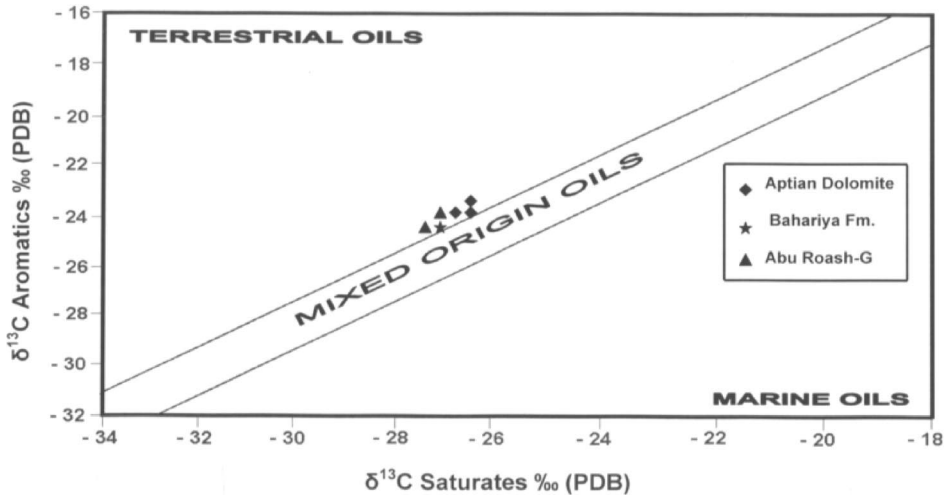

Figure 2: Relationship between the stable carbon isotope composition of the saturate and aromatic fractions to the crude oils from Alamein fields. (after Sofer,1984).