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Source-Bed for Mesozoic and Younger Oils in Saudi Arabia: Constraints of Biomarker Applications

Hussain, Mahbub and Raza Md Jowaher, Earth Sciences Department, King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia

The argillaceous carbonate intervals of the Jurassic Hanifa and Tuwaiq Mountain Formations are widely known as the main source (if not the only source, Ayers *et al.,* 1982) of the Mesozoic and younger oils in northeastern part of Saudi Arabia. It includes the Jurassic Arab-D Formation in the Ghawar field, the largest oil field in the world (Figure 1).

Biomarker study of the Mesozoic oils and suspected source beds in Saudi Arabia has been undertaken by a number of authors including Ayers *et al*., (1982), Cole *et al*., (1993) and Carrigan *et al.,* (1994). The biomarkers recognized include C_{15+} *n*-alkane, isoprenoids (nC_{17} pristine and nC_{18} phytane), carbon ($\delta^{13}C$) isotope, m/z 191 hopanes and tricyclics, and m/z 217 steranes. Biomarker study by Carrigan *et al.* (1994) found close correlation between Arab-D oil and the extracts from Hanifa and Tuwaiq mountain Formation.

A review of the published geochemical data by the present authors, however, observed that except for carbon isotopes ($\delta^{13}C$), biomarkers are ineffective in distinguishing oils from different reservoirs. In addition, this investigation indicates that the oils in the Mesozoic and younger formations may have derived from more than one source including the Paleozoic source rocks.

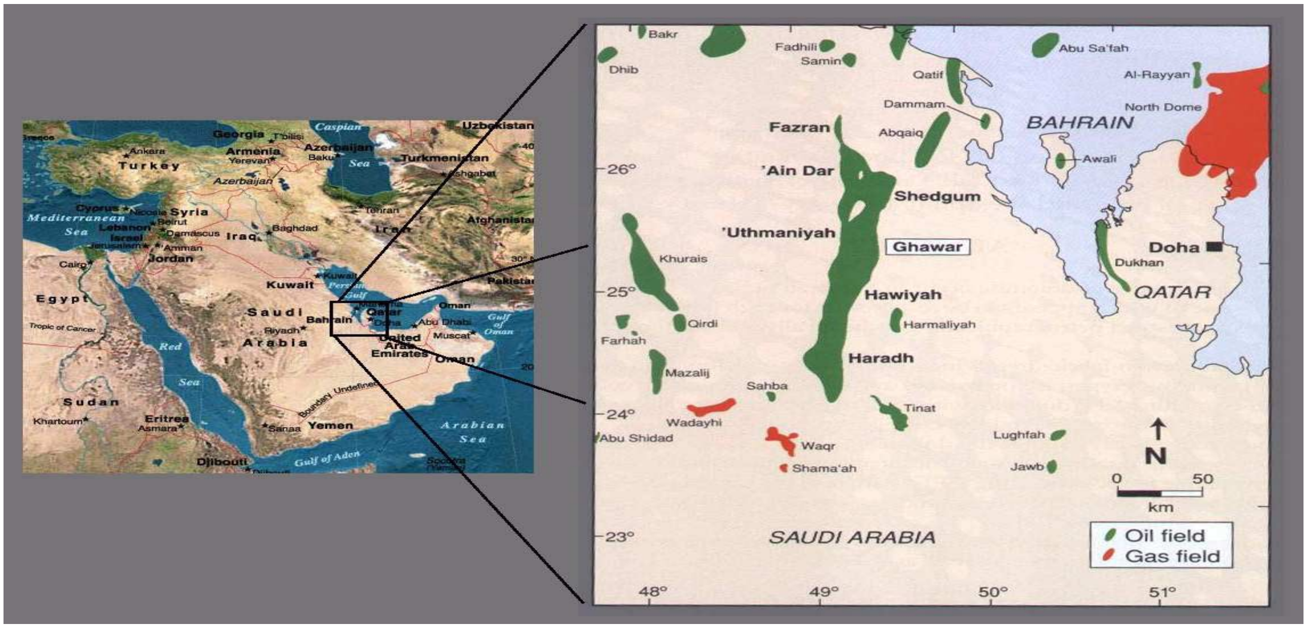

Figure 1. Map showing location of oil and gas fields in central and northeastern Saudi Arabia.

The current work is based on the synthesis and interpretation of all available published biomarker of the oils and source rock extracts from different formations of central and eastern Saudi Arabia. In addition, biomarker data from other formations in the region were also used.

The main focus, however, is on the following: Jurassic Arab D oils, Permian Khuff and Unayzah oils, from Hawtah field, Basal Qusaiba extract, Jauff extract, Hanifa extract, Tuwaiq Mountain extract reported as in Cole *et al.,* (1994) and Carrigan *et al.,* (1994). The gas chromatographic data on n-alkane, m/z 191 hopanes and tricyclics, and m/z 217 steranes used in interpretation were normalized to offset any effects of the operating conditions of the equipment and also to ensure the consistency of the data for comparison . The data were manipulated using statistical package STATISTICA ®.

n-Alkane

As shown in the following frequency plots (Figure 2), the dominant peaks of the *n*-alkane of the samples compared, cluster between nC15 and nC22. The frequency distribution curves show two main associations: (i) Tuwaiq Mountain extracts, Jauf extracts, and Arab D oil, (ii) Basal Qusaiba extract and Hanifa extracts. The frequency curve of the Paleozoic oil does not match with either one of these associations. The correlation matrix generated by the principal component also shows the strength of the association. For example, the correlation coefficient (r) between the Basal Qusaiba extract and Hanifa extract is over 0.9. factor analysis of the relative intensity data of different n-alkanes in the samples.

Hopanes and Tricyclics

m/z 191 hopanes and tricyclics data shows dominance of the peaks in 22, 29, 30-Bisnorhopane to 17α, 21β(H)-29-Trishomohopa-nes range. The frequency plots show close association among basal Qusiaba, Jauf, and Tuwaiq Mountain extracts (Figure 3).

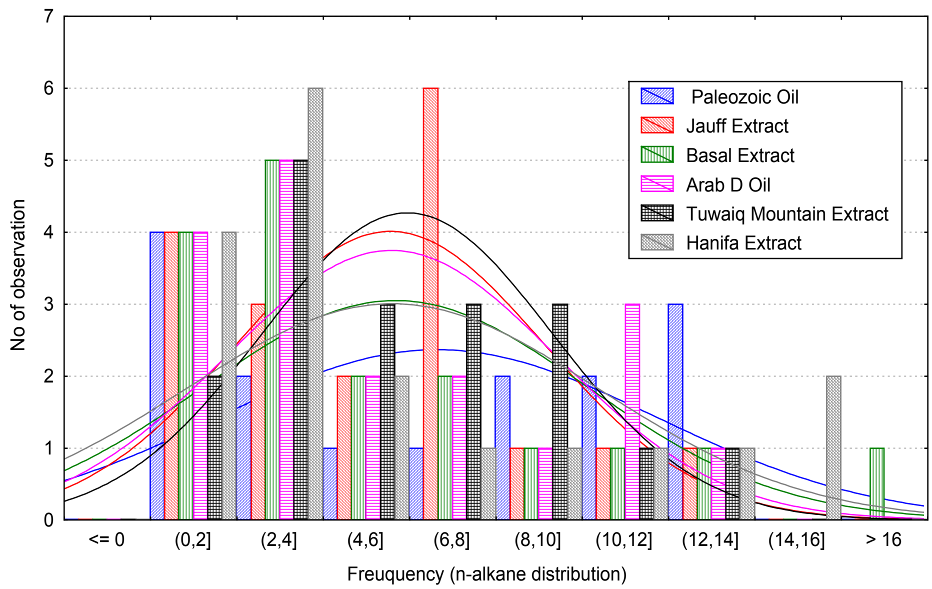

Figure 2. Frequency histogram showing the relative distribution of different in n-alkanes in oil and source rock extracts. Note two main associations : (i) Tuwaiq Mountain extracts, Jauf extracts, and Arab D oil, (ii) Basal Qusaiba extract and Hanifa extracts.

The overall trend of the distribution of hopanes and tricyclics two oil samples is not significantly different. However, compared to the intensity of the dominant peaks of the Arab D oil and peaks of the Paleozoic oil are much subdued, and correlation of the samples is also low (r = 0.76). A strong correlation among the Paleozoic oil, Jauff and basal Qusaiba extract is also apparent. On the other hand, Arab D oil shows a strong correlation (r=0.94) with the Hanifa extract. The correlation between the Basal Qusaiba extract and the Hanifa extract (r = 0.90) is also significant.

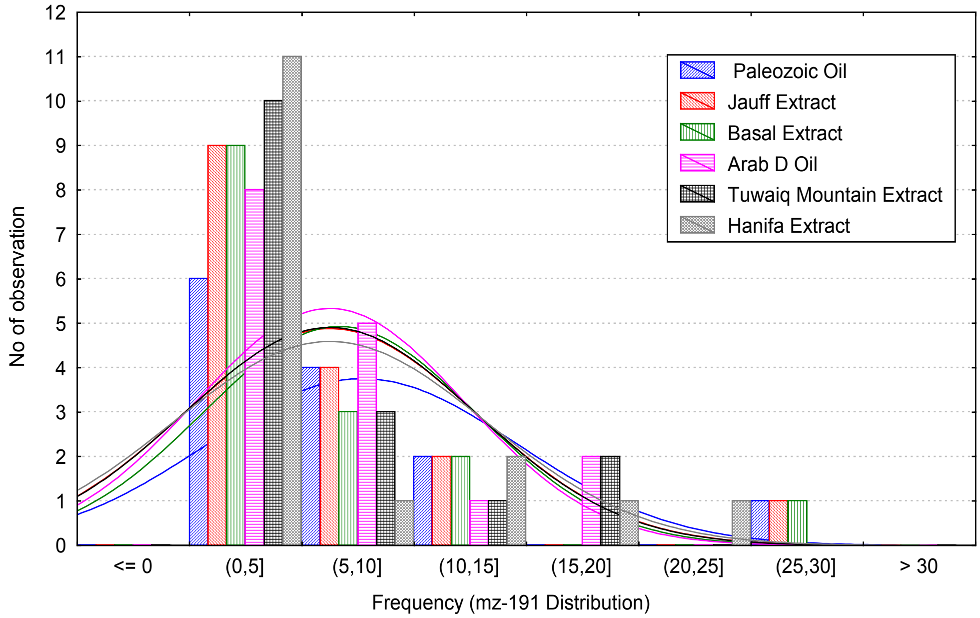

Figure 3. Frequency histogram showing the intensity of different in hopanes and tricyclics in oil and source rock extracts from different formations and reservoirs. Note a strong correlation between the Arab D oil and the Hanifa extract. The correlation among the Paleozoic oil Jauff and Basal Qusaiba extract is also significant.

Sterane

The dominant peaks of m/z 217 steranes fragmentograms of the Arab D oil are confined between C27αααα20S to C29 ααα20R range. Prominent peaks were also recognized in the mid (diasteranes) and low-molecular weight fractions. Compared to the histograms and frequency plots of the alkane and hopanes, the plots of the steranes are irregular and do not show any clustering. However, based on overall trend of the frequency distribution (Figure 4), the samples can be divided into two groups: (i) high-intensity group comprising the Basal Qusaiba extract, Hanifa extract and Arab D oil, (ii) the low-intensity group Tuwaiq Mountain extract, Jauf extract, and the Paleozoic oil.

Carbon ($\delta\ ^{13}C$) isotope

Carbon isotope ($\delta\ ^{13}C$) values of the oils and source rock extracts from the Arabian peninsula have been reported by several authors including Ayers *et al.*, (1982), Edgell (1991), Carrigan *et al.*, (1994), Cole *et al.*, (1994). The average of $\delta\ ^{13}C$ isotope values for the Hanifa-Tuwaiq Mountain, Paleozoic oil, Arab D oil, Jauff extract, and basal Qusaiba extract are –26.4%o, 29.6%o, 26.6%o, -27.0%o, 29.8%o, respectively. A plot of the isotope values of the oils as shown in the box whisker plots (Figure 5) shows that the isotopes of the Arab D oil are significantly heavier than that of the Paleozoic and Precambrian samples in the region. The isotope values of the oil, however, are very similar to the values of the extracts from both Hanifa and Tuwaiq Mountain

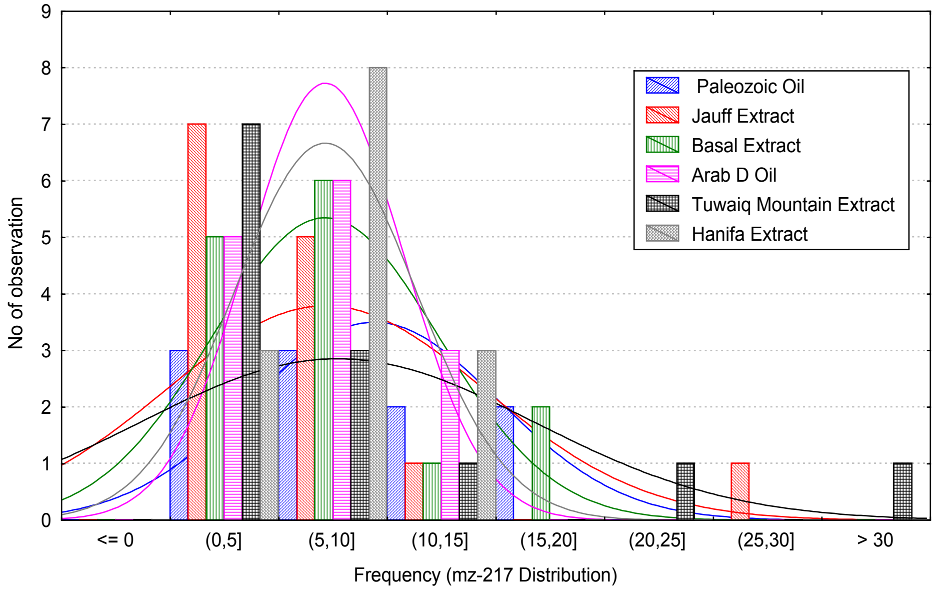

Figure 4. Frequency histogram showing the intensity of different in steranes in oil and source rock extracts from different formations and reservoirs. The Basal Qusaiba extract, the Hanifa extract, and the Arab D oil values show a high intensity trend. On the other hand, the Tuwaiq Mountain extract, Jauf extract, and Paleozoic oil values show a low intensity trend.

samples. The isotope values of the Paleozoic oils, on the other hand, are close to those of the basal Qusaiba extracts suggesting basal Qusaiba as the source of the Paleozoic oils in the area.

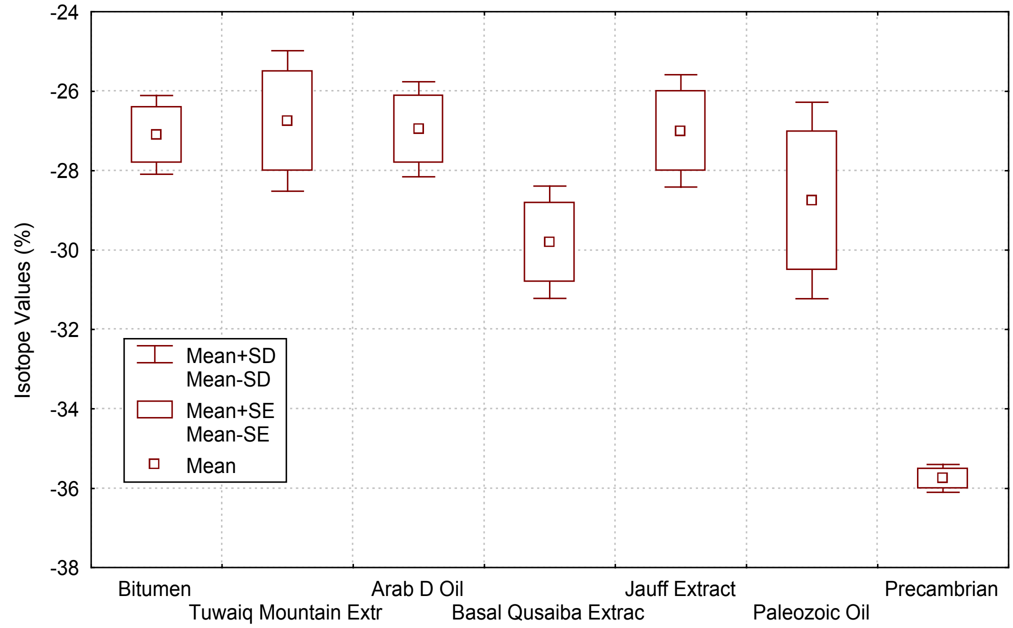

Figure 5. Box Whisker Plot of $\delta\,^{13}C$ isotope distribution in oil and source rock extracts from different formations and reservoirs.

REFERENCES CITED

Ayers, M.G., Bilal, M., Jones, R.W., Slentz, L.W., Tartir, M., and Wilson, A.O., 1982, Hydrocarbon habitat in main producing areas, Saudi Arabia: AAPG Bulletin, v. 66, pp. 1-9.

Carrigan, W.J., Cole, G.A., Colling, E.L., and Jones, P.J., 1994, Geochemistry of the Upper Jurassic Tuwaiq Mountain and

Hanifa Formation petroleum source rocks of eastern Saudi Arabia: In Katz, B.J. (edt.), Petroleum Source Rocks, Springer-Verlag, 327p.

Cole, G.A., Abu-Ali, M.A., Aoudeh, S.M., Carrigan, W.J., Chen, H.H., Colling, E.L., Gwathney, W.J., Al-Hajji, A.A., Halpern, H.I., Jones, P.J., Al-Shardi, S.H., Tobey, M.H., 1994, Organic geochemistry of the Paleozoic petroleum system of Saudi Arabia: Energy & Fuels, v.8, pp.1425-1442.

Edgell, H.S., 1991, Proterozoic salt basins of the Persian Gulf area and their role in hydrocarbon generation: Precambrian Research, v.54, pp.1-4.