Hydrocarbon continuity investigation of Sarvak and Ilam reservoirs in Azadegan oilfield using integration of geochemical, geological and reservoir engineering data

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1-Introduction

The N-S trending Azadegan oilfield has been located in Abadan Plain, SW Iran, near the Iraq border. It considered being one of the largest undeveloped oilfields in the world. The Upper Cretaceous Sarvak (Turonian) and Ilam (Santonian) reservoirs, dominated by carbonate lithology, contain heavy oil and separated from each other by Shaly Lafan (Coniacian) Formation (Alizadeh et al., 2012, 2016; Du et al., 2016; Abdollahie Fard et al., 2006). The vertical continuity of Calcareous Sarvak and Ilam formations in Azadegan oilfield is unidentified. Therefore, in this study, organic geochemical methods were first used to specify geochemical and genetic characteristics of the Sarvak and Ilam reservoir oils. Subsequently, vertical continuity of these reservoirs was investigated using the integration of the results obtained from reservoir geochemical methods (England, 2007) with lithological information and reservoir pressure data.

2-Methodology

A variety of geochemical analyses including liquid chromatography (LC), gas chromatography (GC), gas chromatography-mass spectrometry (GC-MS) and 13C stable isotope analysis were carried out on the Sarvak and Ilam reservoir oils. Also, C7 light hydrocarbon analysis was done to investigate the reservoirs continuity by detecting the compounds in the range of C5 to C9 using GC8000 instrument equipped with a flame ionization detector (FID). Measuring nickel (Ni) and vanadium (V) elements in the oil samples were performed using inductively coupled plasma-mass spectrometry (ICP-MS). Also, geological and lithological information of the studied reservoirs were extracted from the available reports and interpretation of the well logs, while the reservoir pressure data obtained from pressure measurements in the well test operation.

3-Results and discussion

The data obtained from liquid chromatography analysis shows that a significant portion of the studied samples contains polar (resins/asphaltenes) and aromatic compounds. The gas chromatograph patterns of the oil samples are identical. However, the higher degree of biodegradation for the Ilam reservoir oil sample can be inferred from a larger unresolved hump in its chromatogram (Peters et al., 2005; Volkman et al., 1986; Connan, 1984). Tissot and Welte's (1984) ternary diagram, which is constructed based on the amounts of saturated, aromatic and polar compounds, introduces the studied samples as paraffinic-naphthenic oils.
The relationship between pristane/n-C17 and phytane/n-C18 ratios as well as the low values of terrigenous to aquatic ratio (TAR) and pristine/phytane < 1 (Table 1) all indicate a marine carbonate source rock for the oil samples, deposited in an actively reducing environment (Peters et al., 2005).

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Table 1. The results obtained from liquid and gas chromatography analyses on the studied oil samples

Reservoir	Saturate	Aromatic	Polar	Pr/Ph	Pr/nC_{17}	Ph/nC_{18}	TAR	CPI
Ilam	22	42	36	0.32	0.50	1.2	0.10	0.79
Sarvak	20	39	41	0.47	0.60	1.21	0.27	0.99

Pr/nC_{17} = pristane/n-heptadecane; Ph/nC_{18} = phytane/n-octadecane; TAR = terrigenous to aquatic ratio ($[nC_{27} + nC_{29} + nC_{31}]/[nC_{15} + nC_{17} + nC_{19}]$);CPI = carbon preference index ($2[C_{23}+C_{25}+C_{27}+C_{29}]/[C_{22}+ 2 (C_{24}+C_{26}+C_{28})+C_{30}]$).

Based on the relation between C27, C28 and C29 steranes (Table 2) as well as $\delta^{13}C_{Sat}$ and $\delta^{13}C_{Aro}$ data (Sofer, 1984), the oil samples generated from a carbonate marine source rock belonging to Lower Cretaceous or Jurassic (Grantham and Wakefield, 1988; Moldowan et al., 1985). On the other hand, C29 Sterane 20S/(20S+20R) was investigated related to C29 Sterane ββ/(ββ+αα) to identify the level of thermal maturity, indicated the middle oil generation window for the source rock which has generated the studied oil samples (Peters et al., 2005).

Table 2. Different facies and age related sterane biomarkers for the studied oil samples

Facies related biomarkers							Age related biomarkers
Reservoir	% C_{27} Sterane	% C_{28} Sterane	% C_{29} Sterane	C_{27} Dia/ (Dia+Reg) Sterane	DBT/PHEN	C_{27}/C_{29} Sterane	C_{28}/C_{29} Sterane
Ilam	34	25	41	0.1	4.3	0.82	0.62
Sarvak	36	23	41	0.1	3.1	0.87	0.57

C_{27} Dia/(Dia+Reg) Sterane = C_{27} Diasterne/(Diasterane + Regular Sterane); DBT/PHEN = dibenzothiophene/phenanthrene; C_{27}/C_{29} Sterane = C_{27}/C_{29}αααα20R steranes; C_{28}/C_{29} Sterane = C_{28}/C_{29}ααα 20R steranes.

Geochemical features of the Sarvak and Ilam reservoir oil samples are identical, indicating the same genetic family for them. However, C7 light hydrocarbons obtained from high-resolution gas chromatography (HRGC) and Halpern diagrams (Halpern, 1995) were used to investigate the continuity in these reservoirs. The parameters obtained from C7 light hydrocarbon analysis are not identical in the studied oil samples, resulting in a separation between the samples in the star diagrams (i.e., C1-C5, TR1-TR5, and A-F) (Figure 1). So, two different oil groups were identified in the studied reservoirs.

The diagram of Toluene/Ethylbenzene versus Dimethylbenzene indicates the relatively same level of thermal maturity for the oil samples (Thompson, 1979, 1983, 1987, 1988, 2006) (Figure 2a). Also, the plot of toluene/nC7 against nC7/MCH (Figure 2b) shows that the Sarvak and Ilam reservoir oils have been affected by evaporative fractionation and water washing, respectively. Overall, based on the results obtained from HRGC analyses on the oil samples it can be concluded that the oils of Sarvak and Ilam reservoirs are not continuous. It may be a result of a barrier between the studied reservoirs which disconnected the oils connectivity.

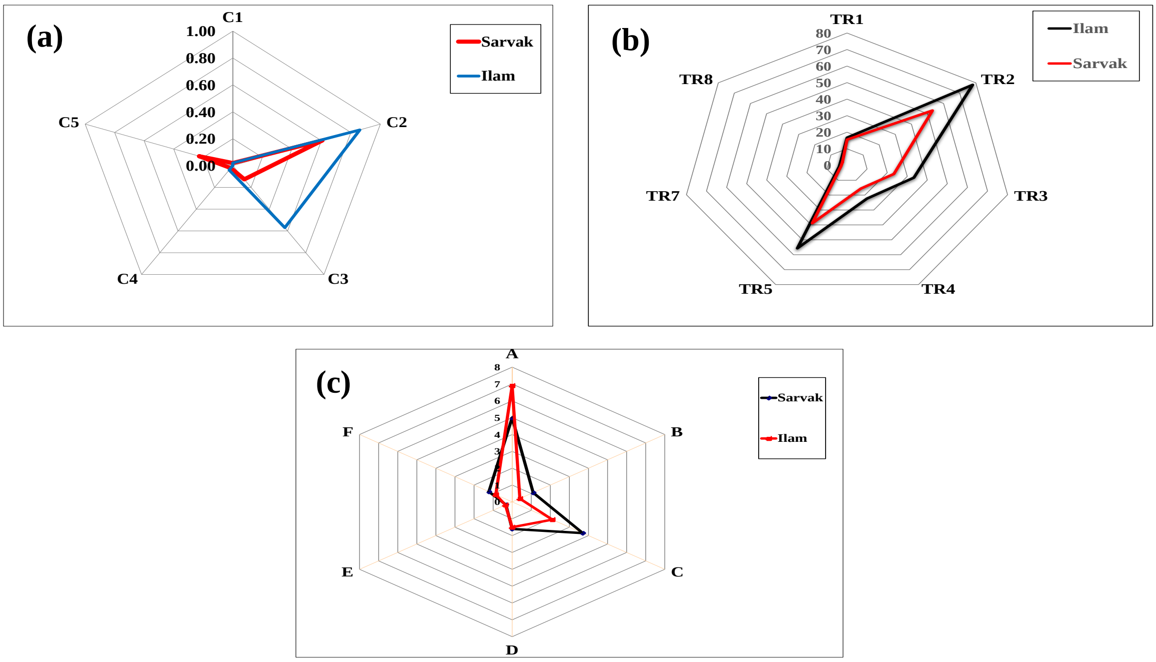

Figure 1. The star diagrams based on the ratios obtained from C7 light hydrocarbon analysis including (a) C1-C5[a] (b) TR1-TR8[b] and (c) A-F[c]

aC1 = 2,2-dimethylpentane/P3; C2 = 2,3-dimethylpentane/P3; C3 = 2,4-dimethylpentabe/P3; C4 = 3,3-dimethylpentane/P3; C5 = 3-ethylpentane; P3 = 2,2-dimethylpentane + 2,3-dimethylpentane + 2,4-dimethylpentane + 3,3-dimethylpentane + 3-ethylpentane; bTR1 = toluene/X; TR2 = nC7/X; TR3 = 3-methylhexane/X; TR4 = 2-methylhexane/X; TR5 = P2/X; TR6 = 1-cis-2-dimethylcyclopentane/X; TR7 = 1-trans-2-dimethylcyclopentane/X; TR8 = P2/P3; X = 1,1-dimethylcyclopene; P2 = 2-methylhexane + 3-methylhexane; cA = n-C7/toluene; B = benzene/1,1-dimethylcycloC5; C = nC7/methylcycloC6; D = 2tethylmethylcycloC5/1,2-dimethylcycloC6; E = 2,6-dimethylC7/1,1,3-trimethylcycloC6; F = m-xylene/4-methylC8.

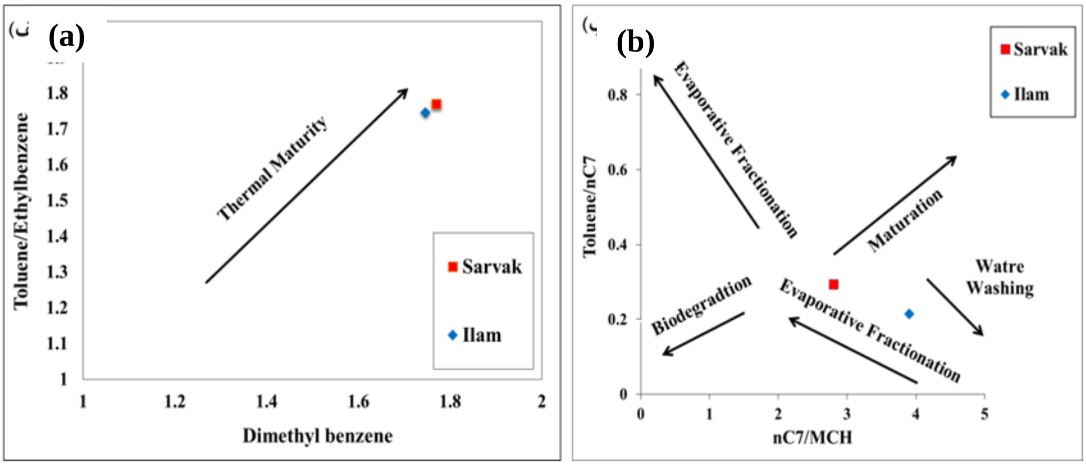

Figure 2. (a) The cross-plot of Toluene/Ethylbenzene versus Dimethylbenzene, indicating the relatively same level of thermal maturity for the oil samples, and (b) the relationship between toluene/nC$_7$ and nC$_7$/MCH, represents that the Sarvak and Ilam reservoir oils have been

affected by evaporative fractionation and water washing, respectively

The pressure data versus depth (Paez et al., 2010) represent different pressure gradients for the Sarvak and Ilam reservoir oils. Also, the water-oil contact in these reservoirs is not identical. On the other hand, the stratigraphic column of the studied well show that the Shaly Lafan Formation plays the role of a barrier, separating the Sarvak and Ilam reservoirs. The geochemical results confirmed the separation of these reservoirs. Therefore, Sarvak and Ilam reservoirs in Azadegan oilfield must be considered as different compartments in reservoir modeling.

4-Conclusions

In this study, vertical hydrocarbon continuity of Cretaceous Sarvak (Turonian) and Ilam (Turonian) reservoirs in Azadegan oilfield was investigated using the integration of the results obtained from a variety of geochemical analyses on their oil samples (e.g., LC, GC, GC-MS, HRGC) with geological information and reservoir pressure data. The results of LC, GC, and GC-MS analyses indicate that the studied oil samples have a same genetic family, originated from a natural marine source rock (Garau or Sargelu) in the middle generation oil window. However, the Halpern star diagrams which are constructed based on the ratios obtained from C7 light hydrocarbon analysis (i.e., C1-C5, TR1-TR5, and A-F) indicate two different oil groups in the Sarvak and Ilam reservoirs, confirmed by the various pressure gradients in them. This is due to impermeable Shaly Lafan Formation which is located between the studied reservoirs and disconnected their connectivity.

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