Petroleum System Prediction Based On Geochemical Characteristics of Hydrocarbons in the South Pars Field

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Abstract

The South Pars field, the world's largest independent gas reservoir with suitable exploitation potential of oil layer located on Iran-Qatar borderline in the Persian Gulf. In order to petroleum system determination, four condensate and three oil samples were subjected to intensive geochemical analyses. The condensate samples collected from Kangan and Dalan reservoirs. The analyzed oil samples were belonging to Sarvak (Maudud Mb.) and Dariyan formations. The oil samples were analyzed according routine geochemical analysis; namely column chromatography, gas chromatography and gas chromatography-mass spectrometry. In order to separate and identify the biomarker fingerprint of condensate, new methods were employed. These methods were: (I) Mild evaporation of unwanted hydrocarbons, (II) Mild oil topping for two weeks to remove medium molecular weight hydrocarbons (C_8-C_{15}), (III) Urea adduction to concentrate biomarkers containing fractions and (IV) finally, molecular analysis using GC-MS technique used as for oil samples. Different parameters of biomarker fingerprint such as, Hopanes (m/z=191) and Steranes (M/Z=217) biomarkers were calculated. Interpretation of oil samples biomarker fingerprint indicated that oils were generated from carbonate source rock which has been deposited in a anoxic condition and originated from esturine source rock with minor terrestrial organic matter. These oils were produced from mainly type II and III kerogens. Evaluation of biomarker maturity parameters are shown peak of oil window maturity for organic matter. Geochemical studies of biomarker parameters from condensate sample revealed that condensate were generated from clastic source rock and deposited in an anoxic sedimentary condition. Condensates were originated from esturine source rock with minor terrestrial organic matter too. The maturity of condensate samples is relatively high, at late oil generation stage to early gas window. Based on the correlation of geochemical properties of oil and condensate samples, two different petroleum systems are determined in South Pars field. Some of researchers believe that Permian-Triassic hydrocarbon reservoirs in Persian Gulf charged by Silurian shale. Result of this investigation confirms their theories. Consequently Kangan and Dalan reservoirs charged by Paleozoic (Silurian) petroleum system. Moreover, geochemical study results on oil samples indicated that Jurassic system (Hanifa Formation) in Arabian part of Persian Gulf probably charged South Pars oil layer.

Keyword: *South Pars, Petroleum system, Biomarker, hopane, Sterane, Oil Topping, Urea adduction*

Introduction

The South Pars field, the world's largest independent gas reservoir with suitable exploitation potential of oil layer located on Iran-Qatar borderline in the Persian Gulf (Fig1). The Dalan and Kangan (Permian/Triassic) formations are Gas reservoirs and The Dariyan formation and Maudud member of Sarvak Formation (Cretaceous) are a known oil reservoirs in this field. One of the most important goals of this study is to determine the petroleum systems in South Pars field. In order to hydrocarbon system determination, identifying geochemical characterization of source rocks is necessary. The probable source rock frequently unavailable for analysis in studied area as they are buried too deeply, Hence we used the biomarker analysis to evaluate source rocks characterization. Biomarkers are specific chemical fossils which are originated from biological inputs, and reflect the maturity, kerogen type and paleoenvironment conditions of source rocks [1, 2, 3]. Biomarker fingerprint can be used when access and direct analysis of generative probable source rock are impossible. Characterization of oils and condensates has allowed us to extend our hydrocarbon-family. This paper presents results of complementary geochemical biomarker study examining steranes and hopanes of concentrates samples from oil and condensate

Methods

Three and four oil and condensate samples were selected from oil and gas reservoirs respectively. Hydrocarbon fractionation of oil samples were achieved by column chromatography using silica gel and alumina as adsorbents. In order to separate and identify the biomarker from condensate, new analytical methods were employed. These techniques were: (I) Mild evaporation of unwanted hydrocarbons, (II) Mild oil topping for two weeks to remove medium molecular weight hydrocarbons (C_8-C_{15}), and (III) Urea adduction to concentrate biomarkers containing fractions. Saturate fractions of oil and condensate sample were analyzed according to routine geochemical analysis after sample preparation; namely gas chromatography and gas chromatography-mass spectrometry. The hopane and sterane biomarker distributions were determined using the m/z=191 and m/z=217 mass fragmentogram respectively. Fragmentograms observed for triterpanes and steranes are shown in Fig. (8, 9, 10).Results of calculated parameters is shown in table (1).

Result and Discussion

Biomarkers in oil can reveal the environment of deposition as marine, lacustrine, fluvio-deltaic or hypersaline, the lithology of the source rock and the thermal maturity of the source rock during generation [4]. Besides biomarker analysis is one of the best paleoenvironmental tools to identify anoxic and euxinic conditions in the water column [5]. Pr/Ph ratio has been used to indicate the redox potential of the source sediments [6]. According to these authors [6] Pr/Ph<1 ratios of oils suggest anoxic depositional conditions and suboxic environment for condensate of South Pars field. However, this interpretation should to compare with other biomarker parameters. Pristane/nC_{17} versus Phytane/nC_{18} [7] plot suggests anoxic depositional conditions for the source rock of the oils and condensate (Fig.2). These hydrocarbons were generated predominantly from type II and minor type III kerogen.

In order to lithological characteristics identification, C_{29}/C_{30} Hopane ratios versus C_{34}/C_{35} Homohopane [8] are plotted in Fig(3). C_{29}/C_{30} Hopane ratio of oils is ranging from 0.96 to 1.21 indicating the source rock of oils is thought to be carbonate rocks. Condensates have wide range of the ratio which suggests the condensates were derived predominantly from clastic source rock. Moreover, C_{34}/C_{35} ratio confirms the other interpretations of anoxic depositional environment. Based on C_{35}s/C_{34}s Hopane vs. C_{29}/C_{30}Hopane plot [9] (Fig.4), oils and condensate in south pars filed were generated from carbonate and clastic-carbonate source rock respectively.

Huang and Meinschein (1979) [10] indicated that the ratio of C_{27}-, C_{28}-, C_{29}- sterol homologs on ternary diagram might be used to differentiate depositional settings and ecosystem. Fig. (5) Presents C_{27}-C_{28}-C_{29} sterane distribution ternary diagram for oils and condensates. Oils are genetically related being derived from an esturine source rock with minor terrestrial organic matter, while the condensate seems to be generated from source rocks with predominantly terrestrial organic matter.

One of the most widely used applications of biomarkers is the measurement of thermal maturity of organic matter [11,12]. Hopanes and steranes include the biomarkers most commonly used for maturity assessment [13,14,15]. The observed triterpane and sterane maturation parameters are shown in Table (1). Plots of ββ/ (ββ+αα) versus 20S/(20S+20R) for the C_{29} sterane [16] are shown that oils are mature being expelled from their source at or close to the peak oil generation stage. Fig (6) indicated that condensates have high level of maturity about at first gas window stage.

In order to more attentiveness in maturity level estimating, we used C_{32}-Hopane 22S/22S+22R versus C_{29} Sterane 20S/20S+20R plot [17]. This plot indicated similar maturity equals other maturity parameters (Fig.7).

Conclusions

Based on geochemical investigation results such as diversity of depositional environment conditions of candidate source rock(s), differences of organic matter maturity level of kerogen, the existence of two different petroleum system for gas and oil reservoirs are distinguished. First, Jurassic petroleum system and secondly, Paleozoic petroleum system (Silurian). According Ibrahim et al. (2002) [18] South Pars oil layer probably charged by equivalent Surmeh formation in Arabian part of Persian Gulf like Hanifa formation. Some of researchers believe that Permian-Triassic hydrocarbon reservoirs in Persian Gulf charged by Silurian shale [19,20,21,22,23]. Results of this investigation confirm their findings. A Paleozoic petroleum system with hydrocarbon production from Silurian shale which has been responsible for gas accumulation in South Pars filed. Consequently Kangan and Dalan reservoirs charged by Silurian petroleum system.

Table (1): Values of biomarker parameters calculated from South Pars field oil and condensate samples

Sample No.	Pri/Phy	Pr/nC17	Ph/nC18	C_{29}/C_{30}	C_{34}/C_{35}	C_{32} S/S+R	Ts/Ts+Tm	C35s/C34s	C29 S/S+R	C29 ββ/ββ+αα	%C_{27}	%C_{28}	%C_{29}
Con.1	1.31	0.47	0.51	0.77	1.4	0.63	0.51	0.79	0.5	0.61	30.53	36.64	32.22
Con.2	1.15	0.6	0.67	0.42	0.42	0.6	0.57	1.77	0.51	0.42	35.53	23.96	40.49
Con.3	1.25	0.45	0.52	0.62	1.13	0.58	0.51	0.89	0.4	0.5	28.57	34.22	36.5
Con.4	1.14	0.48	0.56	0.53	1.2	0.56	0.49	0.87	0.59	0.63	44.49	25.51	30
Maudud	0.59	0.79	0.53	0.96	0.83	0.61	0.56	1.28	0.45	0.61	39.1	25.3	35.6
U.Dariyan	0.49	0.9	1.02	1.21	0.88	0.56	0.51	1.5	0.45	0.59	36.8	19.9	44.3
L.Dariyan	0.43	0.44	0.52	0.99	1.16	0.6	0.47	1.26	0.46	0.55	41.7	26.3	32

Fig.1. Geographic setting of South Pars filed

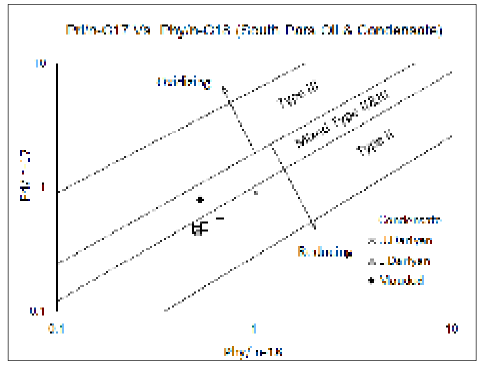


Fig.2.Plot of Pri/nC$_{17}$ Vs. Phy/nC$_{18}$

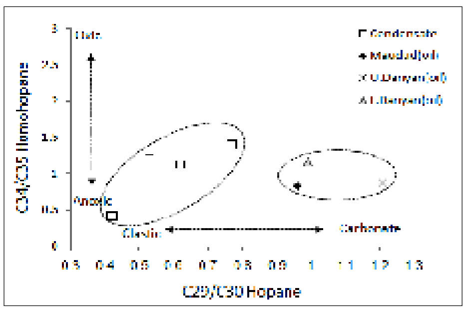


Fig (3): Plot of C$_{34}$/C$_{35}$ vs. C$_{29}$/C$_{30}$

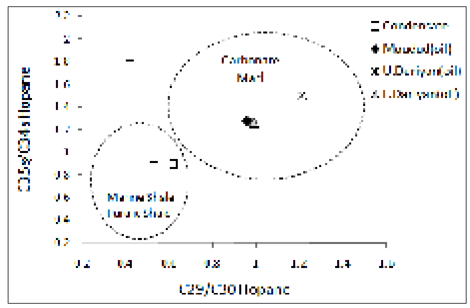


Fig (4): Plot of C$_{35}$s/C$_{34}$s vs. C$_{29}$/C$_{30}$

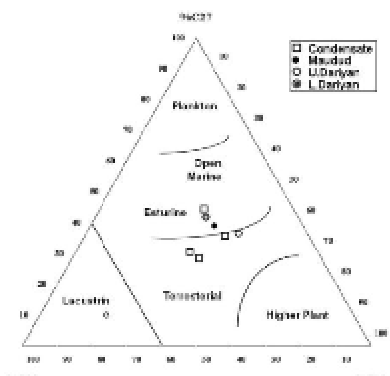


Fig (5): Ternary diagram of rel ative abundance for regular steranes C$_{27}$, C$_{28}$, C$_{29}$

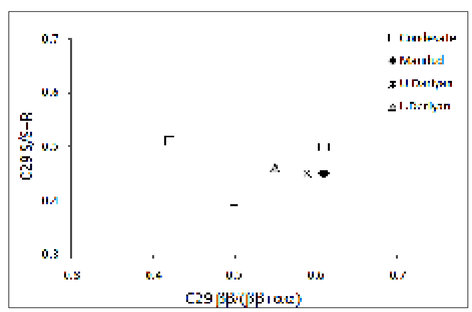


Fig (6): plot of C$_{29}$ S/S+R vs. C$_{29}$ ββ/ββ+αα

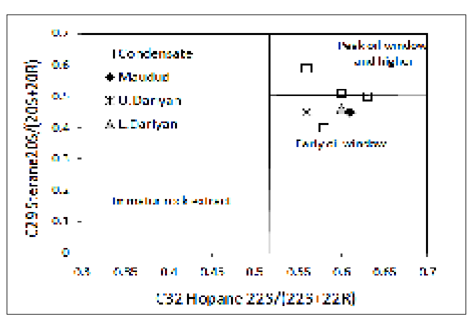


Fig (7): Plot of C$_{29}$ S/S+R vs. C$_{32}$ 22S/(22S+22R)

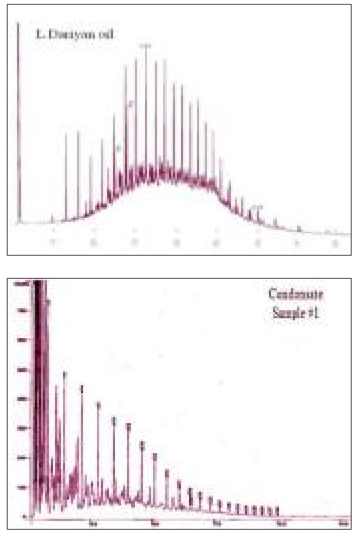


Fig. (8): Sample of Gas Chromatogram of oil and condensate

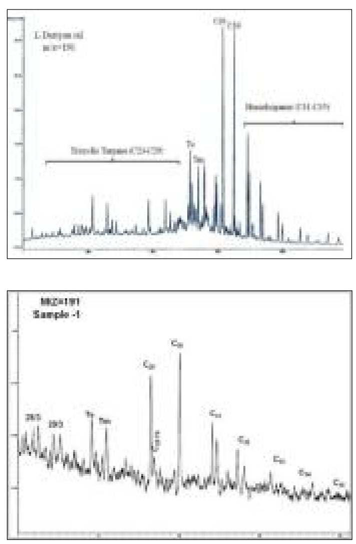
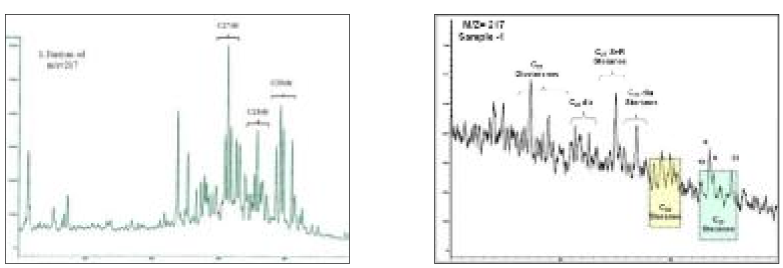


Fig (9): Fragmentograms of triterpanes, m/z 191 of oil and condensate samples



(10): Fragmentograms of steranes, m/z 217 of oil and condensate samples

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