1D PETROLEUM SYSTEM MODELING IN SEVERAL COASTAL FARS HYDROCARBON FIELDS AND ANALYSIS OF KANGAN FORMATION'S SHALY SUB LAYERS GENERATION POTENTIAL

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Abstract: Coastal Fars Fields contains enormous amounts of hydrocarbons especially in form of gas and condensate (some oil). Petroleum system and sedimentary basin modeling is a cheap and useful method for reducing uncertainties in exploration costs and risks of drilling wells. In this study, using geological data, Rock-Eval 6 analysis and 1D basin modeling by Petromod version 11 and 12 software, the probability of Sarchahan formation and shaly sections of Kangan formation to produce two hydrocarbon fields in the Coastal Fars. Results showed that the Sarchahan formation is the original source rock of this area which reached a maximum burial depth of around 1.6 to 1.9 M.a, and produced around 2 million tons of hydrocarbon; Results also showed that shaly sections of Kangan formation produced a little amount of hydrocarbon but not as much to be the source of enormous amounts of hydrocarbon in this region.

Keywords: Basin Modeling, Sarchahan Formation, Kangan Formation, Coastal Fars.

INTRODUCTION

The Persian Gulf is a 966 km long Gulf, separating Southern Iran from the Arabian Peninsula is one of the most intensively explored regions in the world. It is a marginal sea of the Indian Ocean located in the southern part of the foreland basin of the Zagros range, covering approximately 226,000 km with a water depth of less than 110 m (35m in average)(Ross, Uchupi, and White 1986). According to BP Statistical Review of World Energy (June 2017) at end of 2016, Iran contains 9.3% of world proved Oil reserves, and 18% of world proved Gas reserves, most of which is accumulated in the Iranian Part of Persian Gulf.

So far, the only important source rock in Iran's Zagros Basin for Late Paleozoic– Late Triassic successions is the organic-rich, radioactive shales of Sarchahan Formation (Bordenave 2008, 2014; Le Heron and Dowdeswell 2009; Lüning et al. 2000). The black shales of Sarchahan are diachronous throughout the Zagros Basin, ranging from the Hirnantian to Liandoverian (Ghavidel-syooki et al. 2011; Ghavidel-Syooki et al. 2014). Some of the wells drilled in this area were penetrated through Sarchahan formation, but due to manifold geological structures in this area results are not applicable to all coastal Fars region, and the thickness of this formation still requires more investigations (Bordenave and Hegre 2010).

Whereas the gas fields in this area are likely sourced by Silurian – Ordovician "Hot shales" (Bordenave 2008; Saberi and Rabbani 2015; Saberi, Rabbani, and Ghavidel-syooki 2016), the origins of hydrocarbon in Permo-Triassic units of some fields are mentioned as shaly sub layers of Kangan formation, which suggests that due to the cap rock characteristics of Nar formation, the source of the hydrocarbon above Nar formation (Upper Dalan) is completely different from the hydrocarbon below it (Lower Dalan) (the hydrocarbon in lower Dalan is originated from Sarchahan formation, and the hydrocarbon in upper Dalan and Kangan formations are originated

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from shaly sub layers inside Kangan formation) (Ahanjan, Rabbani, and Khajooie 2016; Ahanjan, Rabbani, and Kamali 2017).

In the present paper, 1D and 2D Basin and Petroleum System Modelling (BPSM) were used to investigate the maturity evolution of potential Silurian-Ordovician source rock in the studied area, and to reconstruct the timing of hydrocarbon generation and migration. Calculated volumes of accumulated hydrocarbons are compared with actual volumes in order to investigate the presence or absence of Silurian-Ordovician source rocks in this area. Although possibility of source potential for shaly sections is investigated in field B (in field A, there are no shaly sections with potentials to generate hydrocarbon). Sedimentary basin modelling is one of the most modern methods for analysing hydrocarbon generation and migration inside a sedimentary basin life cycle. In the Persian Gulf region and coastal areas of Iran, a lot of basin models have been built. In this study, researchers tried to investigate the reason for oil generation in a gas zone using 1D modelling.

METHODS

1-Rock-Eval Analysis

In this study, after geological studies on the area, samples were taken from 2 exploration wells (A, and B) and analyzed by Rock-Eval 6 pyrolysis to determine the hydrocarbon generation potentials and types of organic matter. Rock-Eval analysis has been utilized in many studies but the full description and the obtained parameters are given by Espitalie et al. and Lafargue et al. (Espitalie, Deroo, and Marquis 1985; Lafargue, Marquis, and Pillot 1998). The main focus of this study is on the following parameters recorded during the analysis: S1 (mg HC/g rock), the amount of free hydrocarbon released at 300°C; S2 (mg HC/g rock), the amount of hydrocarbon released; Tmax (°C), the temperature of the pyrolysis oven recorded at the top of the S2 peak; the total organic carbon (TOC, Wt. %), the sum of all the carbon moieties (HC, CO and CO_2) attributed to the decomposition of the organic matter and integrated during the pyrolysis and the subsequent oxidation stage; and HI (mg CO_2/g C_{org}), corresponding to the quantity of HC released relative to TOC, namely, S2/TOC, and correlated to the H/C ratio.

2-Numerical Modelling and Input Data

Basin and petroleum system modelling (BPSM) is considered as a dynamic forward modelling of geological processes occurring during the evolution of sedimentary basins. Models are basically developed to quantify different processes during sedimentary basin formation and evolution for 2 wells (A, and B). The main input data is the current depth of the horizons, lithologies, and the geological events in terms of deposition and erosion, or the time of non-deposition (hiatus). Assigning source rock data such as TOC, HI, and hydrocarbon generation kinetics to the model enables the study of hydrocarbon generation dynamics. Vitrinite reflectance data and the temperature at the bottom of the well were used in this study as calibration data. 1D models were constructed using the petroleum modelling software IES PetroMod Schlumberger™ (version 2011). 1D modelling was used on both wells for a better understanding of the burial and thermal history and to get a first impression about magnitude of erosion and heat flow values. Also, 1D models were utilized to better comprehend the burial-thermal history, thermal maturity, and the petroleum generation of the Silurian source rock and the shaly sublayers in Permo-Triassic units throughout the Coastal Fars area.

FINDINGS AND ARGUMENT

1.Geochemical analysis

In the studied area, 28 samples were collected from well B, and 29 samples from well A for geochemical analysis, and also data from Saberi et. al 2016 findings was used as the characteristics of Sarchahan formation (Saberi, Rabbani, and Ghavidel-syooki 2016). All samples had an indigenous origin and were not contaminated by migration (Fig 1).

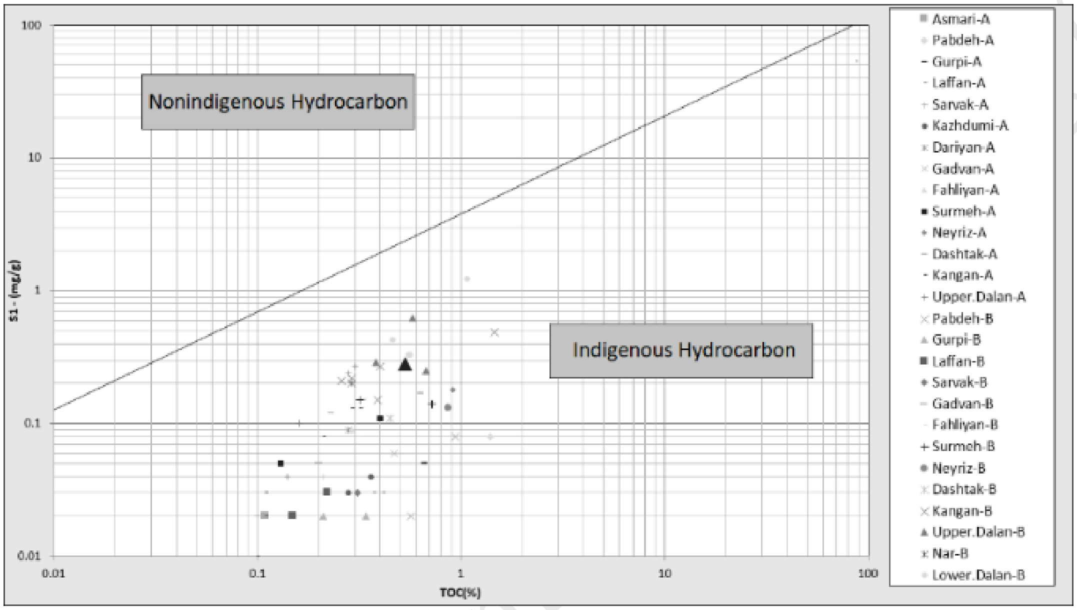

Fig. 1. S1 vs. TOC for distinguishing between indigenous and nonindigenous samples collected from studied fields. Inclined line equals S1/TOC=1.5

The scatter plot of genetic potential versus TOC (Fig.2) shows that the studied samples can be mainly considered as poor hydrocarbon potential; except for some of the Kangan samples in well B showing hydrocarbon generation potential of medium to high, and some samples from upper Dalan in well B showing fair hydrocarbon generation potential.

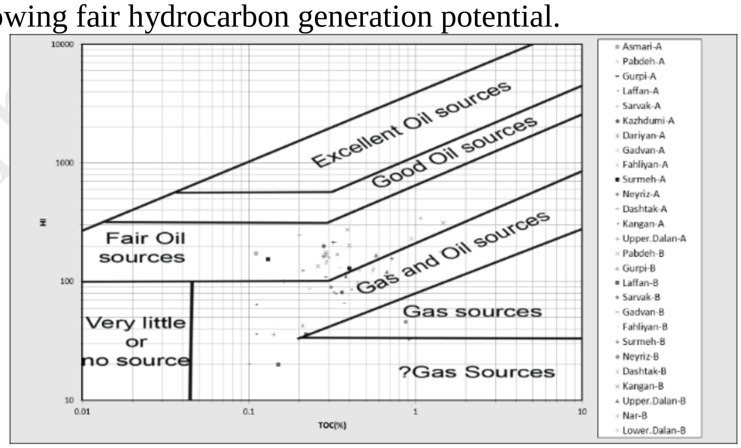

Fig. 2. HI vs. TOC for determination of source potential

Samples were found to be mostly from type II and III kerogens; Based on these results and also the findings of Saberi et al. in 2016,Sarchahan is the possible source rock in the studied area, which is divided to two parts; upper and lower , while only the lower part has the capacity to produce hydrocarbon (Saberi, Rabbani, and Ghavidel-syooki 2016).

2.Burial and Thermal history reconstruction

In both wells, the best accordance between measured and calculated calibration data was achieved when a heat flow of 65 mW/m2 was used.

In well A, the basement of Sarchahan formation had reached 5182 m in 1.9 Ma and had been exposed to a temperature of 154.01 °C. Other formations in 1.9 Ma. were as followed: the upper Sarchahan (5158 m, 153.22 °C), Zakeen (5107 m, 151.65 °C), Faraghan (5036 m, 149.58 °C), the lower Dalan (4907 m, 145.92°C), Nar (4511 m, 137.52 °C), the upper Dalan (4094 m, 129.04 °C), and Kangan (3811 m, 122.13 °C). It is Also obvious that Sarchahan, Zakeen, Faraghan, and the lower portion of lower Dalan were at late oil window, the rest of lower Dalan, Nar, the upper Dalan, Kangan, and the lower portion of Dashtak formation were at middle oil window, the rest of Dashtak, Neyriz, and 2/3 of Surmeh formation were at early oil window, and the rest of Surmeh, and other formations were immature according to vitrinite reflectance coefficients (Fig 3, and 4, right).

In well B, the base of Sarchahan formation had reached 5429 m in 1.6 Ma, and had been exposed to a temperature of 160.92 °C. Other formations in 1.6 Ma were as followed: the upper Sarchahan (5402 m, 160.09 °C), Zakeen (5351 m, 158.48 °C), Faraghan (5068 m, 149.99 °C), the lower Dalan (4957 m, 146.66°C), Nar (4597 m, 138.12 °C), the upper Dalan (4387 m, 133.78 °C), and Kangan (4034 m, 125.05 °C). It is Also obvious that Sarchahan, Zakeen, and Faraghan were at late oil window, the lower Dalan, Nar, the upper Dalan, and Kangan were at middle oil window, Dashtak, Neyriz, and 3/4 of Surmeh formation were at early oil window, and the rest of Surmeh and other formations were immature according to vitrinite reflectance coefficients (Fig 3, and 4, left).

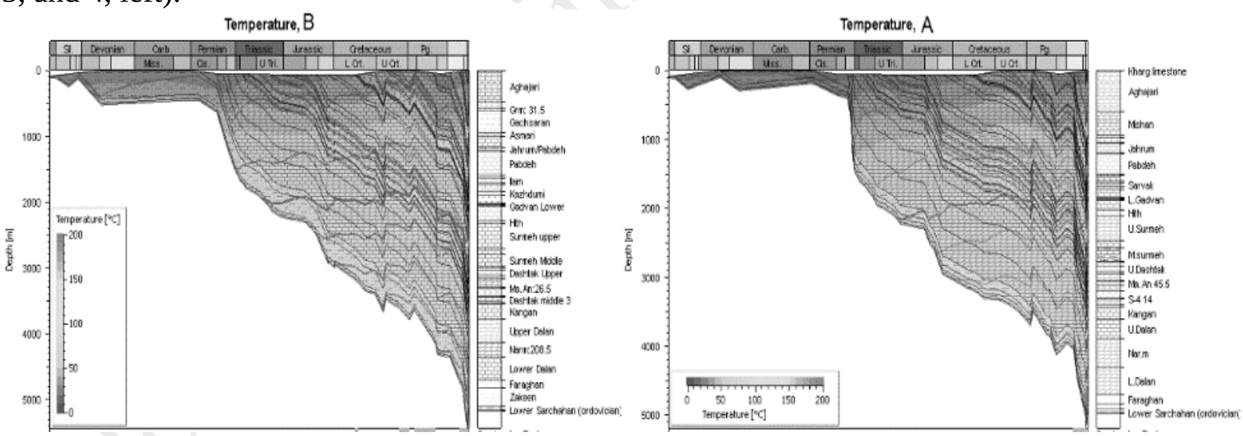

Figure 3 Burial history with temperature overlay in well A (right), and well B (left)

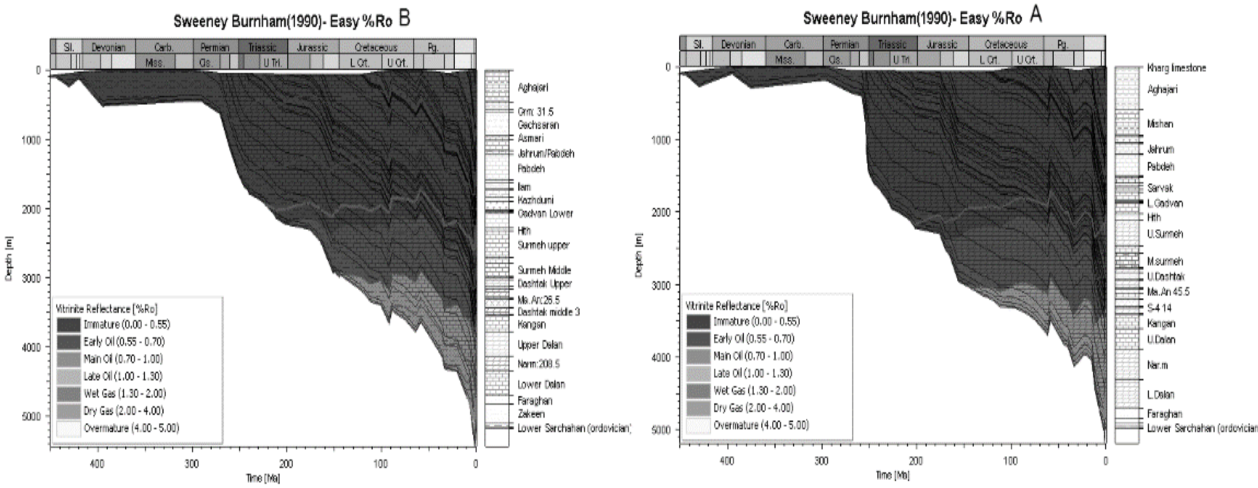

Fig. 4. Burial history with maturation overlay with the categorization of vitrinite reflectance *(Sweeney and Burnham 1990)*

Kerogen transformation ratio for Sarchahan formation at the maximum depth of well A and B is 78.23%, and 84.35%, respectively. Bulk generation for Sarchahan formation in well A and well B equals 0.88, and 0.96 MT, respectively.

Fig. 5 shows the generation time and amount of shaly sections inside Kangan formation, which are less than 20m inside well B, according to well data. Results showed that this shaly section started generation 100 Ma, and the maximum generation had been 0.03 Mton. Hydrocarbon did not migrate from this layer. This amount of production cannot be the origin of the 170 million barrel of oil inside this field; thus the hypothesis that suggests the oil inside Kangan formation in well B was originated from these shaly sub layers is rejected.

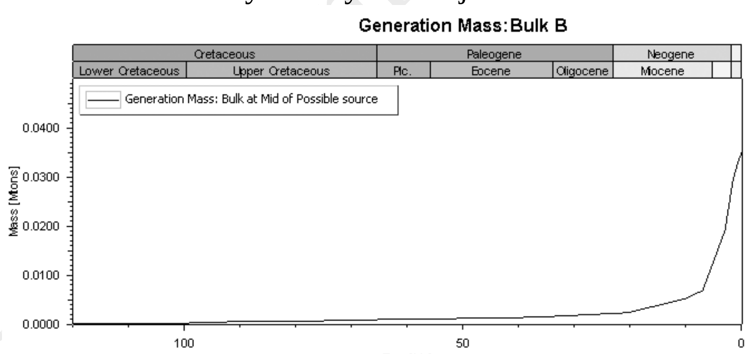

Fig. 5. hydrocarbon generation time and amount for well B

Conclusion

- A 65 mw/m2 gives the best fit between calculated data and bottom hole measured data (temperature of the bottom of the well, and vitrinite reflectance coefficient).
- Rock-Eval analysis results showed that most of the rocks in studied fields were immature or had a poor maturity level so studied samples did not have the hydrocarbon generation potential required to produce the present amount of hydrocarbon inside the fields. In S1 vs. TOC formations aged from Triassic, Jurassic and Cretaceous did not show evidence of migration.

- Sarchahan was the main source rock and reached the mature level in both fields. Sarchahan in well B had been subsiding until 1.6 Ma, and had reached 160.92 °C temperature and 5446 m depth.
- In field A the subsidence has stopped around 1.9 Ma, and Sarchahan had reached a maximum temperature of 154.01 °C and a maximum burial depth of 5182 m. The subsidence has ended later in eastern parts (well B).
- The amount of generated hydrocarbon in eastern parts of studied area (well B) were more than western part (well A) which it is due to the maximum burial depth and the exposure of organic matter to higher temperatures.
- The field reservoir group for both has been Palaeozoic reservoir system because the two fields were adjacent, and the petroleum system for both fields were formed at the same time.
- Due to the similarity in the formations, hydrocarbon migration from both fields were almost simultaneous, with an insignificant time difference of 0.5 Ma.
- Kangan shaly sections generated some hydrocarbons, but the generated amount cannot be the origin for the huge amounts of hydrocarbon in this area.

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