Generative potential, thermal maturity, and TOC modeling of petroleum systems in Southwestern Khuzestan Province, Zagros Basin, Iran

Mehdi Poor Jahangiri Pilehrood

Petroleum Geoscience, Islamic Azad University, Damavand Branch, Tehran, Iran

ABSTRACT
In this study, a series of analytical geochemistry and petro-physical studies has been done to a number of effective source rock samples in the southwestern region of Khuzestan province and it illustrates that some strata’s in investigated wells have high hydrocarbon generation potential with the existence of commercial hydrocarbon production. There are some practical drawbacks to these analytical strategies, which can be solved through a combination of the results of different analyses, such as Thermal maturity, TOC, Rock Eval analysis that the main reason behind implementing different strategies in this paper. Twenty-five samples were analyzed in terms of TOC, PI, HI, OI, S3, S2, Tmax and we could determine oil/gas prone samples (resource areas) and distinguish them from strata’s with very low organic matter content Larter & Douglas, (1982). These predictions are quite crucial to E&P stage hydrocarbon exploitation as they will lead to solid predictions and they would avoid substantial expenses and eliminate uncertainties. In conclusion, after in depth comparison and study of organic carbon content, hydrogen and oxygen index, Type of organic matter content and Maturity of organic matter, we determined that studied resource areas are considered for medium to large size hydrocarbon discoveries and should be considered favorable.

1. Methodology
Pyrolysis Rock-Eval method constitutes studying the hydrocarbon generative potential via studying sediments capabilities for generating any sorts of hydrocarbon, type of organic matter and also in terms of thermal maturity and how it might influence the process of hydrocarbon generation. The often-used analytical techniques for these researches throughout hydrocarbon exploration are TOC analysis, vitrinite reflectance analyze and Rock Eval pyrolysis. Some of the practical drawbacks to these analytical strategies can be solved through combination the results of different analyses which is why we took different analytical approaches, and retaining in thinking the viable blunders that would possibly occur from each method. Main objectives of this study has been accomplished by evaluating of 25 samples at six different places all along the Southwestern Khuzestan Province and ended up in determination of thermal maturity, hydrocarbon generative potential, Kerogen Types and also TOC, it has been confirmed that source-rocks of Pabdeh formation have the high hydrocarbon generation, which mostly are Type-II kerogen, and this maturity had come about in the Cretaceous (80 to 72 Ma).

2. Geology setting of Zagros Basin
Zagros Basin is the most substantial basin in in the Middle East with the Gigantic Petroleum and gas reserves (Figure 1), as It is depicted by means of local basin and sedimentary evolution, petroleum distribution traits and predominant controlling elements of petroleum accumulation Rezaee, (2001). In the Zagros Basin, Pabdeh Formation has precipitated all through global rise of sea levels in Inter shelf basin, induced through presence of clay minerals and anoxic conditions. The essential cause of existing of the organic matters in the rocks might be clay minerals. The Pabdeh Formation is a well – known to be an effective source rock which has generated enormous amount of hydrocarbon in the most oil fields in the Zagros (Figure 2), Zagros extends from northwest to southwest Iran hundreds of kilometers. Interestingly, Pabdeh Formation as one of the prime source rocks in Zagros has drawn the attention of big petroleum corporations around the world and obviously geologists and geophysicists from ages ago. The Zagros basin, which trends NW-SE, is deposited from a sea during the Paleogene, the thickness of the Pabdeh Formation in some areas is about 220 m and it consists of crimson shale at the bottom, gray shale, marl and marl-limestone with few horizons of limestone at the top. One of the most tremendous Cretaceous and
Paleogene deposits discovered in Zagros is pelagic sediment of the Gurpi and Pabdeh formations, which first discovered in the Zagros Basin by James and Wayne.

3. Introduction

3.1. Objectives

This study investigates and characterizes the hydrocarbon generation potential of the whole Paleocene organic-rich rocks of Southern areas of Zagros Basin, Iran, through TOC content evaluation and Rock-Eval Pyrolysis technique. These goals have been accomplished in this study: (i) Organic-rich samples collection from the Naft-e-Sefid, Dehluran, Pazanan, Gachsaran in Zagros basin. (ii) Assessment of the quality of these organic-rich rocks using geochemical methods, for instance, TOC content, and Rock-Eval pyrolysis and Thermal maturity.

3.2. Stratigraphy

The sediments composing the Zagros Basin is up to Twelve-Thousand Meters thick and, except for the Devonian and Carbonic structures missing in all through the Basin, the section is almost conformable,
continuous sequence from Cambrian to Pliocene. Sedimentation commenced with an important early-Cambrian carbonate sediments, accompanied by the marine evaporates, accompanied by the marine carbonate sediments of the Lower Paleozoic from Permian and throughout the Mesozoic and up until Miocene. Subsequently, thick evaporates accompanied through continental red beds represent the Pliocene and Folding accompanied by tectonic molasses (Figure 3).

3.3. Pabdeh formation

Pabdeh is named after Pabdeh Mountain-Range in the Khuzestan Province (Figure 4), which James & Wynd (1965) described the type section at Pabdeh strait, 32° 25’ N, 49° 16’ 22” E. Pabdeh and also Gurpi are recognized within outcrops and in sub surfaces in the Fars, Khuzestan and Lurestan Provinces of Iran. Anoxic stipulations have happened in the Late Eocene, within S-N trend, from the northern parts of the Fars province, within the Dezful Embayment and Lurestan into Iraq Jahani, 2012. Argillaceous sedimentation persisted through Paleocene in Dezful Embayment and also in Fars Province, till the end of the Oligocene in Lurestan. In Fars, a few outcrops exhibit 160-270 m of fine-grained darkish gray marls that contain algal-type Kerogen with limited organic matter content, simply due to the presence of angiosperm pollen and herbaceous particles (Darvish Zadeh et al, 1991). These marls consist of marine fauna such as Globigerina and Rotalids. Benthic fossils have been absent, possibly due to the anoxic environments of the deep-sea bottom. In the Bibi-Hakimeh and also in Rag-e-Safid area, about 300 m of marls are regarded to be terrific potential source rocks. In Lurestan especially in southwestern areas, numerous sections of upper Eocene illustrate 90-140 m of organic-rich marls. In a few sections an anoxic stipulation continued into the Oligocene and has been accountable for the deposition of any other one hundred m of organic rich marls, albeit much less prosperous with regard to the organic matter content. Rock-Eval method is one of the easiest and quickest strategies used for assessing the hydrocarbon generation potential of the possible source rocks that meet the wants of petroleum prospects (Espitalie et al, 1986). It offers essential information about the type of organic matter content of rocks and their maturity. This approach allows us to predict petroleum generation windows of any kind and estimates the extent of hydrocarbon generated off of a specific source rock.

4. Pyrolysis rock eval

This study consists of collecting organic rich rock samples along the Zagros Basin including: (Naft-e-Sefid, Dehluran, Gachsaran, Pazanan, Mansuri, Lab-e-Sefid, southwestern Iran, 25 samples in total were collected. Some of the collected samples were taken to the Zagros Geochemistry Laboratory, where they were dried in an oven for 12 H at 120°C, and grounded with the help of a unique mortar-pestle. The crushed rocks were analyzed geochemically to determine the values of TOC, HI, PI, OI, S1 and S2.

4.1. Kerogen types

The organic matter type is an essential parameter in evaluating potential source rocks and it has an important effect on the type of the produced hydrocarbon. Interestingly, mature source rocks have tendency to possess Low HI for gas prone source rocks with a value of less than 150, gas/oil prone source rocks have high Hydrogen Index, ranged between 150 and 300, as opposed to the oil prone source rocks which are more than 300 Hunt, 1995. therefore, it is very essential to decide the kerogen types of the possible source rocks as they have a substantial control on the hydrocarbon generation after maturation Claypool, & Reed, (1976). The results of this study confirmed that the Hydrogen Index values are higher than 290 for the most of the collected and investigated samples. Hence, they are responsible for oil embedded in young reservoirs and considered as oil prone. However, there are few exceptions. The Lab-Sefid samples have HI value of round 65 mg/g, which means that it is an ideal potential gas generator. The Naft-e-Sefid samples have the Hydrogen Index figures of around 185 mg/g indicating that they are gas and oil prone.

4.2. Pyrolysis process

Samples that were submitted to Zagros Lab were analyzed by Rock-Eval II Instrument for TOC contents (Figure 5), Oxygen Index (OI), T-max (temperature of maximum kerogen pyrolysat), Hydrogen Index(HI),

Figure 3. Zagros basin stratigraphy (cenozoic era).
The Labs oven was initially maintained isothermally at 335°C for 7 minutes and during that time loose hydrocarbons are evaporated and the S1 peak was recorded and measured via Flame-Ionization Detector. Pyrolysis of organic materials were later performed at 314–610°C with a temperature rise of 32°C/min. This was the phase of evaporation of hydrocarbons with high carbon numbers (>C30), as well as the breaking up the unstable organic matters. The hydrocarbons released from this thermal breakage are registered as the S2 values. The temperature that (S2) reaches its peak depends on the organic matter and thermal maturity of the kerogen and this is supposed to be measured as Tmax values. Kerogen crackage in the 310–380°C results in trapping CO₂. The temperature of the trap is increased, and Carbon dioxide is released and detected on a Thermal Conductivity Detector during the temperature dropping, which recorded as S3 values Horsfield, (1985). With the aid of Production Index, which increases throughout the maturity and can be calculated from PI formula (PI = S1/S1+ S2), we was
able to decipher immature, mature and overmature samples, (immature (>0.10), mature (0.1-0.03) oil window and overmature (<0.3) gas window). Needless to say we needed Hydrogen Index to distinguish the kerogen type and had it calculated via: (HI = [100 x S2]/TOC) Clementz et al., 1979.

5. Conclusions
This study has confirmed the importance of source rock assessment studies and basin modeling in hydrocarbon generation potentials determination of Southwestern of Zagros Basin. Investigation of Paleogene sediments suggests that most shale units of the Pabdeh Formation are good to excellent source rocks in the Mansuri, Dehluran, Naft-Sefid and Pazaran Areas. High hydrogen index suggests that gas had to be generated at high maturity levels and thorough cracking of the oil. Kerogen type and total organic carbon data from Rock-Eval pyrolysis point out that most shale units of the Paleogene depositions incorporate mainly Type II/III kerogen with High hydrogen index values (200–500 mg HC/g TOC). Paleogene source rocks have entered the oil window stage for significant hydrocarbon generation all through Paleogene–Neogene and are capable of charging the interbedded Eocene reservoirs. This study offers
information that improves our understanding of the Paleogene-sourced facies.

This research reveals that (Table 1):

(i) Dehuran, Pazanan, Mansouri, and Naft e Sefid include predominantly Type II kerogen and are both oil- and gas-prone, and the organic matter content material intermediate from good to very excellent and so does the generative potential from average to excellent. (Table 1)

(ii) Lab E Sefid contains mostly Type III kerogen and is gas prone, but the organic carbon content is typically only poor to fair so the generative potential is lean.

5.1. Discussion and recommendation

The outcomes of this study additionally unlocked the petroleum generation potential of the least studied organic-rich rocks in the Zagros basin including, Pazanan, Gachsaran, Naft E Sefid, Dehuran and this study revealed that they have reached to a point of commercial hydrocarbon production alongside the fault breakouts which are the best structures for migration to happen, except for the Lab E Sefid with poor to fair generative potential. Therefore, it is endorsed that these wells should be considered for medium to large size hydrocarbon discoveries.

The results of the our investigations propose that hydrocarbon generation from the Paleogene source rocks in the Zagros happened at some stage in the Paleogene–Neogene times. Long-distance migration of the hydrocarbon of these source units is expected to be the main source of the hydrocarbon charged layers of the sands structures and young reservoir units. Possible hydrocarbon migration is predicted alongside fault breakouts and unconformities to adjoining prolific reservoir rocks. The presence of hydrocarbon in the studied well suggests the viability of the Paleogene-sourced play in the Southwestern Zagros Basin. Hydrocarbon drilling activities in the Southwestern Zagros Basin have to focus on identification of different, fault breakouts, and unconformity as it has been proven that most possible migration of hydrocarbon in the area has happened in these structures.

Disclosure statement

No potential conflict of interest was reported by the author(s).

ORCID

Mehdi Poor Jahangiri Pilehrood http://orcid.org/0000-0002-9185-6503

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