Geochemical Appraisal using Vitrinite Reflectance and Rock-Eval Data, of Shishtu and Sardar Formations Central Iran

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Abstract

Organic geochemical and petrological investigations were carried out on Upper Devonian (Shishtu F.) to Lower Carboniferous (Sardar F.) sedimentary succession. Three outcrops of these Formations from Shotori range (east of Tabas block, Central-East Iranian Micro-continent) were sampled to evaluate their hydrocarbon potential. Fifty nine and twelve samples were analyzed with Rock-Eval pyrolysis and Vitrinite reflectance methods, respectively. According to the TOC values from Rock-Eval data, samples from Shishtu and Sardar formations have a good source rock potential (average TOC of 1.2 and 0.92 wt %, respectively). HI values have up to 138 (mg HC/g TOC) with average of 11, consistent with type III to IV kerogens. Very low S2 values (less than 0.2 (mg HC/gram rock) for most of the samples render Tmax ambiguous to be used as a maturity index. According to average Tmax values (507°C), all the studied samples fall in post-mature (dray gas) stage, while Vitrinite reflectance data demonstrate peak of oil generation window, hence late maturity stage of these sediments. Concerning low HI values, intense weathering of the samples at outcrops may be the main reason for abnormally high Tmax values as a maturity index. Rock-Eval data significantly demonstrate type III to IV kerogens, capable of producing mainly gas.

Keywords: *Rock-Eval, Vitrinite reflectance, Hydrocarbon Potential, Shishtu and Sardar Formations, Tabas Basin, East of Iran.*

1. Introduction

Tabas basin is one of the exploratory blocks in the central Iran structural zone that has been received less attention from petroleum geologists till date. Thick Paleozoic and Mesozoic sedimentary succession exceeding 15 Km [1], mostly shale and marl with several coal seams encourage petroleum geologist to characterize them as of possible source rocks. Preliminary geochemical investigations defined upper Triassic-middle Jurassic sediments (Nayband and Shemshak Formations) as gas-prone potential source rocks [2]. This introductory work comprises determination of TOC, extractable organic matter (EOM) and pyrolysable carbon content (PC) by means of elemental analysis and pyrolysis methods. The aim of this study is to evaluate upper Paleozoic probable source rock properties and their hydrocarbon potential in this area. Since there is neither outcrop samples nor cuttings from a discovery wells drilled up to these formations in Tabas basin [3], sampling was performed on limited outcrops from western flank of Shotori Mountains in eastern part of the study area (Figure 1). Then Rock-Eval pyrolysis and Vitrinite reflectance measurements were carried out and their results were evaluated.

2. Geological setting

The Tabas basin has been formed as a great graben by thrusting Shotori range to west and Kalmard Mountains to east. This compressional phase was performed in the Middle Tertiary to Early Quaternary [1]. The study area is a part of Central-East Iranian Micro-continent (CEIM) [4] and structural units of Tabas block in central Iran. Kalmard and Nayband basement Faults define western and eastern structural limits of this basin. They were acted as normal and thrust faults through their geologic histories depending on prevailing tectonic events [3]. Paleozoic Tabas basin occurred as result of tension and thinning of Precambrian continental crust. Later, normal-Listric faults developed in a rift system with constant subsidence [1]. Shishtu and Sardar Formations like other contemporary succession in Albourz and Zagros regions have been deposited on shallow carbonate platform system [5]. These sediments extend as a narrow patchy band at eastern margin of the basin. Shishtu (Upper Devonian-Lower Carboniferous) and Sardar (Lower to Middle Carboniferous) Formations are sedimentary units of Ozbak-Kuh group in central Iran. Outside the Tabas area (e.g. in Kalmard Mountain), Clastic facies of these rocks change to carbonate-evaporate successions. This shows that the depth of basin was decreased toward west. In Tabas block, Carboniferous sediments have been deposited in a basin with high rate of subsidence. Hence, there are rapid and extent variations in thickness and facies of concurrent strata [3]. Fully sea conditions were predominated in Paleozoic depositional environment from Middle Devonian to Early Upper Carboniferous. Extensive uplift occurred at the end of Carboniferous and converted the whole area to a single continental regime [5].

3. Methods

Fifty nine outcrop samples were collected from Kale-Sardar, Hoze-Dorah and Kuhe-Baghevang sections in west flank of Shotori range. Rock samples were crushed, grinded and pulverized before analyses. The samples were then pyrolized using Rock-Eval 6. Twelve Samples with higher TOC content were selected for Vitrinite reflectance measurements. Polished pellets were prepared from crushed samples mounted in epoxy resin. At least 60 to 70 readings were made on each sample depending on their macerals frequency. Using J & M-MSP 200 software the results were plotted as histograms and interpreted based on different maceral population modes, in order to determine Indigenous Vitrinite particles [6].

4. Results and Discussion

Shishtu and Sardar Formations average TOC contents of about 1.20 and 0.90% wt. respectively. This identifies them as good potential source rocks. Their intervals in Hoze-Dorah section represent the richest strata, while Kuhe-Baghevang comprises the lowest TOC content (0.47 % wt.). This could be due to more terrigenous organic matter input in Hoze-Dorah, in compare to the other two sections. Petrographical studies and Rock-Eval pyrolysis data also confirm this hypothesis. Rise in organic matter content reveals an increasing in terrigenous input from north to south of the basin. Modified Van Krevelen diagram plotted for studied samples (Figure 2) indicates that organic matter type is mainly mixed Type III and IV kerogens. As these samples gathered from outcrop sections, their organic matter is mainly oxidized and depleted in hydrogen content so they may reveal unrealistic characteristics under weathering effects [7, 8, 9, and 10]. This matter can be deduced from more detailed analysis on molecular signatures of organic matter (under publication). Very low S_2 values (mainly less than 0.2 mg HC/g rock) together with low TOC contents for most of the samples, show poor to fair potential. This causes Tmax and HI values obtained by Rock-Eval pyrolysis to be suspicious [11]. However, each section comprise some samples that show reliable Tmax values in comparison with other maturity indices like production index and Vitrinite reflectance data. According to the reliable Tmax data, maturity level of OM may be in peak of oil generation window to late mature stage (445-450°C Tmax). Very high Tmax values (up to 600°C) are probably due to oxidation of organic matter in outcrops and/or partly related to mineral matrix effect in lean shally source rocks. PI values for most of samples fall in 0.1-0.4 range with average value of about 0.26 that show peak stage of oil generation window. Plot of Tmax vs. PI (Figure 2) displays wide variation of Tmax data for samples. Petrographical investigations were carried out to assess their maturity level. According to Vitrinite reflectance data, Shishtu and Sardar Formations in study area show thermal maturity of about 0.9-1.20% Ro. Microscopic evidences such as macerals with dark margin, fractures and decomposed pyrites defined highly weathered organic matter affected by surface oxidation [12]. Existence of more oxidized or reworked phytoclasts i.e. Inertinite group macerals in Kale-Sardar samples may be related to more oxidizing paleodepositional environment in this part. As shown in Figures 3, Shishtu and Sardar Formations contain type III and IV kerogens, but their proportions vary from sample to sample. Finally according to all available data, the depositional environment of these formations may be varying from shallow marine to paralic and coastal swamps. Decreasing in Oxygen index and Inertinite group maceral populations from south to north may be related to increasing depth and dominating more marine conditions.

5. Conclusion

According to TOC content (0.39- 14.1% wt.) nearly all of the studied samples have fair to good potential. S2 values mainly less than 0.2 (mg HC/g rock) implicate that these formations, except some interval of Shishtu Formation in Hoze-Dorah, have no potential to generate oil, but can produce insignificant amounts of wet or dry gas. Vitrinite reflectance data reveal that these formations already reached end of oil generation window or even early gas phase. Considering all available data, Sardar formation affected by Carboniferous erosion phase, comprise more oxidized organic matter mostly type III. These results show that studied rocks were deposited in paralic to shallow marine settings. Existing evidences suggest that these formations may be possible gas source rocks in Tabas basin and further surveys are recommended.

6. Acknowledgement

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7. References

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8. Tables and Figures

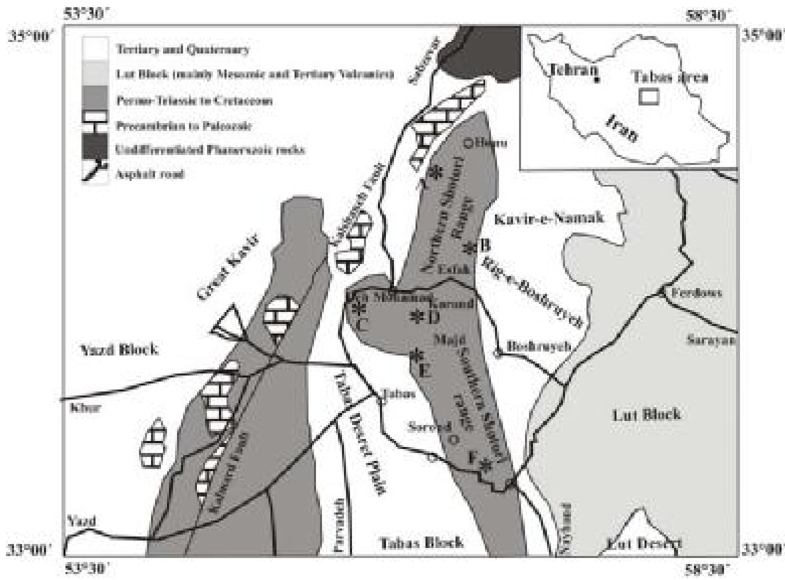

Figure 1- Study area showing geological features and sample locations, A, B, C, D, E and F; Tabas area, Central Iran

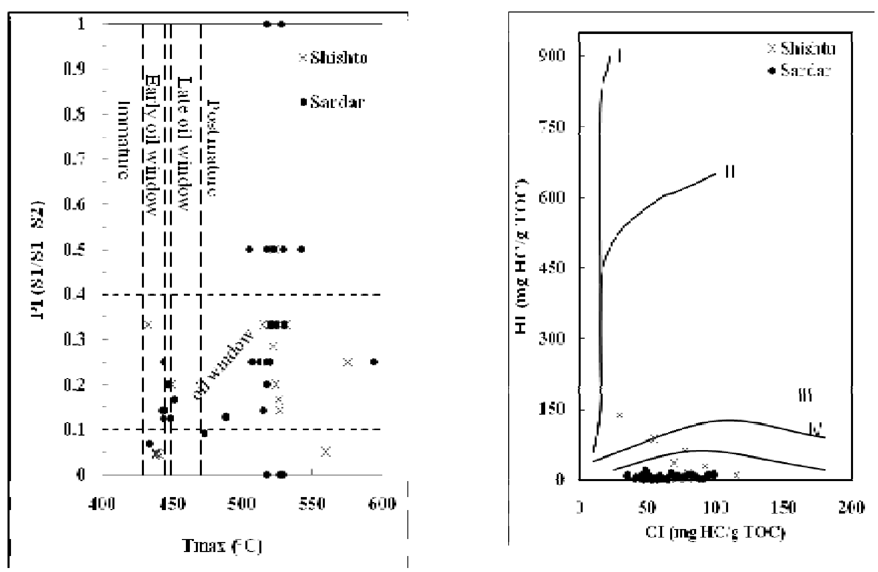

Figure 2- Modified Van Krevelen diagram showing kerogen type for studied sample and Tmax-PI diagram showin g the thermal maturity of the sample.

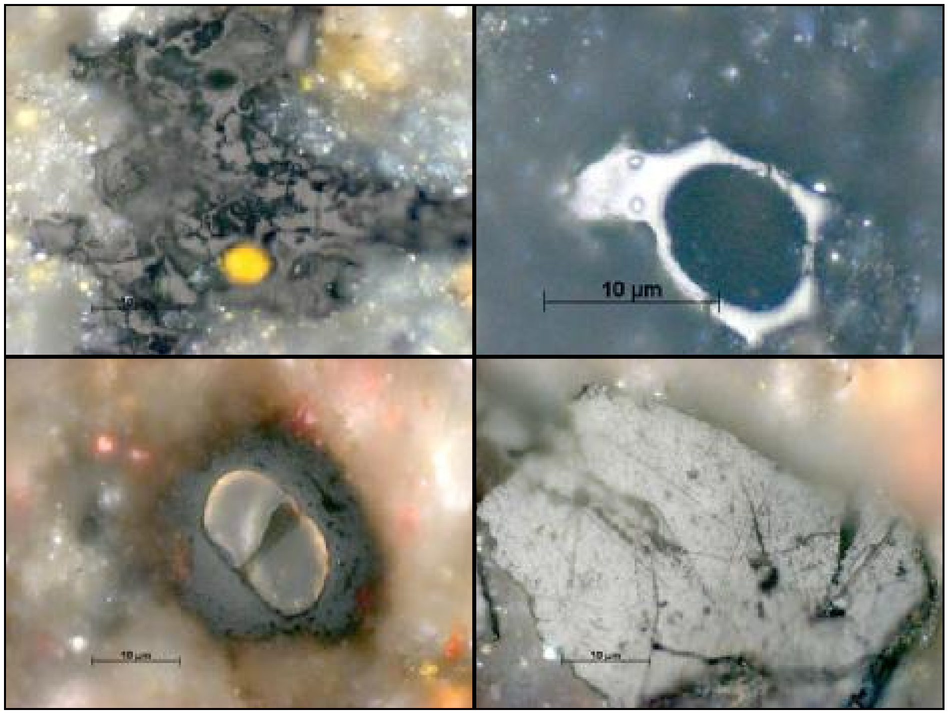

Figure 3- Type III and IV group macerals from Shishtu and Sardar Formations, Hoze-Dorah, 100X ppl, in immersion oil.