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Geochemical Characterization of Kazhdumi Source Rock in the Khaviz Oil Field, Southwest of Iran, Using Rock-Eval Pyrolysis

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Abstract

The Khaviz oil field located in Dezful embayment is one of Iran's southwest oil fields. In this study, a total of 28 cutting samples from Kazhdumi formation (well No. KZ1, Khaviz oil field) were subject to geochemical investigation using Rock-Eval pyrolysis for the first time. The results of pyrolysis indicated that Kazhdumi source rock has significant hydrocarbon production potentiality and already entered the oil generation window. As inferred from the diagram of OI versus HI, Kazhdumi source rock contains organic matter type II kerogen deposited in paralic environment with anoxic to suboxic conditions. Using the diagram of S_2 versus TOC, the absorbed carbon content, neutral carbon, and active carbon were calculated to be 0.42, 0.39, and 2.43 wt.% respectively.

Keywords: Khaviz Oil Field, Kazhdumi Source Rock, Rock-Eval Pyrolysis, Geochemical Evaluation

1. Introduction

Geochemical studies of oil can play an important role in exploring reservoirs of oil and gas in the world. One of the important goals of oil geochemical studies is to determine the geological layers, which could be the best source rocks in one specific area (Hunt, 1995). This study is aimed at the assessment of the amount of organic carbon, active carbon, and neutral carbon, and the evaluation of the effect of mineral matrix on absorbing carbon in Kazhdumi source rock in Khaviz oil field for the first time. Dezful embayment is one of the most important oil-rich regions in the southwest of Iran, with a large number of oil reservoirs. In this area, Kazhdumi is one of the significant source rocks which plays a major role in oil production. Considering that no work has yet been reported about the condition of Kazhdumi source rock in Khaviz oil field, it is essential to study this source rock.

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Therefore, in the current work, the geochemical characteristics of Kazhdumi source rock based on geochemical parameters of Khaviz oil field is investigated using Rock-Eval pyrolysis for first time. Previously, similar studies have been conducted in Zagros fold and thrust belt (Alizadeh et al., 2009; Ghasemi Nejad and Ghaniabadi, 2009; Khani et al., 2015; Bolandi et al., 2015).

2. Geological setting

Zagros area is one of the important oil regions in the world, containing more than 10% of all oil reservoirs of the world. This area is extended from north-west to south-east. Also, Khaviz oil field is one of Iran's southwest oil fields located in Zagros area, which is in the southeast of Khuzestan 10 km away from the northeast of Behbahan city, near large oil fields such as Maroon, Aghajari, and Mansouri. In terms of geology, an anticline on the ground made of Asmari formation uplift exists in Khaviz oil field. This anticline has a length of 42 km and a width of 5 km and is located in the south of central Zagros and north of Dezful embayment (Figure 1). This study focuses on geochemical characteristics of Kazhdumi formation in Khaviz oil field. This formation is one of formations in Bangestan group, and its age is between Aptian and middle Albian. The lithology of Kazhdumi formation includes mixture of clay limestone, marl, and shale. This formation is located in the structural zone of Zagros and, due to the high quantity of hydrocarbon, it is one of the most important source rocks in Zagros region.

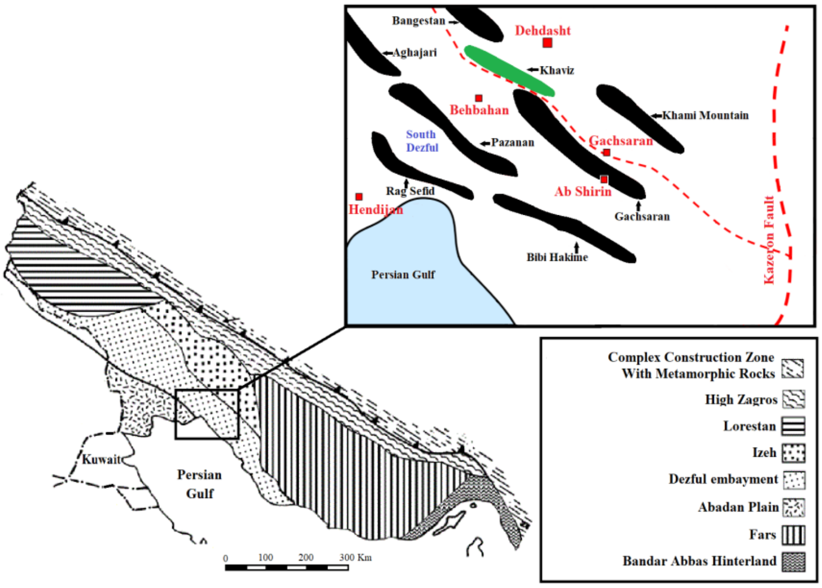

Figure 1

Geography and geology of the studied area.

3. Materials and methods

Pyrolysis Rock-Eval machine, or source rock assessor machine, which is widely being used in oil industry, was first introduced in France oil institute by Espitalie et al. (1984). In order to conduct this study, 28 cutting samples from Kazhdumi source rock of well No. KZ1 of Khaviz oil field were collected and analyzed (Table 1). The samples were collected from a depth in the range of 1193 to 1478 m. Before analyzing the samples, they should be purged of any pollutants. For purging, the samples were washed by a sample washing machine using a nonpolar solvent. After washing the samples, they were powdered, and 100 mg of every sample was put in the Rock-Eval pyrolysis machine. The mechanism of this machine is based on increasing temperature.

Table 1

Geochemical parameters determined using Rock-Eval pyrolysis.

No	Well No.	Formation	Oxygen index	Hydrogen index	production index	PP	T_{max} (°C)	S_2	S_1	Depth (m)	TOC (%)
1	**KZ1**	**Kazhdumi**	15	462	0.07	29.99	433	27.98	2.01	1193	6.05
2	**KZ1**	**Kazhdumi**	68	334	0.14	7.33	432	6.27	1.06	1204	1.88
3	**KZ1**	**Kazhdumi**	53	364	0.11	8.67	433	7.75	0.92	1218	2.13
4	**KZ1**	**Kazhdumi**	35	348	0.11	11.21	435	9.98	1.23	1230	2.87
5	**KZ1**	**Kazhdumi**	38	486	0.10	19.17	435	17.21	1.96	1239	3.54
6	**KZ1**	**Kazhdumi**	92	407	0.12	9.47	435	8.38	1.09	1248	2.06
7	**KZ1**	**Kazhdumi**	49	487	0.11	18.23	434	16.16	2.07	1260	3.32
8	**KZ1**	**Kazhdumi**	51	356	0.14	14.65	434	12.66	1.99	1272	3.56
9	**KZ1**	**Kazhdumi**	48	452	0.11	16.16	435	14.38	1.78	1277	3.18
10	**KZ1**	**Kazhdumi**	42	387	0.13	14.74	434	12.89	1.85	1280	3.33
11	**KZ1**	**Kazhdumi**	39	380	0.14	13.86	435	11.87	1.99	1291	3.12
12	**KZ1**	**Kazhdumi**	58	470	0.13	16.43	435	14.33	2.1	1298	3.05
13	**KZ1**	**Kazhdumi**	84	342	0.15	11.67	435	9.89	1.78	1309	2.89
14	**KZ1**	**Kazhdumi**	122	365	0.24	6.71	435	5.08	1.63	1321	1.39
15	**KZ1**	**Kazhdumi**	26	503	0.09	33.14	436	30.06	3.08	1332	5.98
16	**KZ1**	**Kazhdumi**	55	455	0.10	25.09	437	22.54	2.55	1341	4.95
17	**KZ1**	**Kazhdumi**	69	420	0.13	11.78	436	10.20	1.58	1350	2.43
18	**KZ1**	**Kazhdumi**	52	417	0.12	15.51	437	13.71	1.80	1362	3.29
19	**KZ1**	**Kazhdumi**	77	445	0.11	10.46	437	9.31	1.15	1376	2.09
20	**KZ1**	**Kazhdumi**	119	332	0.14	5.75	436	4.94	0.81	1400	1.49
21	**KZ1**	**Kazhdumi**	89	205	0.18	6.92	437	5.69	1.23	1410	2.78
22	**KZ1**	**Kazhdumi**	98	373	0.15	8.97	437	7.60	1.37	1416	2.04
23	**KZ1**	**Kazhdumi**	127	268	0.17	4.49	435	3.73	0.76	1426	1.39
24	**KZ1**	**Kazhdumi**	183	3110	0.18	5.66	437	4.62	1.04	1434	1.49
25	**KZ1**	**Kazhdumi**	116	397	0.13	8.97	435	7.79	1.18	1445	1.96
26	**KZ1**	**Kazhdumi**	176	344	0.14	4.45	435	3.82	0.63	1461	1.11
27	**KZ1**	**Kazhdumi**	57	357	0.11	9.80	436	8.70	1.10	1475	2.44
28	**KZ1**	**Kazhdumi**	99	248	0.19	9.88	437	7.99	1.89	1478	3.22

4. Results and discussion

At first, by plotting S_1 versus TOC, we should assure that the cutting samples are not polluted; in other words, the diagram confirms the lack of pollution of the samples (Figure 2).

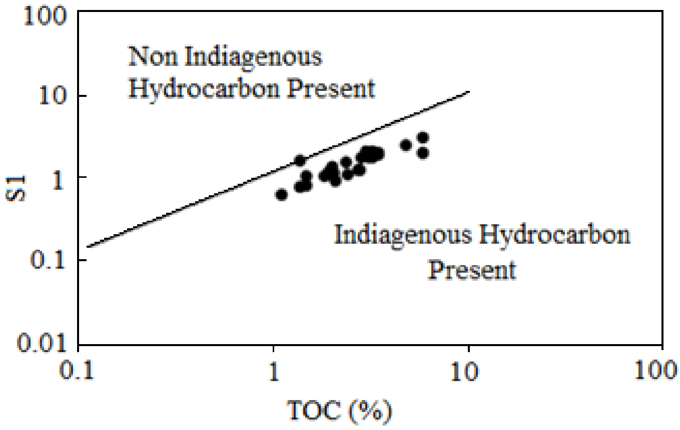

Figure 2

Determining the contamination of the samples by using TOC and S_1 parameters.

4.1. Hydrocarbon potentiality

To determine the hydrocarbon production potentiality of Kazhdumi formation, the results of Rock-Eval pyrolysis of the cutting samples were used (see Table 1). Using the data of Rock-Eval pyrolysis and plotting S_1+S_2 as a function of TOC (Figure 3), the hydrocarbon potentiality of the Kazhdumi formation was studied. The classification of hydrocarbon potentiality of Kazhdumi formation as a source rock, based on the TOC contents and S_1+S_2 parameters, seems to be excellent. On the other hands, the increase of hydrocarbon production (S_2 peak) during the pyrolysis stage indicates the high hydrocarbon potentiality of Kazhdumi formation. If the amount of released S_2 during the pyrolysis is less than 4 mgHC/(g Rock), the source rock has low potential for hydrocarbon production, but if S_2 is higher than 4 mgHC/(g Rock), the source rock has high potential for hydrocarbon production (Peters, 1986). The average of S_2 for the studied samples is 11.27, so Kazhdumi source rock has high potential for hydrocarbon production.

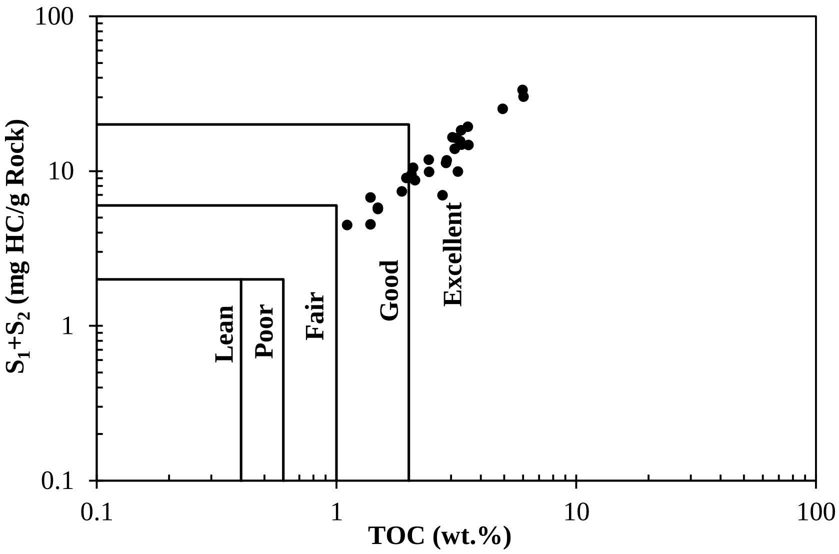

Figure 3

Hydrocarbon production potentiality.

4.2. Kerogen typing

Hydrogen index (HI) is a key variable for source rock which is used in modeling the quantity of extracted hydrocarbons as well as classifying kerogen typing (Pepper and Corvi, 1995). In order to determine the type of kerogen, the diagram of HI as a function of OI was used (Figure 4), which can be a type-modified Van Kerevelen chart. According to this graph, the organic matter of Kazhdumi source rock is mainly kerogen type II, which has the potential for producing oil and a little gas. Its H:C atomic ratio is between 1.2 and 1.5, and its O:C atomic ratio is less than kerogen type III and IV; also, the hydrogen index of kerogen type II in sediments ranges from 300 to 600 mgHC/gTOC (Kamali and Ghorbani, 2006). Kerogen type II is usually made of liptinitic macerals such as zooplankton, sporinite, phytoplankton, and bacterial remnants. Compared to other kerogens, the amount of sulfur in this type of kerogen is higher, and this kerogen is indicative of a marine environment (Kamali and Ghorbani, 2006).

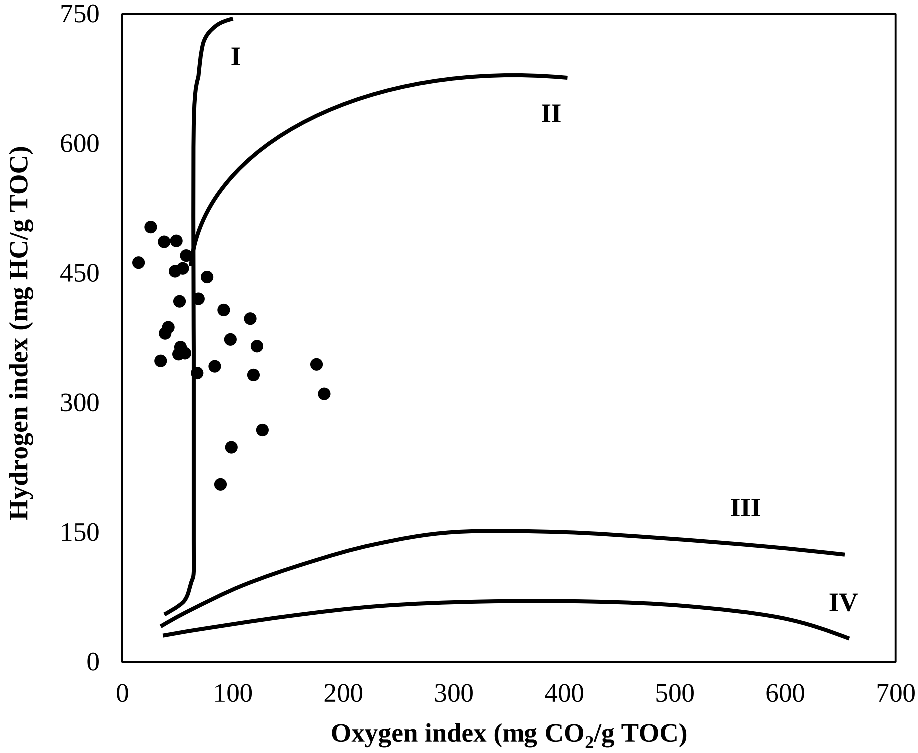

Figure 4

Cross-plot of hydrogen index versus oxygen index for kerogen typing.

4.3. Maturity

One way to determine the maturity level of organic materials and the type of kerogen by Rock-Eval pyrolysis method is using T_{max} (Hunt,1995). According to the variation of PI against T_{max} (Figure 5) and an average T_{max} value of 435.28 °C, Kazhdumi source rock in Khaviz oil field is at the beginning of oil generation window (OGW). Nevertheless, according to average value of T_{max}, 435.28 °C, it can be claimed that Kazhdumi source rock entered oil generation window since T_{max} is higher than 435 °C. On the other hand, with increasing maturity during catagenesis stage, the amount of produced hydrocarbon, i.e. production index (PI), and T_{max} are increased. An increased value of T_{max} indicates the increased energy required to break the remaining bonds of kerogen for hydrocarbon production

(Peters, 1986). According to the variations of T_{max} and PI versus depth (Figure 6), increasing depth raises both T_{max} and PI, and it can be interpreted that Kazhdumi source rock with an average TOC of 2.82 and an average T_{max} of 435.28 °C entered oil generation window.

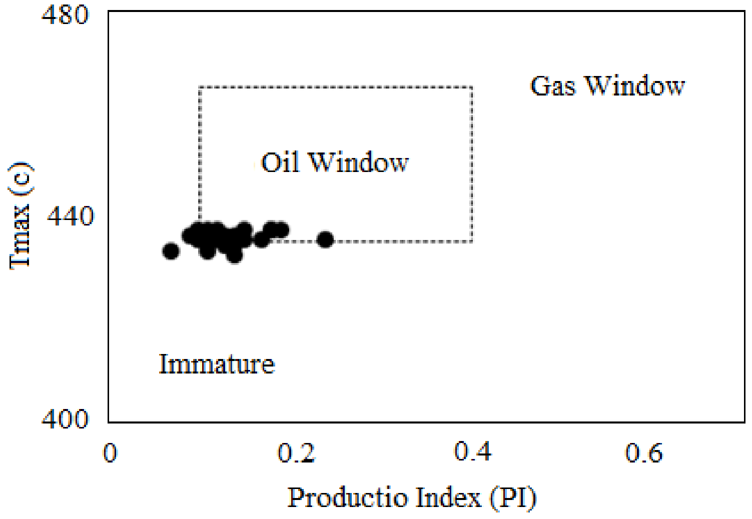

Figure 5

Cross-plot of T_{max} versus PI for determining the maturity of organic materials and the type of kerogen.

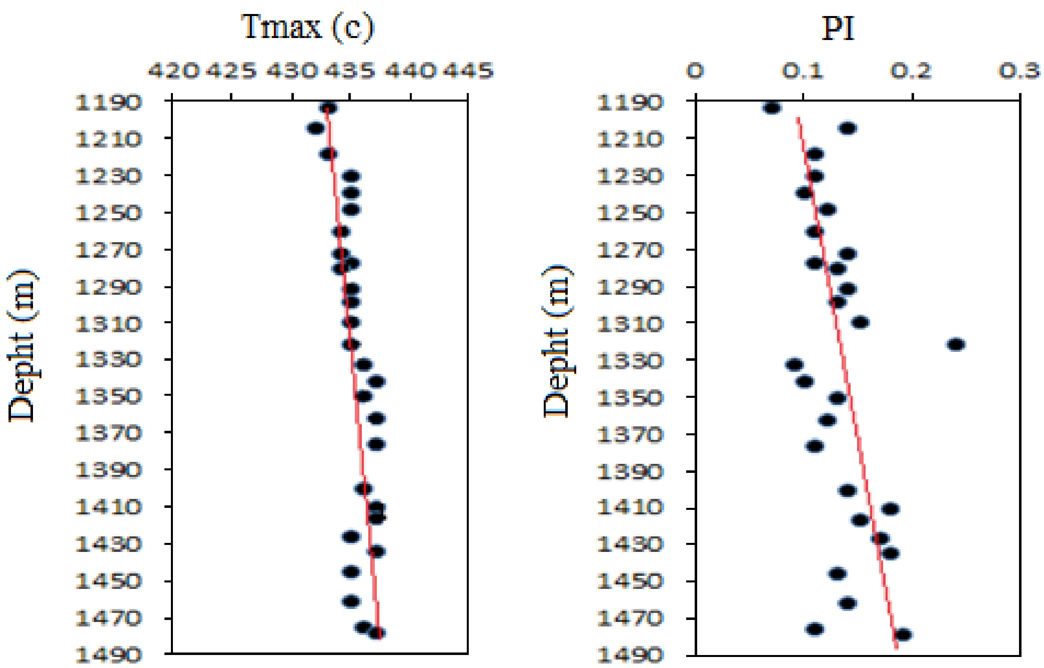

Figure 6

The variations of production index (PI) and T_{max} as a function of depth.

4.4. Determination of organic facies using Jones diagram

Jones diagram is based on variations of hydrogen index versus oxygen index and is employed to determine the organic facies. The diagram has some zones as follows:

A: Lake environments with extremely anoxic conditions;

AB: Progressive marine environments with anoxic conditions;

B: Lake or marine environments with relatively anoxic conditions;

BC: Environments with marine and continental organic materials and with a high rate of sedimentation in suboxic conditions;

C: Environments with a medium rate of sedimentation in anoxic conditions;

CD: Deep environments near orogenic areas;

D: Continental environments with extremely oxic conditions (Jones, 1987).

According to Jones diagram, the depositional environment of Kazhdumi source rock in Khaviz oil field was determined to be a marine environment with marine and continental organic materials in anoxic and suboxic conditions (see Figure 7).

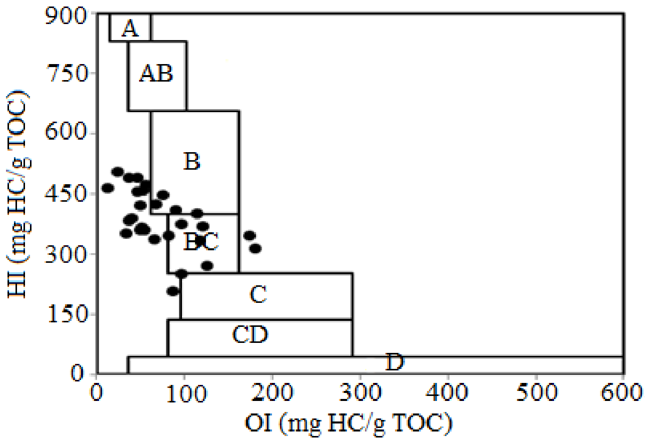

Figure 7

Jones diagram, i.e. HI versus OI, to determine the organic facies.

4.5. Effect of mineral matrix

Using the variation of S_2 against TOC, the amount of organic carbon absorbed by the mineral matrix can be measured. In an ideal phase, the regression line of the samples should cross the origin of coordinates; however, except for special and limited cases, the regression line usually is far away from the origin of coordinates. The location of the collision of regression line with S_2-axis yields the hydrocarbon adsorption by the mineral matrix (Langford and Blane-Valleron, 1990). In such a case, multiplying the point at which the regression line crosses S_2-axis by the stoichiometry factors, the mean of which for oils is 0.084, indicates the amount of organic material absorbed by the mineral matrix (Dahl et al., 2004). According to Figure 8, the regression line for Kazhdumi source rock crosses S_2-axis at about -5, so by multiplying the stoichiometry factors (0.084) by -5, the quantity of the organic materials of Kazhdumi source rock absorbed by the mineral matrix was calculated at 0.42 wt.%. In the mineral matrix, clay mineral is the most important factor in absorbing organic carbon. It is worth noting that the type of clay minerals also affects absorbing organic materials.

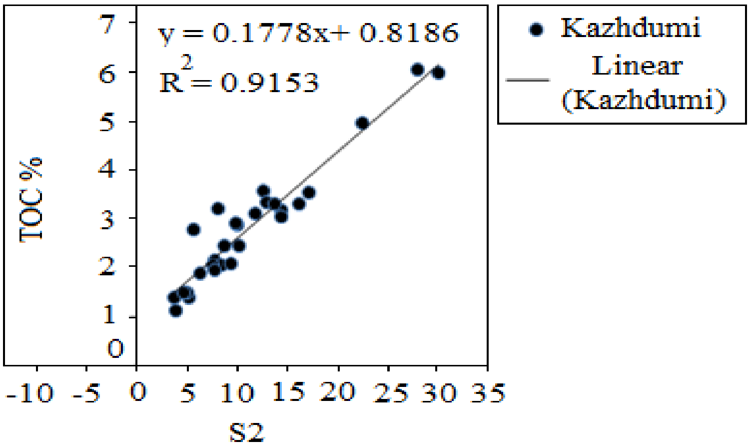

Figure 8

Cross-plot of TOC versus S_2 for determining the amount of neutral carbon and absorbed carbon.

4.6. Active carbon (TOC live) and neutral carbon (TOC inert)

Equation 1 can be used to determine the amount of active organic carbon. Based on the variations of TOC against S_2, the amount of neutral organic carbon of Kazhdumi source rock was calculated at 0.39 wt.%. According to the below equation, the amount of active carbon of Kazhdumi source rock was determined to be 2.43 wt.% (see Table 2).

$$\text{TOC Live} = \text{TOC Observed} - \text{TOC Inert} \quad (1)$$

Table 2

The amounts of absorbed, active, and neutral organic carbon of Kazhdumi source rock.

Well No.	TOC Observed	TOC-S_2 equation	TOC Inert	TOC Live	TOC Adsorbed
KZ1	2.82	y=0.1778x+0.8186	0.39	2.43	0.42

Based on the results obtained for Khaviz oil field and the previous researches on Kazhdumi formation in Rag-e-Sefid oil field (Alizadeh et al., 2009) and Aghajari oil field (Khani et al, 2015), the values for the adsorbed organic carbon of Kazhdumi source rock in Khaviz, Rag-e-Sefid, and Aghajari oil fields are 0.42, 0.79, 0.18 wt.% respectively. Furthermore, the amounts of the neutral organic carbon of Kazhdumi source rock in Khaviz, Rag-e-Sefid, and Aghajari oil fields are 0.39, 0.5, 0.23 wt.% respectively. The values for the active organic carbon Kazhdumi source rock in Khaviz, Rag-e-Sefid, and Aghajari oil fields are also equal to 2.43, 1.97, 2.06 wt.% respectively. Moreover, the potential for producing oil is high in the above oil fields. Finally, the depositional environment of Kazhdumi source rock in the above oil fields is marine environment in anoxic conditions, and kerogen of the Kazhdumi source rock is type II.

5. Conclusions

The data obtained from the geochemical analysis of the cutting samples and from the variation of S_1+ S_2 with TOC confirmed that Kazhdumi source rock has high potential for hydrocarbon production. The variation of hydrogen index with oxygen index also clarified that kerogen of Kazhdumi source rock is type II. In terms of the maturity level of organic materials, the variation of production index with T_{max} and the average T_{max} of 435.28 °C indicated that Kazhdumi source rock entered oil generation window. To determine the organic facies of Kazhdumi source rock, Jones diagram demonstrated that this formation was deposited in a marine environment with continental and marine organic materials and anoxic and suboxic conditions. The values for the absorbed organic carbon, neutral organic carbon, and active organic carbon of Kazhdumi source rock in Khaviz oil field were calculated at 0.42, 0.39, and 2.43 wt.% respectively.

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