Petroleum and Coal

Article Open Access

INVESTIGATION OF ASPHALTENE PRECIPITATION IN BANGESTAN RESERVOIR, KUPAL OIL FIELD, SW OF IRAN

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Received January 23, 2019; Accepted February 19, 2019

Abstract

One of the most important problems is the production of asphaltene sedimentation is in oil reservoirs. Enclosure in the porous environment of the oil field, well heads and processing plants is a serious problem in the production of asphaltene oil. The complex composition of deposited materials is proportional to the type of crude oil composition, well depth, formation temperature, and pressure drop and production process. These factors will disrupt the chemical equilibrium in the reservoir and result in the formation of asphaltene sedimentation. The main purpose of this study is to investigate the causes of asphaltene sedimentation in the Bangestan reservoir of Kupal oil field. The results showed that despite the existence of a single source rock for productive reservoir layers, the oil wells of the reservoir of Bangestan lacked the peripheral and perpendicular continuity of the reservoir during the reservoir, and were based on independent production areas. The values of asphaltene colloidal instability index (CII) (0.93-1.26) indicated that this oil field is prone to precipitation of asphaltene. The study of our data in the Bangestan reservoir showed that temperature has no direct or indirect effect on sedimentation. The evaluation of pressure – time diagram showed that when the production increased, the reservoir pressure decreased and the asphaltene sedimentation was formed. Finally, it can be prevented from the formation of asphalt precipitation by the principled production of the reservoir.

Keywords: *Kupal oil field; Bangestan reservoir; Asphaltene Precipitation; SARA test.*

1. Introduction

One of the most important problems in the production of oil reservoirs is the formation of asphaltene sedimentation [1]. Reducing the permeability of the rocky reservoir, the formation of sedimentation in the well and reducing the recovery of petroleum products are among the major problems encountered by asphalting reservoirs. One of the most important factors affecting the sedimentation of asphaltene in oil reservoirs is the change of pressure and injection of solvent [2]. Asphaltene is generally heavy compounds found in crude oil. According to laboratory studies, part of the asphaltic compounds is thought to be solved and partly different in the form of colloids in oil. The sedimentation of asphaltene in reservoirs depends on changes in pressure, temperature, and composition of the oil. These factors will disrupt the chemical equilibrium of the reservoir and result in the formation of asphaltene sedimentation [3].

Asphaltene is either soluble in oil or as a colloidal suspension, which is found in oil that is absorbed by resins on their surface in a state of equilibrium [4]. Asphaltenic is a cut of an oil or other carbon-based material that is soluble in paraffinic solvents with a low boiling point (such as normal heptane) and in benzene.

The disparity in the components of the oil components due to environmental and operational factors will cause many problems and issues [5-6]. The most important consequences of this type of instability in the system of equilibrium of oil compounds are the formation, growth, and sedimentation of heavy organic compounds. The most important of these sedimentations are the problems associated with sedimentation of asphaltene components [7].

In the primary and secondary phases of oil production, due to changes in the thermodynamic conditions of hydrocarbon fluids, such as the change in the composition of oil, temperature and fluid pressure, the stability equilibrium of the thermodynamics of organic asphaltene is disrupted and asphaltene sedimentations are formed by various mechanisms and due to moving through porous medium of the formation, enclosures are created in the wells as well as in oil transportation and processing facilities [8].

The sedimentation of asphaltene causes a lot of problems in the recovery, transfer and refining of oil. For example, sedimentation of asphaltene on the porous surfaces of the reservoir rock causes changes in oil reservoir wettability. Also, this process during the exploitation of well will stop production [9]. Due to the fact that the financial damage caused by this phenomenon is significant, how to produce from such wells has become an important place.

Reservoir quantities, oil composition, resin and asphaltene concentrations in oil, pressure, temperature and flow characteristics will be effective in the formation of asphaltene sediment in the reservoir [8,10].

In Iran, many reservoirs have the problem of depositing heavy compounds such as asphaltene. For example, the formations of the Bangestan group which include oil fields of Ahwaz, Marun, Ramshir, Rag-e-Safid, Aghajari, and Gachsaran. Asphaltene sedimentation in oil reservoirs reduces the permeability and changes the reservoir wettability and, finally, reduces the production of oil, which has become a major problem in the production from Bangestan reservoirs (Illam and Sarvak). To study the sedimentation behavior of asphaltene in a different light and heavy oils as well as to predict the best method of preventing or remedy this problem, a research study was conducted. Asphaltene is precipitated by increasing the viscosity of the fluid, changing the properties of the cement and the blocking pores and flow paths causes damages to the reservoir.

2. Geological properties of Bangestan reservoir of Kupal oil field

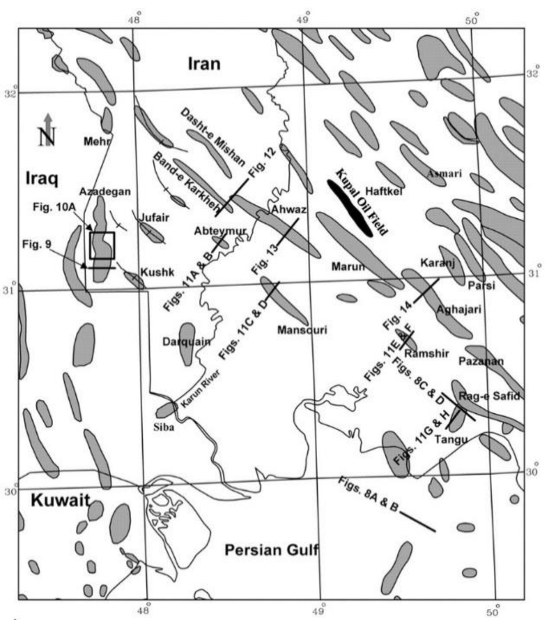

Figure 1. Location of the Kupal oil field and the wells selected for sampling

The data from the study of wells drilled in the Bangestan reservoir of Kupal oil field (Fig.1) indicated that the reservoir is less productive than those in the vicinity of Ahwaz, due to factors such as salt production, low porosity, and high saturation. The Bangestan group varies in a sedimentary environment in the northwest in the Lurestan region to the continental shelf in the south-east of Fars. In these areas, more than 800 meters of shallow neritic limestone, along with fluctuations in the margin of sedimentation, is also reported. Limestone of Kupal oil field has a special distribution. In the northwest, it is found in shallow, intertidal and enclosed seas, and in the south-east, limestone of free seas are observed.

The Bangestan reservoir in the Kupal oilfield [11], like the Asmari reservoir, is an anticline sinus whose length is 32 km and its width is 4.5 km. The geophysical information of the Bangestan reservoir in Kupal oil field showed the presence of a thrust fault in the south-eastern part of the field, suggesting that if the intersection of such a fault was associated with a normal fault, it could lead to the formation of a fracture system with abundant production. Based on studies, the Bangestan reservoir of this oilfield is divided into nine zones that consisted of four reservoir zones, of which porous carbonates were separated by the denser carbonate layers [12]. The most amount of in place oil of this field is located in the highest part of the Sarvak formation, which is the main productive zone of this field. The aforementioned zone is bounded by two discontinuity planes of early Cenomanian - late Turonian at the base and a nonconformity plane of the early Turonian-late Santonian from the top.

3. Zones susceptible to precipitation of asphaltene

Asphaltene is deposited in oil wells due to changes in well pressure or changes in other reservoir quantities, including temperature and composition crude oil. Some wells are at the beginning of the asphaltene sedimentation problem, but in the later phases of production, this problem will arise. Therefore, for this study, the zones susceptible to precipitation of asphaltene in the reservoir should first be identified.

Increasing the amount of asphaltene sedimentation is due to reduced solvent solubility and its ability to maintain the suspension of asphaltene-resin clusters. To determine the zones susceptible to sedimentation of asphaltene, a 7 number of samples of crude oil wells were selected. Subsequent samples were then analyzed by column chromatography and, for each individual sample, the saturated, aromatic, resin and asphaltene portion (SARA) are specified for samples and zones susceptible to asphaltene sedimentation were identified (Tab.1). The Colloidal Instability Index (CII) of asphaltene can be measured using SARA Laboratories (Tab.2).

Table 1. Geochemical data and gross chemical composition of oils

Sample No.	Well No.	Saturated	Asphaltene	Resin (N.S.0)	Aromatic
1	4	45.5	1.8	14.9	27.2
2	26	37	1.6	14.6	26.7
3	71	38.2	2.2	13.2	29.3
4	23	46.6	2.3	14.7	36.3
5	44	54.9	0.9	15.1	29.1
6	32	49.7	1.2	12.2	36.9
7	8	46.5	1.9	11.8	29.3

Table 2. CII data of Bangestan reservoir oils in Kupal oilfield

Sample No.	1	2	3	4	5	6	7
CII	1.12	0.93	0.95	0.95	1.26	1.03	1.17

This index is known and calculated as the ratio of total amounts of saturated and asphaltene to the sum of aromatics and resins. If the CII value is less than 0.7, asphaltenic oil is stable in the formation of heavy sediments, while asphaltenic oil is unstable for values of 0.9-0.7 and is released under the conditions of the oil system. For asymmetric values of more than 0.9, the asphaltenic oil will be completely unstable. On the basis of this, it was observed that the indices of colloidal instability in hydrocarbon fluids were more than 0.7. Therefore, the desired oils are instable due to the formation of asphaltene sediment (Fig. 2).

Also, in order to determine the asphaltene stability in the reservoir, the ratio of the Saturated/Aromatic components to the ratio of Asphaltene/Resin was used. According to this, most of the oil samples from the Bangestan reservoir are located in the instable zone (instable zone of Middle East). This illustration clearly shows that one of the main factors of asphaltene sedimentation in these wells is the low content of resin and aromatic components in oil (Fig. 3). Study of the ratio of CII and resin ratio to asphaltene that wells are instable, so that the CII values change from 0.7 to 0.9 are high. An examination of the quantities considered in the Bangestan reservoir of Kupal oil field indicated that all of them were susceptible to sedimentation of asphaltene, but this phenomenon was observed in wells studied.

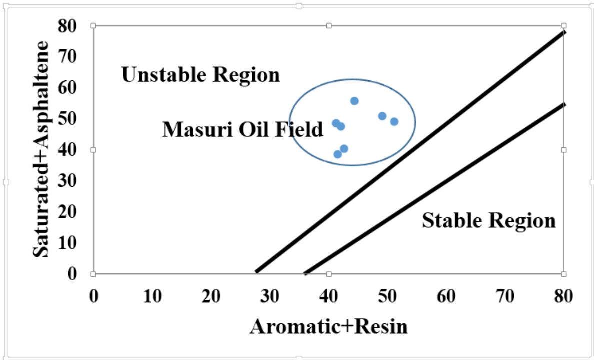

Figure 2: Study of the CII index in reservoir samples indicates that samples are placed in a stable range [13].

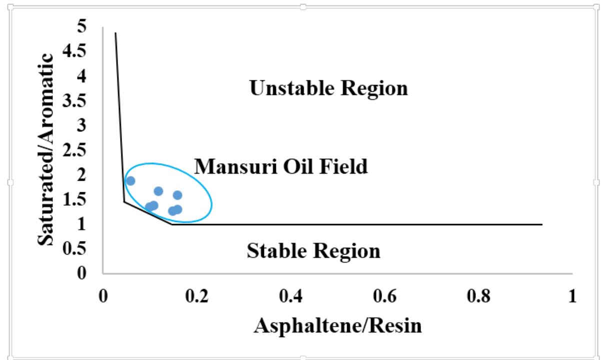

Figure 3. Changes in the Saturation/Aromatics ratio versus Asphaltene/Resin ratio in the samples of oil in the Bangestan oil reservoir show that all of the impurities are in a stable range [13]

4. Variation in oil composition

The methods used in the geochemistry for determination of oil properties, determination of the distribution of hydrocarbon and the presence of various compounds, including normal alkaline and isoprenoids such as pristane (Pr) and phytane (Ph), are used for gas chromatography (Tab.3). Using the data derived from this method, one can determine the type of organic facies, the type of kerosene, the type of sedimentation environment, thermal maturation and the effect of biodegradation and leaching on samples [14].

Evidence such as the single modal pattern of gas chromatograms in samples, the normal frequency of light alkanes (nC_{12}-nC_{20}), the values of the Carbon Preference Index (CPI) near one, and the low ratios of normal alkanes to isoprenoids imply that the studied oils have the same origin rock and belongs to the environment with organic material of algae type [15]. The results of the gas chromatography analysis of the samples showed a spectrum of carbon C_{11} to C_{36} and also showed that light hydrocarbons have a high frequency of C_9 to C_{26} and hydrocarbons heavier than C_{20} have a low frequency (Fig. 4).

Table 3. Isotopic and Pr/Ph data of Bangestan reservoir oils in Kupal oilfield

Sample No.	4	8	32	23	71	44	26
Pr/Ph	0.84	0.91	0.88	0.77	0.9	0.94	0.86
$\delta^{13}C$	-25.6	-25.4	-.25.6	-25.5	-25.5	-25.6	-25.5

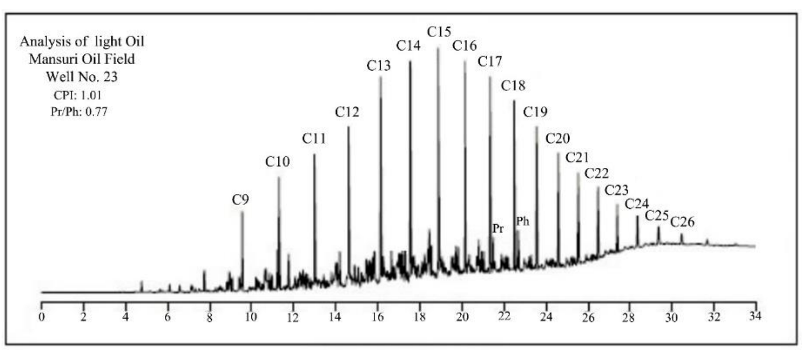

Figure 4. Chromatogram obtained from gas chromatography analysis of saturated samples of oils from Bangestan reservoir in Kupal oil field

A star diagram is used to indicate the ratio of the odd to even normal alkanes [16]. Using this figure, it was determined that the values of the normal ratio of alkanes with very clear overlapping represent the origin of the rock that they derive from [17-18](Fig. 5).

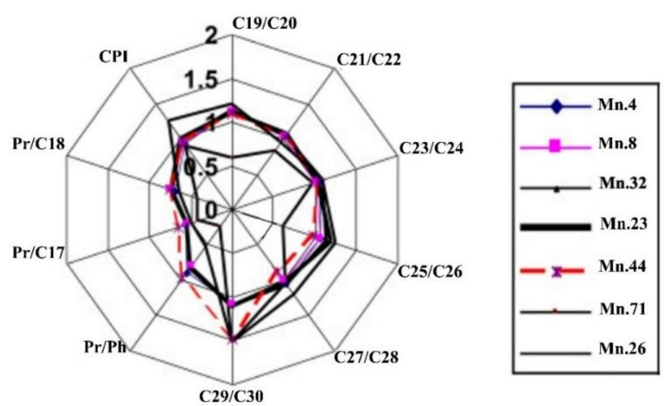

Figure 5. Star diagram was drawn to determine the same origin for samples of oil from the Bangestan reservoir via the results of gas chromatography

Using the pristane/phytane ratio (Pr/Ph) for a sample of studied oils, this ratio was found to be less than one (at least 0.77 and a maximum of 0.94) in all samples. This could indicate the sedimentary rocks of the origin of the Bangestan oil in a reduction environment. Of course, this result should be compared with other quantities [19].

With a high frequency of quantities of light normal alkanes, high molecular levels of oil, as well as any other alteration process, such as leaching and biodegradation, were established. The Pr/Ph ratio is calculated for reservoir oil (less than 2), which can be used to indicate the formation of crude oil from an organic-rich marine-reduction carbonate rock.

The diagram of carbon isotope values variation $\delta^{13}C$ by Pr/Ph ratio can be used in order to determine the age and lithology of origin rock of oil in rethe servoir of Bangestan oilfield) (Chung, 1992). Based on this diagram, it was discovered that high crude oil was produced from Mesozoic Age carbonate origin rock (Fig. 6).

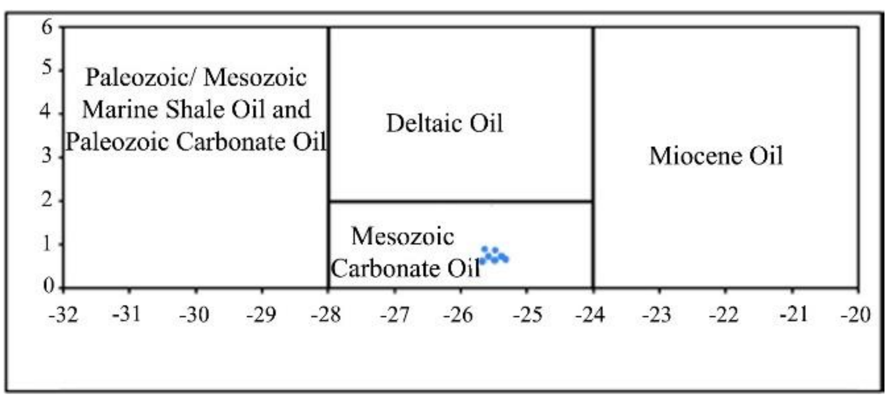

Figure 6. Changes of carbon-13 isotope of crude oil ($\delta^{13}C$) relative to Pr/Ph ratio to determine the age and lithology of the origin rock in sampled oils from Bangestan reservoir of Kupal oilfield (*adapted from* [20])

5. Effect of pressure

One of the most important factors in the formation of asphaltene sediment is reservoir oil pressure variation. Changing pressure is usually accompanied by a change in temperature. These changes cause physical and chemical instability and eventually the formation of asphaltene in crude oil. The change in pressure alone can also cause sedimentation of asphaltene [21]. By decreasing the pressure to reach the bubble point, the crude oil solubility decreases, which is due to the loss of crude oil density. In order to investigate the pressure variations in the formation, data from the repeated layer tests and hydrostatic pressure of the well was used.

Abnormal pressure is defined as changes in formation fluid pressure gradient relative to the hydrostatic pressure gradient. This pressure is caused by the presence of one or a number of impermeable layers that interfere with layers fluid [22]. Interpretation of pressure in a multilayered reservoir is made to examine the lateral and perpendicular continuity and estimate the gradient of the pressure [23].

Time is an important factor in controlling changes in the pressure of oil reservoirs [24], so that if the pressure decreases or increases in a few million years, the fluids will have more time to disperse and the pressure is slightly offset from the equilibrium state and vice versa, if pressure is increased in less time, fluids of different pressure can be generated [25]. This causes the pressure to be offset from equilibrium. In this case, the pressure changes caused the asphaltene to be removed from the oil and reduce its solubility and sedimentation in the reservoir.

Different studies are necessary to obtain the information on reservoir rock performance from the beginning to the end of production. In reservoirs with high pressure zones, the increase in temperature will be consistent with increasing pressure. Increasing the pressure reduces the molecular volume and increases the solubility of the hydrocarbon fluids. Also, under bubble point, the higher pressure from the gas (hydrocarbon gases) in the crude oil is solved, and it decreases the solubility [26]. The lowest solubility of asphaltene in crude oil occurs at the bubble point, which is associated with the maximum amount of asphaltene sedimentation. In an underground reservoir in general, with increasing pressure, the stability and degree of solubility of the asphaltene (constant temperature and constant volume of gas) increase.

Investigation of asphaltene sedimentation in the reservoir showed that the highest amount of asphalt sediment was observed around one of the wells. Asphalt sedimentation is due to changes in the equilibrium condition of asphaltene in the reservoir. A study of the reservoir pressure observed in a 40-year period indicated that the production pressure of the reservoir is reduced by increasing the reservoir pressure. Therefore, with decreasing pressure in the reservoir, it seems that there is a direct relationship with increasing asphaltene precipitation (Fig. 7). The study of the number of wells that faced deposited in a ten-year period indicated that with increasing production from the Bangestan reservoir, the number of these wells has increased, so that between1980-2015, the number of these wells is increased from 2 to 12 wells.

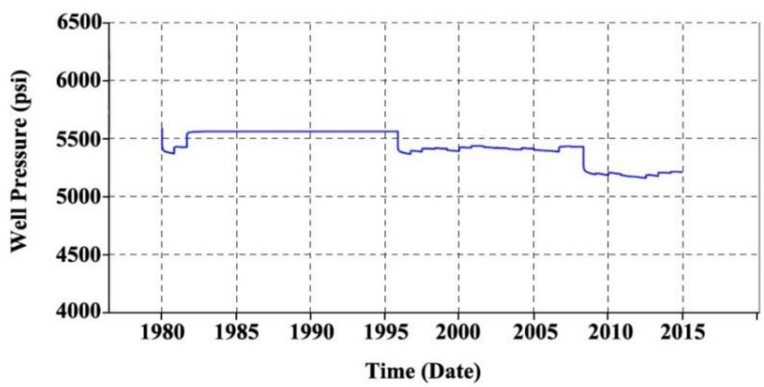

Figure 7. In Bangestan reservoir, pressure varies in the pressure-time graph, and pressure data is staggered relative to time

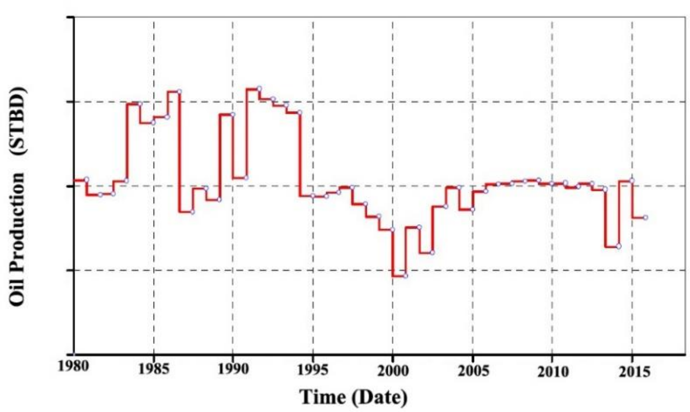

Figure 8. Chart of production to time in well No.23, and changes over a period of approximately 40 years, and production decline over time

6. Temperature drop

The temperature drop is the most common reason for wax sedimentation [27] because the solubility of wax in oil decreases with decreasing temperature. Regarding precipitation of asphaltene, temperature changes are less effective than the effect of pressure and oil composition [28-30].

As the temperature of the system increases, the resins are dissolved, and thus a kind of balance of electrical charge between the particles occurs, because the solubility of the oil depends on the resin in the asphaltene. In other words, because of the effect of the temperature on both the evaporation and the density of the liquid, the temperature changes in these properties, and this ultimately leads to a decrease in the solubility of crude oil. Asphaltene sediment is therefore observed at low temperatures.

There are many observations relating to the effect of temperature variations on the frequency of asphaltene. According to Andersen and Beardy [31], the asphaltene sedimentation rate increases with increasing temperature. In explanation of this phenomenon, it can be said that with increasing temperature and molecular mobility, the probability of collision and bonding of particles increased and eventually lead to asphaltene sedimentation. But generally, in addition to the above factors, the increase in temperature causes an increase in the movement or in other words the Brownian motion of the molecules of oil, which increases the probability of collisions of particles with each other and the absorption of particles of resin by particles of asphaltene which finally decreases the probability of formation of asphaltene sediment [4].

Usually, the drop in pressure is accompanied by a drop in temperature. The temperature is generally considered as a direct factor in the precipitation of asphaltene, which is due to the instability of dependent forces that are caused by the change in temperature. The temperature may affect the solubility of maltenes and the resins, and a temperature drop will lead the system to the production of paraffin deposits. This change of temperature may also occur with the expansion of carbon dioxide gas.

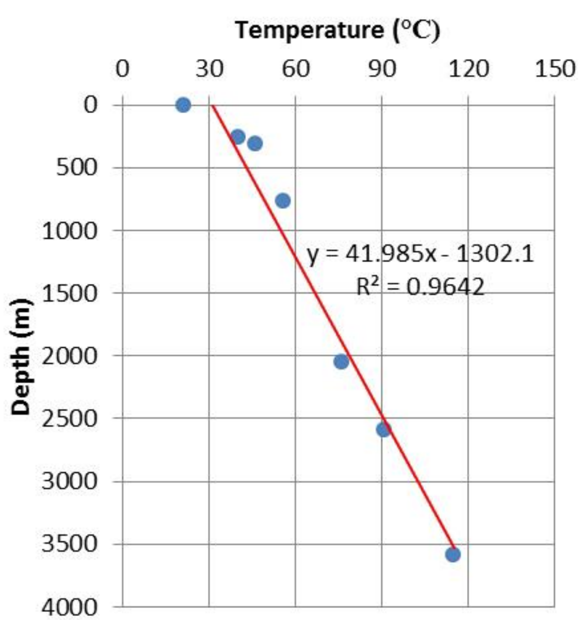

Figure 9. To determine the geothermal gradient of the area, temperature data of 7 wells were used

To study the effect of temperature and determine the geothermal gradient of the field, 7 wells were selected throughout the field. Using the temperature data of the wells, the geothermal gradient of the area was drawn.

According to the Andersen and Beardy [31], asphaltene sedimentation began to decrease with increasing temperature to more than a certain temperature (about 60 degrees), which caused it to overcome the kinetic energy that applied the system to the adherence of asphaltene particles to be bonded. Investigations indicated that the depth of the asphaltene was 2100-3000 meters, which would have a temperature between 60°-80°C with respect to the geothermal gradient (Fig. 9). By studying the temperature data of the Bangestan reservoir of Kupal oil field, the temperature variation cannot be considered as a direct factor in the sedimentation of asphaltene.

7. Conclusion

The carbon preference index was determined in samples from C_{10} to C_{26}. This determines the marine origin of the organism and the organic materials and indicates the origin of rocks belonging to reducing environments, saline waters along with evaporative sequences. The results of the oil fingerprinting method indicate that the studied samples from the wells of Bangestan reservoir in Kupal oilfield were different from the viewpoint of the considered variables that were plotted by stars. Therefore, it can be concluded that in the Bangestan reservoir of Kupal oil field, drilled wells in the study area are not related to reservoir continuity, and the reservoir has independent production sections.

By studying the temperature data from the reservoir, the temperature cannot be considered as an indirect or indirect effect on the formation of asphaltene sedimentation. The analysis of changes in pressure data in reservoir layers confirms that the pressure of different zones was different and had different trends. As a result, there seems to be no pressure relationship between the reservoir zones. As pressure from the reservoir increases, production of oil pressure decreases and therefore, it seems that there will be a direct relationship between pressure drop and sedimentation of asphaltene in the reservoir, so that in the wells with deposited asphaltene, the pressure was reduced. Finally, principled production from the reservoir can lead to prevention of pressure drop and consequent the asphaltene precipitation.

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