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Introduction of Developed Reservoir Quality Index in Characterization of Hydrocarbon Reservoirs, Study of Kangan Formation in one of Fields in South of Iran

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Abstract

The purpose of this study is to determine reservoir quality in different zones of Kangan reservoir formation in a well located at one of hydrocarbon fields in south of Iran. This study was performed to evaluate the reservoir petrophysical characteristics of Kangan formation using probabilistic method. In this study, the effective parameters on the reservoir quality comprising of porosity, permeability and water saturation were selected. Then, the effect of each of these parameters was investigated on the reservoir quality, and subsequently, a new index or formula, called developed reservoir quality index (DRQI), was introduced as a result of development or modification of reservoir quality index (RQI). Based on the importance of each of these parameters in the introduced reservoir quality, different values were selected for the coefficients A, B, C, and the powers α, β and γ in the formula, and consequently, the best values of these coefficients and powers were obtained by plotting DRQI in terms of water saturation and maximizing the amount of regression or determination coefficient. In order to determine the validity of the formula introduced as the DRQI for other reservoir formations, this formula was used for Sarvak carbonate formation in an oil field. For different depth units or members of Kangan reservoir formation, the values DRQI and RQI were calculated, and plotted against depth, and then, the results of these two indexes were compared. As a result of this comparison in the member or zone K2of the Kangan formation, we find out that the DRQI, compared to the RQI, better demonstrates the reservoir quality. This finding has been confirmed by the results of petrophysical evaluation of the Kangan formation using all the relevant well logs and information from this formation.

Keywords: Kangan, Porosity, Permeability, Water saturation, Developed reservoir quality index (DRQI).

Introduction

The aim of petrophysical studies is the reservoir formation zoning, determination of net pay zones, and, finally, investigation of the reservoir quality in different parts of the reservoir formation, and therefore, to determine the most suitable zones for optimal production from the reservoir and for more expert development of the hydrocarbon field. Porosity, water and hydrocarbon saturations, and permeability are the most important parameters that should be determined in petrophysical assessment to understand the reservoir quality. The purpose of this study is to determine the reservoir quality in different zones of Kangan reservoir formation in a well located at one of hydrocarbon fields in south of Iran.

The concept of reservoir quality index (RQI) was introduced by Amaefule et al. by considering the reservoir permeability and porosity [1]. Worthington used the RQI to determine the cut-off for the most important petrophysical parameters including porosity, permeability, water saturation and volume of shale, and then, discriminated the net pay zones from the gross zones [2]. Izadi and Ghalambor used a new approach for permeability determination and then, introduced the concept of modified reservoir quality index (MRQI) to determine hydraulic flow units in reservoirs [3]. Nabawy and Al-Azazi also defined a new concept, called reservoir potentiality index (RPI), which was introduced based on RQI and flow zone index (FZI) [4].

This study has generally been carried out to evaluate the reservoir petrophysical characteristics of Kangan formation, and has specifically been conducted to assess the reservoir quality of this formation. Following previous researches related to the concept of reservoir quality, we have introduced a new relevant concept called as developed reservoir quality index (DRQI). This concept has then been tested on the Kangan reservoir formation, and the results have been presented in this paper.

Methodology

The concept of RQI was defined by the following mathematical expression [1]:

$$RQI = 0.0314\sqrt{\frac{k}{\varphi_e}} \qquad (1)$$

where k is the reservoir permeability in terms of milli-Darcy (mD), and φ_ε is the effective porosity of the reservoir expressed in percent or fraction. In this research work, another similar concept for reservoir quality, called DRQI, was defined. To obtain an expression for DRQI, first, the effective parameters on the reservoir quality comprising of porosity, permeability and water saturation were selected, and then, the effect of each of the above-mentioned petrophysical parameters was investigated on the reservoir quality, and as a result, the following new index or formula for DRQI was introduced:

$$DRQI = \frac{A k^{\alpha} + B \phi^{\beta}}{C S_w^{\gamma}} \qquad (2)$$

where the reservoir permeability k (in mD), and ϕ and Sw (both in percent or fraction) are the reservoir porosity and water saturation, respectively. The coefficients *A, B, C*, and powers *α, β* and γ are specified based on the importance of each of these parameters in the introduced reservoir quality index. In practice, different values for the coefficients *A, B, C*, and powers *α, β* and γ, based on the trial and error scheme, are specified in the formula, and consequently, the best values of these coefficients and powers are obtained by plotting the *DRQI* in terms of

S_w, and maximizing the amount of regression or determination coefficient.

Taking logarithm from both sides of equation (2), we obtain the following equation:

$$\log DRQI = \log(A k^{\alpha} + B \phi^{\beta}) - \gamma \log CS_w \quad (3)$$

Thus, drawing the quantity *DRQI* versus CS_w in double logarithmic axes, we obtain a straight line, which its slope is equal to -*γ*.

In order to determine the validity of the *DRQI* formula expressed by equation (3), this formula was used for different units (or different depths) of the Kangan reservoir formation in an oil field. Before doing so, the permeability-porosity relationship in the reservoir units K1 and K2 of the Kangan formation was investigated (Figure 1). As can be seen from the Figure, considering the values of determination coefficient (R^2) for these two units, the permeability-porosity relationship in these units is relatively weak.

Setting the powers *α, β* and γ equal to 1, and the coefficients *A, B* and *C*, equal to 4, 2 and 1, respectively, just based on the importance of each of these parameters generally in the conceptual reservoir quality, we can write equation (3) in the following form:

$$\log DRQI = log\ (4k + 2\phi) - logS_w \quad (4)$$

Thus, by employing the petrophysical data (*k, ϕ and* S_w) obtained from different depths of the units K1 and K2 of the Kangan formation and computation of *DRQI* values using equation 4, and then, drawing the computed *DRQI* values versus S_w data in double logarithmic axes, and fitting a straight line to each of the units, we obtain the chart shown in Figure 2. As indicated in the Figure, the determination coefficient (R^2) for the units K1 and K2 are 0.37 and 0.76, respectively.

However, if we set the coefficients A, B and C equal to 1, and the powers α, β and γ, equal to 0.4, 0.1 and 1, respectively, the following equation will be obtained:

$$\log DRQI = log\ (k^{0.4} + \phi^{0.1}) - logS_w \quad (5)$$

Thus, by drawing the DRQI values, computed using equation (5), versus Sw data of different depths of the units K1 and K2 in the Kangan formation, and fitting a straight line to each of the units, we obtain the chart presented in Figure 3. As can be seen from the Figure, values of R^2 for the units K1 and K2 are, respectively, 0.90 and 0.93, which have substantially been increased compared to those in Figure 2.

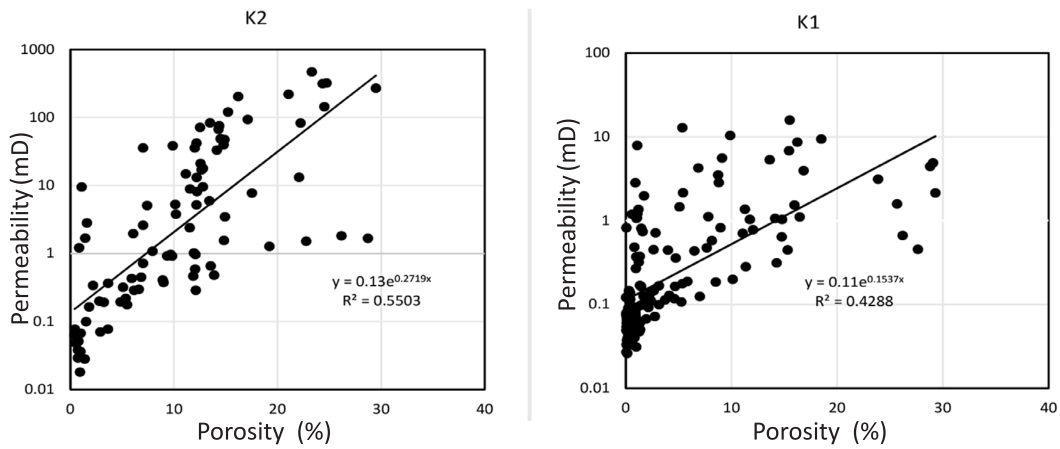

Figure 1: Permeability-porosity relationship in the reservoir units K1 and K2 of the Kangan formation.

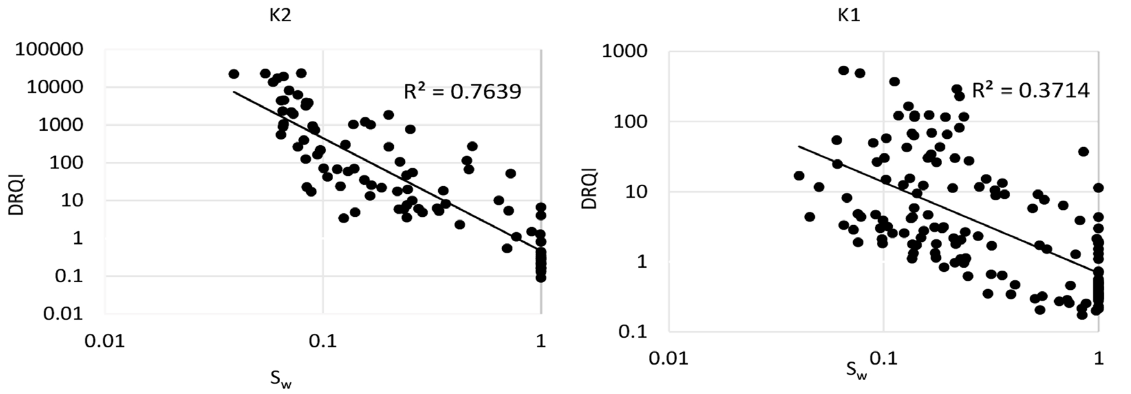

Figure 2: The *DRQI* values, computed using equation (4), versus S_w data in the reservoir units *K1* and *K2* of the Kangan formation.

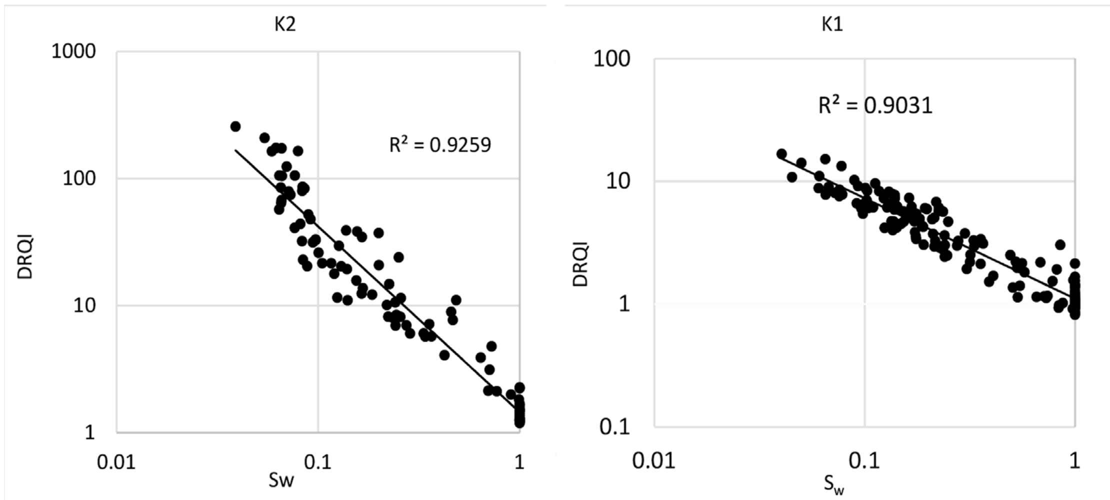

Figure 3: The DRQI values, computed using equation (5), versus S_w data in the reservoir units K1 and K2 of the Kangan formation.

Discussion and Results

Setting other values to the coefficients *A, B* and C and the powers *α, β* and *γ*, we can obtain other specific expressions

similar to equations 4 and 5 that might improve the determination coefficient of the chart of *DRQI* versus S_w. However, plotting the *DRQI* values, computed using one of the above equations, and the traditional *RQI* values, computed using equation 1, versus S_w in each of the units of the Kangan formation, and then, comparing the results, we see that the unit K2, compared to the unit K1, has more appropriate reservoir quality in terms of the *DRQI* unlike the *RQI*. This result is in good agreement with the petrophysical evaluation of the Kangan formation.

Conclusions

The reservoir quality of different reservoir units of Kangan formation was investigated in this study using the new index *DRQI* and the traditional index *RQI*. A comparison between the *DRQI* and *RQI* results in this formation was also made. The comparison showed that the *DRQI* results, compared to the *RQI* results, were often in more agreement with the petrophysical evaluation of the Kangan formation. This is because the *RQI* concept only considers the permeability and porosity petrophysical parameters while the new *DRQI* concept considers water saturation in addition to the permeability and porosity petrophysical parameters. As indicated in the paper, the determination coefficient or R^2 for different units of Kangan formation could be close to unity by considering appropriate values for the coefficients *A, B* and *C* and the powers *α, β* and *γ* in the general logarithmic form of DRQI given by equation 3 in this paper.

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