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CALCULATION OF RESERVOIR PARAMETERS IN GURPI AND PABDEH FRACTURED FORMATIONS, MARUN OIL FIELD, SW IRAN

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Abstract

Marun oil field is one of the biggest Iranian oil fields (65 kilometers length and 7 kilometers wide), is located about 40 kilometers southwest of Ahwaz. Pabdeh and Gurpi Formations are mainly shale and marl and played the role of a fractured reservoir in this field. Estimation of fluid saturations for evaluation of hydrocarbon reservoirs is very important. The presence of clay in fractured and shaly reservoir formations makes the estimation of fluid saturation more complicated. According to the surveys carried out in Maroon oilfield, wells 38 and 48 at depths 3795-3854 and 3834-3799 m in Pabdeh formation are reservoir zones, and hydrocarbon saturations are 45 and 41%, respectively. This study showed that the Gurpi Formation had no significant hydrocarbon fluid, and the fractures contained brine only.

***Keywords**: fractured reservoirs; petrophysics; Pabdeh and Gurpi Formations; fluid saturation.*

1. Introduction

Studies and researches in the Zagros area are due to the existence of significant oil reservoirs in this area. In the meantime, the study of formations that have been considered as oil reservoirs is very significant, but other formations have been less considered. Formations of Gurpi and Pabdeh in the southwest of Iran are source rock and are among the formations that have not been studied more. In some oilfields, these two formations, have some reservoir properties and is some parts of the Dezful embayment are classified as fractured oil reservoirs. Generally, the porosity found in these reservoirs is mainly due to fractures.

According to the Gurpi Formations lithology (the major lithology of marl and calcareous shale) and Pabdeh (shaly lithology) and the manner and amount of stress in these regions, it is likely that these formations are considered as fractured reservoirs and considering the presence of Servak and Asmari reservoirs in this area, these two formations may contain hydrocarbons. By studying a well in the southwestern margin of Marun oil field, which drilled in asmari formations (as the main reservoir of Zagros) and Pabdeh and Gurpei, it was found that the fracture pattern in the Asmari and Pabdeh formations is almost the same, but the fractures condition in the Gurpi Formations which has more depth is different.

The highest fractures density is located in the lower part of Asmari formation and the whole of Pabdeh formation [6]. The highest number of fractures detected in image logs is the open type. The fractures of Asmari and Pabdeh formations have the same pattern, while the pattern of fractures in Gurpi Formation is completely different. Fractures of the Gurpi Formation have been created before or at the same time as the folds. The large dispersion of the directional fracture of the Gurpi Formation may be due to their non-systematic nature. The mechanism of fractures formation is flexural and bending-slip [6].

In this study, using log data and Geolag software (version 6.7.1), lithology, shale volume, porosity, water saturation related to Pabdeh and Gurpi Formations in Marun field have been calculated. The calculation of water saturation in shale-free formations is easily accomplished, but the presence of clay in fractured reservoir formations makes the estimation of fluid saturation more complicated.

2. Marun oil field

Marun oil field is located South of the Dezful Embayment and in the middle part of this structural zone along the Aghajari and Ramin anticlines (Figure 1). This large oil field was discovered by a two-dimensional seismic method in 1963. After drilling the first well, the presence of hydrocarbon in the Asmari reservoir was confirme [4]. The geographic location of this field is limited to Ramin field from the North, Kopal field from the East, Shadegan and Ahwaz fields from the west and northwest and Ramshir field from the south [5].The structure of Maroun Field is an anticline with low width and longitudinal with northwest- southeast direction in western and central parts and northeast-southwest direction in eastern end, with very distinct torsion in the middle of structure that has given to quadrilateral mode to the north direction. The vertical distance between the reservoir crest and the deepest surface of water oil contact in Asmari Formation is about 2000 meters. The construction gradient of the Marun Field varies in cross sections. It has a symmetrical state at the eastern nose, asymmetric state at the western nose to the center (the bending point with a maximum slope of 70°) and semi-symmetric state at north-east [5].

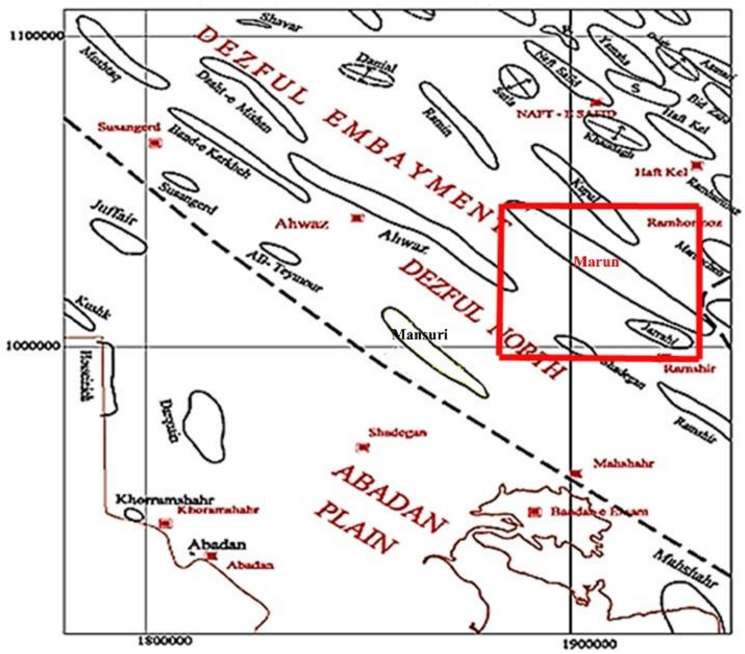

Figure 1. Location of oil fields in the southwest of Iran and Maroon oil field

3. Results and discussion

In this research, 2 wells in Maroon oilfield have been considered for petrophysical studies. These wells have almost complete information and logging data. The most important results of this project are as follows:

3.1. Shale volume

Shale volume is one of the most important parameters in all petrophysical studies and reservoir quality. The volume of shale means the number of clay minerals in the reservoir. In fact, accurate determination of reservoir quality and other petrophysical parameters such as porosity, type, and distribution of reservoir fluid, lithology and permeability are mainly based on the evaluation and determination of this parameter. In addition, the effect of the presence of shale as one of the important components of the rock on porosity and permeability in the analysis of well logging charts, their electrical properties also have a great influence on the calculated strength.

Due to small porosities of clay minerals, the petrophysical properties of the reservoir and so computation of parameters such as saturation and porosity is also affected [8]. Therefore, the calculation of shale volume for accurate estimation of the porosity, based on Well log data are needed. If the effect of shale volume in the formation is not considered, it will have a significant impact on the results of calculated porosity, permeability and water saturation of reservoir [1].

The most common method for calculating shale volume is the linear method using the corrected gamma ray chart (CIR) [8]. The volume of shale from the CGR chart was measured by the following equation.

$$V_{sh} = \frac{CGR - CGR_{min}}{CGR_{max} - CGR_{min}} \quad (1)$$

In this correlation, CGR_{max} is for the shale section, CGR_{min}: for the clean section and CGR: reading the gamma log at the desired depth.

Regarding the fact that the amount of shale volume decreases the reservoir properties, its amount in Pabdeh and Gurpi Formations can be considered as a negative factor in the change of reservoir properties. The average values of shale content in the Gurpi and Pabde Formations of Maroon Oilfield are presented in the tables below (Tables 1 and 2). The high amount of shale volume indicates the non-reservoir properties of these two formations.

Table 1. Average Shale Volume Percentage in Pabdeh Formation of Maroon Oilfield

Name of Formation	Sub-section (Zone)	Average Shale volume
Pabdeh	Zone 1	20.75
	Zone 2	16.5
	Zone 3	29

Table 2. Average Shale Volume Percentage in Gurpi Formation of Maroon Oilfield

Name of Formation	Average Shale volume
Gurpi	25.7

3.2. Calculation of porosity

Porosity is one of the essential parameters for reservoir rock because it represents the amount of hydrocarbon storage. This index is controlled by two factors of sedimentation and diagenetic processes [7]. The porosity of the rock and some hydrocarbon occupied portions are determined by logs. The porosity and percentage of hydrocarbons can be measured directly or indirectly through electrical, nuclear and acoustic logs. Depends on shaly or free from shale formation, the presence of hydrocarbons, as well as the use of different graphs and tools, methods for calculating porosity are different. To calculate porosity, neutron, density, sound, and resistivity logs are mainly used. It is possible to use a combination of some logs to perform this calculation [7].

In this study, cross-plots of neutron-density and neutron-sound have been used for calculation of porosity, which is discussed below.

3.2.1. Calculation of porosity using cross-plots of neutrons-density

The neutron and density logs can measure the total porosity, which can be the total initial porosity (intergranular or inter-crystalline) and secondary porosity (cavity, fracture, fracture) [1].

In this method, the porosity is determined by drawing the neutron values versus the density log. The presence of gas reduces the density of the rock.

The presence of shale in the formation causes the transfer of points to the south-east of the cross-plot. Therefore, before using cross-plots, both neutron and density diagrams must be corrected for shale [3]. Using the RHOB diagram versus NPHI, the total porosity for the Gurpi and Pabdeh Formations was 12% and 17%, respectively (Figures 2 and 3). Using the software and the density and neutron data, the porosity graph was drawn, and its lithology was determined. The major recognized lithologies for the Gurpi Formation are Shale, Marl, and Clay limestones and for Pabdeh Formation are Shale and Calcareous shale. These are shown in figures 2-4 for wells No. 38, 54, and 48.

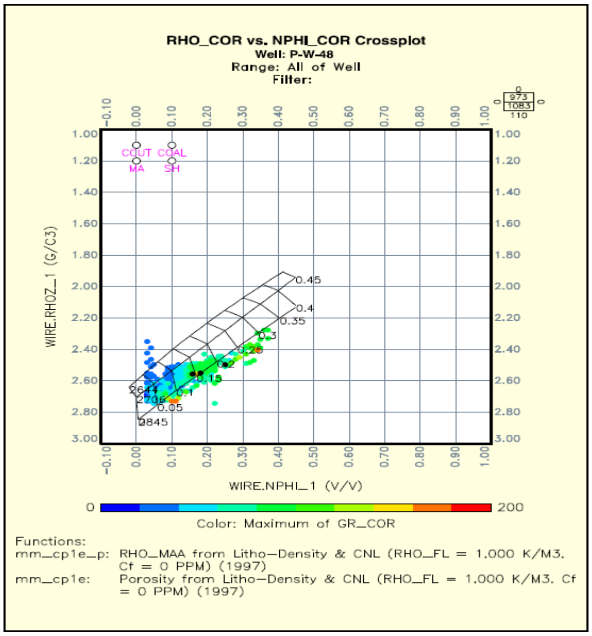

Figure 2. Porosity and lithology determination using software and NPHI, RHOB data for well 48 of Pabdeh formation in Marun oil field

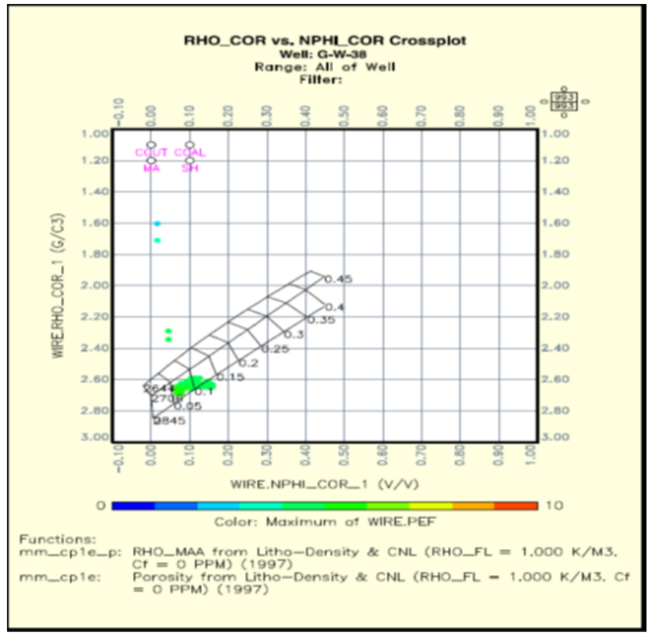

Figure 3. Porosity and lithology determination using software and NPHI, RHOB data for well 38 of Gurpi Formation in Marun oil field

3.2.2. Calculation of porosity using the neutron-sound cross-plot

The sound velocity in sedimentary formations is a function of several parameters, which are essentially dependent on the rock matrix components (sandstone, limestone, dolomite, etc.) and porosity distribution.

In this method, porosity is determined based on drawing of the values of neutron log versus sound log. If the neutron porosity of the shale and matrix Δt are different, the calculated porosity will not be correct. Therefore, shale correction is necessary first [2].

Neutron, density and neutron-sound cross-plots are used for determination of porosity and lithology [3]. Neutron-sound diagrams for wells No. 38 and 48 are shown in Figures 4 and 5.

Secondary porosity can be calculated using this cross-plot and the values for wells No. 38 and 48 of Gurpi and Pabdeh Formations are given in Table 3. This porosity is a result of tectonic activities and has the properties of a fractured formation. The electric illustrator diagram (Figure 6) shows the presence of these gaps in the Pabdeh Formation.

Table 3. Secondary porosity calculated by software and NPHI and DT data for wells 38 and 48 of Gurpi and Pabdeh formations in Maroon Oilfield

Name of Formation	Well no.	Secondary porosity
Gurpi	38	9.7
	48	11
Pabdeh	38	12.13
	48	12.66

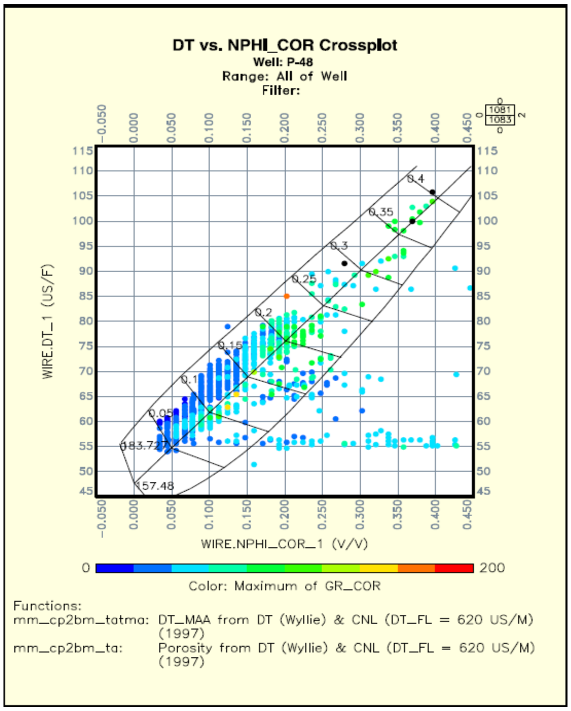

Figure 4. Porosity determination using software and NPHI and DT data for well 48 of Pabdeh formation in Marun oil field

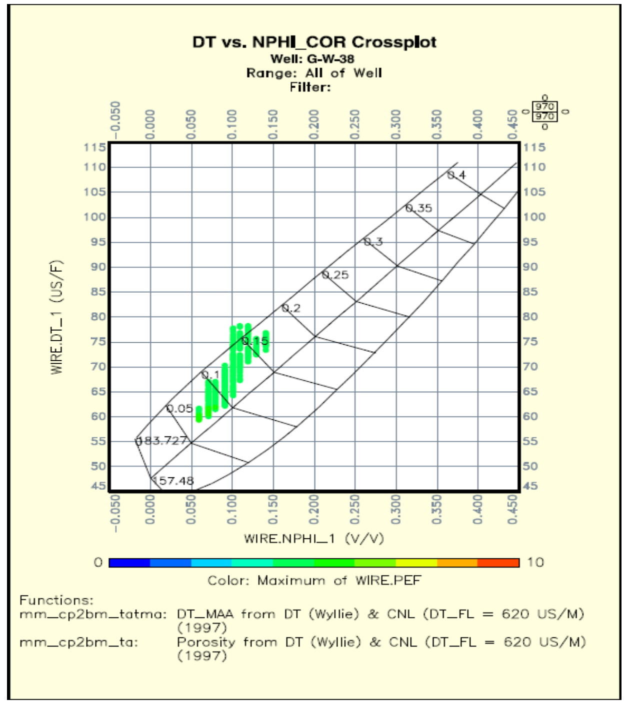

Figure 5. Porosity determination using software and NPHI and DT data for well 38 of Gurpi Formation in Marun oil field

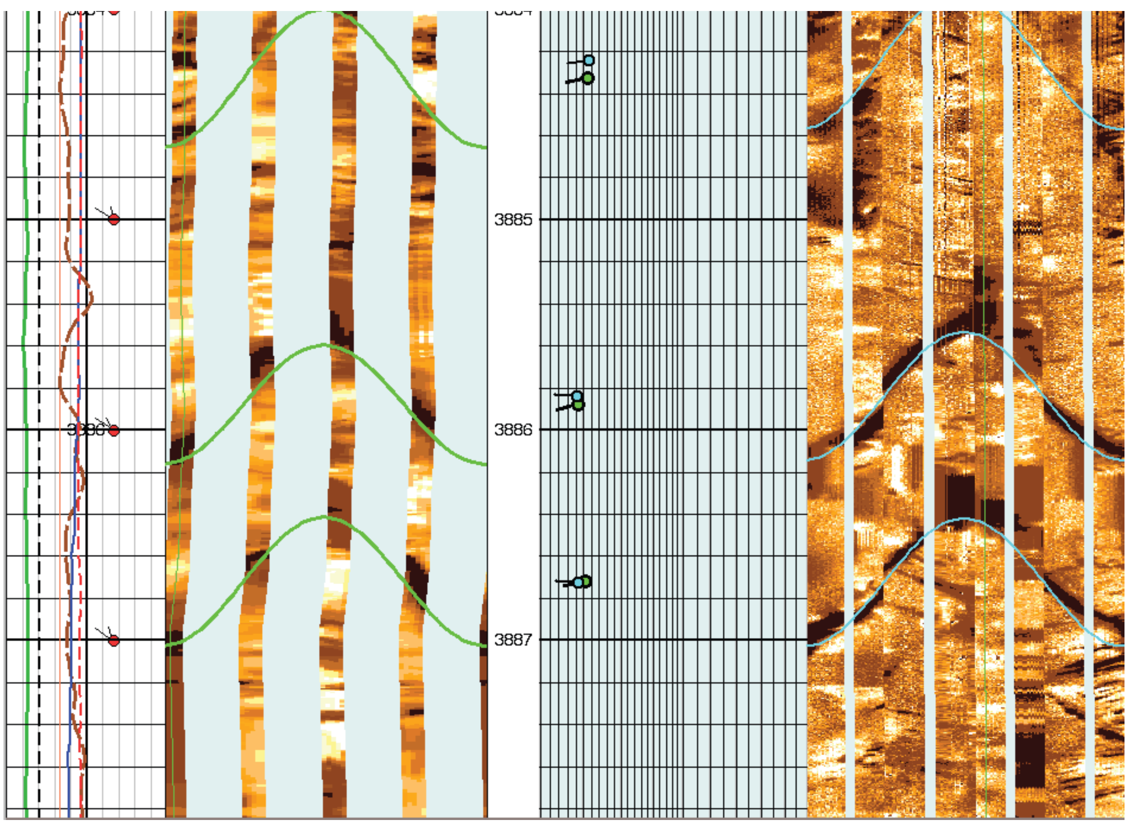

Figure 6. Fractures view in Pabdeh formation of Marun oil field for well No. 38

3.3. Calculation of water saturation

Saturation is one of the parameters that must be calculated using resistive log data. All methods of calculating water saturation are based on the Archie method, which was presented during the years 1941-1942. The Archie Formula does not apply to the depths that shale minerals or shale layers exist along with the matrix. If the Archi formula is used in these layers, the calculated saturation percentage will be unrealistic, because some parts of the water saturation are the water associated with shale minerals, along with the Matrix. Therefore, other methods are used to calculate the saturation of water. The best option is to use the Indonesia formula, which will provide more accurate calculations regarding the presence of shaly minerals in the matrix [1].

In this method, if we determine the electric conductivity of the hydrocarbon from equation (2) and real electrical conductivity from equation (3), the amount of water saturation is calculated from equation (4), which is done by the Geolag software.

$$\sqrt{C_o} = \sqrt{C_w/F} + V_{sh}^{1-V_{sh/2}} \times \sqrt{C_{sh}} \quad (2)$$

$$\sqrt{C_t} = \sqrt{C_w/F \times S_w^{n/2}} + V_{sh}^{1-V_{sh/2}} \times \sqrt{C_{sh} \times S_w^{n/2}} \quad (3)$$

In this equation, C_o: hydrocarbon electrical conductivity, C_w: electrical conductivity of water, F: coefficient of formation, V_{sh}: shale volume, C_{sh}: electrical conduction of shale, C_t: real electric conductivity of the formation and S_w is water saturation.

$$S_w = \left[\frac{R_w}{R_t} \times \frac{R_{sh}}{\left(V_{sh}{}^{1-V}{}_{sh/2}\sqrt{R_W} + Q_e^{m/2}\sqrt{R_{sh}}\right)^2}\right]^{1/n} \quad (4)$$

According to the researches carried out in the studied wells in Pabdeh Formation of Marun oil field, in well no. 48 from depths of 3791 m to 3834 m, which is a reservoir zone, the saturation of water and hydrocarbon were 59% and 41% and in the well No. 38 from depths of 3795 m to 3854 m, which is the reservoir zone, the saturations of water and hydrocarbon are 55% and 45%, respectively (Figure 7 and 8). The Gurpi Formation has no hydrocarbon volumes but contains saline water.

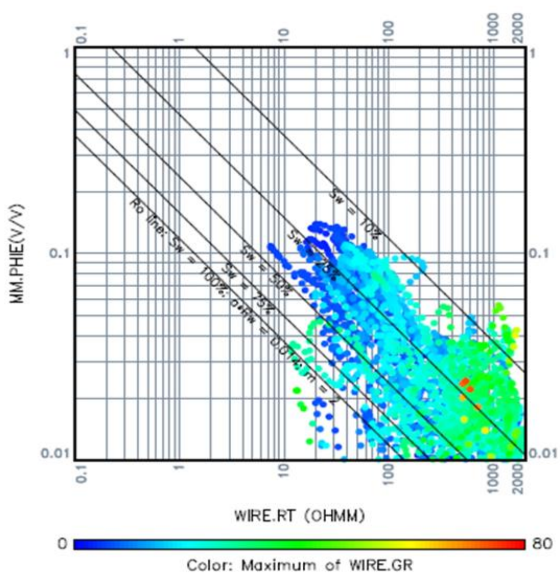

Figure 7. Determination of water saturation using software and data of PHIE, RT, and GR for well 38 of Pabdeh formation at Marun oil field

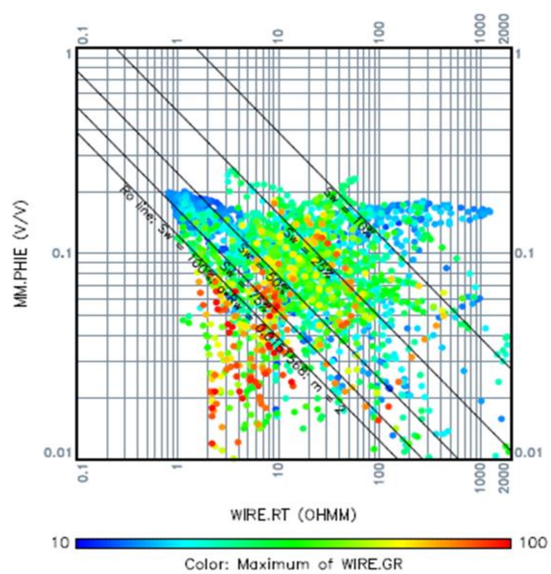

Figure 8. Determination of water saturation using software and data of PHIE, RT, and GR for well 48 of Pabdeh formation at Marun oil field

3.4. Identification of permeable zones

In this research, for the detection of non-reservoir permeable zones, caliper, bit size charts, and CGR diagram have been used. After calibrating these three diagrams, the best location for permeable zones is determined. Typically, when the size of the caliper diagram is less than the size of bit size diagram, the zone is said permeable and porous. In these surveys, the thickness of permeable zones in the studied wells was calculated so that well no. 48 has the maximum permeability. Using these three graphs, reservoir and non-reservoir sections were separated from each other. The whole Pabdeh formation in the studied wells was divided into three zones: Zone No. 1, from a depth of 3752 to 3795 m, is a non-reservoir zone and from depth of 3795 Up to 3828 m is a hydrocarbon reservoir zone (zone 2) and zone number 3 from depth 3828 to 3896 m is a porous zone without hydrocarbon but contains brine, and also the Gurpi Formation in the studied wells has a zone with relatively low porosity and free of hydrocarbons. Due to the lack of information, permeability has not been provided for these zones. Based on the existence of shale amount of 26.3%, well No. 38 in Gurpi Formation, according to the classification, is considered as a clay formation. The sound log in this formation has not many changes and is relatively flat and low, which indicates an increase in speed, that is, porosity is low. On the other hand, the resistance logs (shallow and deep) matched to each other and show a low resistance, indicating a hard and dense zone with saline water.

The calculated water saturation in this well was 99%, and the dominant lithology detected by the PEF graph was marl and clay lime. Well, No. 48 of the Gurpi Formation has a shale volume of 25.1% and water saturation of 99% and has the same lithology and fluid type as well No. 38. Due to lack of information, well No. 54, cannot be accurately evaluated. In well No. 48, Pabdeh formation from the depth of 3733 m to 3753 m contains high shale and low reservoir quality. The sound log in this region is sometimes irregular and distorted in some distances, which can be an indication of fractures. Also, the resistance curves are not consistent and relatively spaced apart, which is also an indication of the fractured zone. Regarding 100% water saturation, this region has no hydrocarbons and only contains saline water. The PEF chart also shows no. 10, which can be due to the penetration of barite into the fractures in this area. From the depths of 3753 m to 3791 m, the CGR decreases from top to bottom, and the average shale volume is 18, which represents a clay zone. The sound log is relatively smooth, and the resistance logs match, which unlike the upper part, is a uniform zone without fracture. This area also has a high water saturation and contains only salt water. By use of PEF chart, the dominant lithology was identified lime and shale lime. At a depth of 3791 m to 3834 m, the shale volume is 20%, which indicates poor reservoir quality. The sound log increases at the beginning of the zone and then decreases rapidly, indicating fluid in the porous space. In this zone, the resistance logs are matched and reduce from up to down, and with a précised look in the neutron and density logs that are almost parallel and the water saturation diagram in this zone, it can be said, this fluid is a most likely hydrocarbon. The PEF chart also shows the lithology of rock in this area is lime and shaly lime. From depths of 3834 m to 3900 m, regarding a high water saturation of 97%, as well as a reducing resistivity log, formation contains saline water, and the dominant lithology by the PEF chart was determined the shaly lime. In well No. 38, like well No. 48 in Pabdeh Formation the same zoning was observed, with the difference that at the top of this well, the fractured zone similar to well No. 48 was not observed and also differs from the depth mentioned for well No. 48. due to the lack of information in well No. 54, it is impossible to accurately evaluate the wells.

4. Conclusions

In this research, we used Geolag software version 6.7.1 for investigation of the reservoir properties, especially fluid saturation, lithology and calculation the amount of shale and porosity in Pabdeh and Gurpi Formations in Marun oilfield and so, the following results have been obtained. The amount of shale volume is 20.75%, 16.5%, 29%, and 25.7%. in the first, second and third zones of Pabdeh and the Gurpi Formation, repectively. In this method, the maximum and minimum CGR values are obtained in Pabdeh and Gurpi Formations in areas where there is no wellbore Collapse. Considering the fact that the existence of shale decreases the reservoir properties, its amount in Pabdeh and Gurpi Formations can be considered as a negative factor in the change of reservoir properties. The average porosity for the Gurpi and Pabdeh formations were 12% and 17%, respectively. The calculated values of the secondary porosity for wells No. 38 and 48 are equal to 9.7 and 11 % in the Gurpi Formation and 12.13 and 12.66 % in Pabdeh formation, respectively. This secondary porosity gives the reservoir properties to these formations, and so they can be classified as fractured reservoirs. According to the studies carried out in Marun oil field, in wells 48 and 38 of Pabdeh formation, the hydrocarbon saturation is 41% and 45%, respectively. Gurpi Formation contains only salt water.

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