FORMATION EVALUATION FOR JERIBE FORMATION IN THE JARIA PIKA GAS FIELD

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ABSTRACT

The Jaria Pika Gas field is a domal anticlinal structure in the northeast of Iraq NW trending, about 3.6 km long and 1.9 km wide. The 55 m thick gas bearing Jeribe Formation is the main reservoir. This study intends to well logs interpretation to determine the petrophysical properties of the Jeribe Formation in the Jaria Pika Gas Field. Total porosity, effect porosity and secondary porosity have been calculated from neutron, density, and sonic logs. Porosity is fair to good in the Jeribe formation. From RHOB-NPHI and N/M cross plot, the Jeribe Formation is composed mainly of dolomite, limestone with nodules of anhydrite. The Fatha Formation contains considerable amounts of anhydrite layers, so it's represented the cap rocks for the Jeribe Reservoir which is recognized based on the reading of Gamma-ray log, Density log, Neutron log, and Sonic log. The Jaria Pika is considered as gas field as the Jeribe reservoir rocks are gas saturated ones.

Keywords: Formation; Gas; Logs; Reservoir

INTRODUCTION

The carbonate Jeribe Formation has been deposited in Lower Miocene. It was deposited relatively uniformly throughout the basin (Al-Juboury et al. 2007). The Jeribe Formation is about 19.56 Ma, and corresponding to Early Miocene (Burdigalian) age (Lawa et al., 2020). (Sun, 1992) suggested that dolomitization occurred when Jeribe Formation was exposed to saline brines following transgression across the carbonate platforms (Aqrawi et al., 2009). The Jeribe formation comprises recrystallized, dolomitized, generally massive limestone and anhydrite (Jassim and Goff, 2006). The interpretation of well logs is important to understand the subsurface reservoir characterization (Cannon, 2016). Subsurface properties require physical measurements made from well logging. Logs data are the most widely used down-hole data to evaluate subsurface rocks and their physical properties. In addition, they are essential in terms of electrofacies studies and (Al-Jaberi and Al-Mayyahi, 2018). Alhadithi and Alhadithi

(2020) mentioned that the difference in elevation between gas-water- hydrocarbon contacts in the reservoir of is due to the structural factor, folding, and elastic behavior of carbonates. The study aims to determine reservoir characterization from logs interpretation, such as lithology from cross-plots, primary and secondary porosity and type of fluids that filled pores from log response and create C.P.I. by using IP program.

AREA OF STUDY

Jaria Pika structure is located in Diyala governorate eastern Iraq about 100 km northeast of Ba'quba city (Fig. 1). NW-SE anticlines are forming the main trap types in NE Iraq due to tectonic movement. The field contains two wells, JP-1 and JP-2 which were drilled in 1975 and 1977 respectively.

Fig. 1. Study area (after Sadeq and Yusoff, 2015)

METHODOLOGY

Two wells were studied using full set logs, the environmental corrections to the log readings were done before starting the interpretation. For environment corrections and interpretation of well logs Interactive Petrophysics software (IP) version 3.5 has been used. Accordingly, the corrected logs have been used to evaluate the Jeribe Formation in the Jaria Pika Gasfield.

The Environmental Correction of Well Logs

The environmental corrections are carried out to cancel the effect of the bad hole conditions and washout (Asquith and Gibson, 1982). To make corrections, IP software has been used. Physical factors such as mud properties, borehole geometry, casing configuration are the most improved existing of environmental conditions characterizations. Typical case history shows that correction process will result in different outcomes, depending on the presumptions chosen (Abdullah, 2014). Correction principle on reading logs is mean removing the environmental factors. Due to borehole conditions during invasion drill-mud through porous beds of formation, that importance doing environmental corrections of logs for exhibit the differences between original logs reading and actual logs reading to customize a good visual indication of the borehole profile. Fig. 2 illustrate the environmental corrections of Gamma ray, Resistivity, Density and Neutron logs). The correction of the environment reveals there are no large disagreement between the measurements of the original logs and the corrected logs readings.

Fig. 2. Environment corrections for well JP-1

Porosity Logs

Density log

Density log measures the bulk density for the required depth then equation (1) is used to calculate the porosity as follow (Pirson, 1993):

$$\Phi D = \frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_f} \quad (1)$$

Where:

ΦD : porosity from density log

ρ_{ma} = Density of the dry rock (g/cm³) in this study = 2.876 (g/ cm³) from dolomite (Asquith, 1982)

ρ_f = Density of fluid (g/cm³) = 1 g/cm³ for fresh water or 1.1 g/cm³ for salt mud

ρ_b = bulk density recorder by log

Neutron log

It is used to determine the porosity directly. Its value is related to the amount of hydrogen in the formation which is either from the hydrocarbons or from water in the pores of the formation (Pirson, 1993).

Sonic log

Sonic log reflects the ability of rock to transmit the compressional sonic wave between the transmitter and the receiver of the equipment, it is represented by delta T which is the time in millisecond needed for the sonic wave to travel between the transmitter and the receiver. Equation 2 is used to calculate the porosity from sonic log value as follow (Pirson, 1993):

$$\Phi_s = \frac{(\Delta t - \Delta t_{ma})}{(\Delta t_f - \Delta t_{ma})} \quad (2)$$

Where:

Φ_s = sonic-derived porosity

Δt = interval transit time in the formation (recorder by log)

Δt_f = interval transit time of the formation fluid (saltwater mud = 185 μ sec/ft, fresh water mud 189 μ sec/ft)

Δt_{ma} = interval transit time of matrix (43.5 μ sec/ft, for dolomite)

Determination of Porosity

Total porosity

It is the ratio of total pore volume to the bulk volume using the following equation (Asquith and Gibson, 1982).

$$\Phi N.D = \sqrt{\frac{\Phi N^2 + \Phi D^2}{2}} \quad (3)$$

Where:

ΦN = neutron porosity

ΦD = density porosity

Effective porosity

It means the ratio of connected pores to the total volume of the rock (Bowen, 2003).

$$\Phi e = \Phi t - (1 - V_{sh}) \quad (4)$$

Where:

Φe = is the effective porosity

Secondary porosity

Secondary porosity is the ratio of the pores that created after deposition, it is maybe created by fracturing, dissolution, etc. SPI is the secondary porosity index and can be calculated as follows, (Asquith and Gibson, 1982).

$$SPI = \Phi e - \Phi s \quad (5)$$

Fig. 3 shows the effective porosity and secondary porosity index for well JP-1 and JP-2 for the Jeribe Formation.

Fig. 3. Total and secondary porosity index for well JP-1 and JP-2

Gamma Ray Log

Gamma ray log is used to detect the radioactive elements such as Uranium, Thorium and Potassium, (Pirson, 1993).

Shale volume determination

Shale volume is an important parameter, it should be determined during any interpretation because it affects the porosity and water saturation values. The shale also controls the existence of hydrocarbon (Bassiouni, 1994). As the Jeribe Formation is Tertiary rock, so that, the volume of shale formula used in this study is the Asquith, and Gibson (1982) as follows:

$$V_{sh} = 0.083 \times [2^{(3.7 \times IGR)} - 1] \quad (6)$$

Fig. 4. Volume of shale for wells JP-1 and JP-2

Resistivity Logs

Resistivity log is a basic measurement of reservoirs fluid saturation and is a function of porosity (Schlumberger, 1989).

Fluid and formation analysis

The amount of pore volume in a rock that is occupied by formation water is called water saturation (S_w) and it is represented as a percentage or decimal fraction (Asquith and Keygowski, 2004).

$$S_w = \frac{\text{formation water occupying pores}}{\text{total pore space in the rock}} \quad (7)$$

In this study Archie's equations have been used to estimate water saturation of uninvasion zone (S_w) and water saturation of invasion zone (S_{x_o}) (Archie G. E., 1942):

$$S_w = \left(\frac{a}{\phi^m} \cdot \frac{R_w}{R_t} \right)^{\frac{1}{n}} \quad (8)$$

$$S_{x_o} = \left(\frac{a}{\phi^m} \cdot \frac{R_{mf}}{R_{x_o}} \right)^{1/n} \quad (9)$$

Where:

S_w = Water saturation of uninvasion zone

S_{x_o} = Water saturation of the invasion zone

R_w = Resistivity of water formation

R_t = True formation resistivity

a = Tortuosity factor (assumed to be 1.0)

n = Cementation factor (assumed to be 2.0)

m = Saturation exponent (assumed to be 2.0)

R_{mf} = Resistivity of mud filtrate at formation temperature

R_{x_o} = Resistivity of invasion zone

From saturation of water of uninvasion zone (S_w) and water saturation in the invasion zone (S_{x_o}) the residual hydrocarbon saturation (S_{hr}) and the movable hydrocarbon saturation (S_{hm}) can be estimated from the following equations (Asquith and Krygowski, 2004):

$$S_{hr} = 1 - S_{x_o} \quad (10)$$

$$S_{hm} = S_{x_o} - S_w \quad (11)$$

Where:

S_{hr} = Residual hydrocarbon saturation

S_{hm} = movable hydrocarbon saturation

S_{x_o} = water saturation in the invasion zone

S_w = water saturation of uninvasion zone

To compute hydrocarbon saturation (S_h) that can be defined as the amount of pore volume filled with hydrocarbon (Serra, 1984). Using (Schlumberger, 1987) formula, (S_h) can be obtained.

$$S_h = (1 - S_w) \quad (12)$$

Formation analysis (bulk volume analysis)

Bulk volume of water of uninvasion zone (BVW) can be computed from water saturation (S_w) and porosity (Φ) (Asquith and Gibson, 1982).

$$BVW = S_w * \Phi \quad (13)$$

And bulk volume of water of invaded zone (BVXO) can be computed from the equation below:

$$BVXO = S_{xo} * \Phi \quad (14)$$

Where:

BVW= Bulk volume of water of uninvasion zone

BVXo= Bulk volume of water of invaded zone

Φ = porosity

While bulk volume of moveable hydrocarbon and bulk volume of residual hydrocarbon can be computed from moveable hydrocarbon saturation (S_{hm}) and residual hydrocarbon saturation (S_{hr}) consecutively and porosity (Φ) from the following equation (Asquith and Keygowski, 2004):

$$Bvo = Sh * \Phi \quad (15)$$

Where:

Bvo =Bulk volume of hydrocarbon

Sh= Hydrocarbon saturation

Φ = Porosity

M-N Cross Plot for Mineral Identification

The demonstration procedure of this type of cross plots for mineral identification was presented by Schlumberger. It is a two-dimensional display of all three porosity log responses in complex reservoir rocks, (Schlumberger, 1989).

An (M-N) cross plot can be used for lithology determination and clay minerals classification. Each mineral has unique set of (M, N) values. However,

$$M = \frac{\Delta t_f - \Delta t \log}{\rho_b - \rho_f} \times 0.01 \quad (18)$$

$$N = \frac{\phi_{NF} - \phi_N}{\rho_b - \rho_f} \quad (19)$$

Δt_f = Interval transit time in fluid (189 (m/s) for fresh water 185 (m/s) for salt mud)

Δt = Interval transit time (the log reading)

ρ_b = Formation bulk density (the log reading)

ρ_f = Fluid density (1 (g/cm³) for fresh water or 1.1 (g/cm³) for salt mud)

ϕ_{Nf} = Neutron porosity for fluid =1

ϕ_N = Neutron porosity

The M-N crossplots for the Jeribe Formation, wells JP-1 and JP-2, show that the lithology of the Jeribe Formation consists of dolomitic limestone with some anhydrite (Fig. 5).

Fig. 5. M-N cross plot for JP-1 and JP-2 Jeribe Formation

Density - Neutron Cross Plot for Lithology

The neutron–density cross plot is one of the oldest quantitative interpretation tools. It is used to determine the lithology of a formation (Darwin and Singer, 2008), as in Fig. 6 for well JP-1 and JP-2. From Neutron-Density cross plot, the Jeribe Formation lithology in JP-1 is anhydritic limey dolomite and in JP-2 it is limey dolomite.

Fig. 6. Density-Neutron cross plot for the Jeribe Formation in JP-1 and JP-2

RESULTS AND DISCUSSIONS

Fig. 7 represents computer processed interpretation (CPI) of well JP-1 and JP-2 that have been deduced using Interactive Petrophysics (IP) software:

1. The lithology track: represents the effective porosity (PHIE), percentage of shale (Vshale), and percentage of Matrix.
2. Fluid analysis track: represents the effective porosity (PHIE), water content, movable and residual hydrocarbon. CPI shows that porosity ranges from 1% to 22% in JP-1 and from 1% to 18% in JP-2. Water saturation in JP-1 is about 16% and in JP-2 about 92%. Vshale is about 18% in JP-1 and about 15% in JP-2. Primary porosity is about 5.3% in JP-1 and 4.2% in JP-2. From Density-Neutron and M-N cross plots the lithology of Jeribe Formation is Limey Dolomite.

Fig. 7. CPI analyses of JP-1 and JP-2

CONCLUSIONS

1. Total porosity, effective porosity and secondary porosity have been calculated from neutron, density, and sonic logs. Porosity is about 16% in JP-1 and 13% in JP-2.
2. The porosity of the Jeribe Formation is good in well JP-1 and fair in JP-2 according to Leverson, L. A. (1972).

3. JP-1 produces hydrocarbon while JP-2 produces water because JP-1 is located at the crest of the fold and penetrates the Jeribe Formation at a depth 1190 m while JP-2 is located on the limb of the fold which has a high dip amount and penetrates it at 1405 m.
4. Hydrocarbon saturation vs. water saturation shows that water saturation in the reservoir is 17% in JP-1 as compared with water saturation in JP-2 is 92%.
5. From RHOB-NPHI cross plot, the Jeribe Formation is composed mainly from dolomite and limestone with some anhydrite layers, from M-N cross plots, the mineralogy of the Jeribe Formation is composed mainly from dolomite, calcite and some anhydrite.

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