PETROPHYSICAL EVALUATION FOR THE RESERVOIR UNITS OF NAHR-UMR FORMATION IN THE LUHAIS OIL FIELD SOUTH OF IRAQ

Zainab H.A. Al-Garbawi¹ and Muwafaq F. Al-Shahwan²

¹Ministry of Oil, Basra Oil Company, Basra, Iraq, email: geozain.h77@yahoo.com
²Assis. Prof., Department of Geology, College of Science, University of Basra, Basra, Iraq

Received: 2 November 2018; accepted: 9 December 2018

ABSTRACT

Nahr-Umr Formation is considered as one of the most important formations deposited during the Cretaceous period and it is one of the main producing reservoirs in southern Iraq and neighboring regions, so it was selected to study and evaluate its petrophysical properties (primary, secondary and effective porosity, permeability, water saturation and movable and residual oil saturation) by employing well logs data interpretation (GR, RHOB, NPHI, Dt, Rt, Rxo). The study included results of well logs analysis of three wells from Luhais oil field (Lu-5, Lu-18, and L-36). Depending on the calculated petrophysical properties; the formation was divided into three main reservoir units, the first one is the upper Nahr-Umr reservoir unit (NRA) which was subdivided into four reservoir subunits (S11, S12, S13, S14), the second one is the middle Nahr-Umr reservoir unit (NRB) which was subdivided into three reservoir subunits (S21, S22, S23), and the third one is the lower Nahr-Umr reservoir unit (NRC), that was subdivided into three subunits (S31, S32, S33, S34, S35). The performance of the reservoir subunits in terms of their economic productivity was determined. The best of these reservoir subunits in most of the study wells were (S11, S14, S23, S31, and S32).

Keywords: Nahr-Umr Formation; BVW; performance of flow units; Petrophysical evaluation

INTRODUCTION

Several studies have been carried out on the Nahr-Umr Formation in south Iraq. Ressan (1998) divided the formation into two main members, the first one was shale member which includes one reservoir unit, and the second member was sand member that includes four reservoir units. Sahi et al. (2017) divided the formation into three
main units (upper, middle, lower), each of the upper and the lower main units subdivided into one reservoir subunit, but the middle main unit subdivided into four reservoir subunits. While in this study we divided the Nahr-Umr Formation into three main units, which subdivided into reservoir subunits. Petrophysical properties evaluation of oil reservoirs by using well log data is important to determine and assess the hydrocarbons presence, and plays a crucial role in determining the oil reservoirs production. Petrophysical properties such as, porosity, permeability, resistivity and water saturation are necessary for the assessment of reservoirs. The main goal of the study to evaluate the petrophysical properties of Nahr-Umr Formation and to determine the performance of reservoir subunits.

Luhais oil field is located in the southwestern part of Iraq of about 105 Km west of Basrah city, and 100 Km south-west of the North Rumaila oil field between latitudes (E: 68000 – 677000 m) and (N: 3368000 – 3364000 m) (Fig. 1). The length of the field is of about 20 Km, while the width is 10 Km (Sahi et al., 2017). Luhais oil field is one of the promising fields within the Mesopotamian basin on the stable shelf, it was discovered in 1961 and started production in 1970, the stratigraphic column consists of clastic and carbonate sedimentary rocks. The base rocks is formed Sulay Formation, and that oil exist mainly in the Yammama, Zubair and Nahr-Umr formations (Aqrawi el at, 2010). At the top of the Nhar-Umr Formation the structure appears to be Amebian shape, and has no clear axis (Sahi et al., 2017) (Fig. 1). The eastern side of the field is more inclined than the west side, where the dip of the west side is one degree while the eastern side is diping 2.5° (Ressan, 1998) (Fig. 1).

**METHODOLOGY AND MATERIALS**

CPI was performed using Techlog software to estimate the properties of reservoir units, and determine the reservoir units performance depending well logs data (Spontaneous potential (SP), Gamma Ray Log (GR), Density Log (RHOB), Neutron Log (NPHI), Sonic log (Δt), Caliper log, Resistivity Logs (Rxo, Ri, Rt) for wells (Lu-5, Lu-18, Lu-36). To determine the petrophysical properties of the Nahr-Umr Formation, it is necessary to evaluate petrophysical parameters as follows:
**Shale volume**

Shale volume can be calculated from SP log, Neutron, density logs and GR log, which it is more accurate than the above mentioned ways. Calculation of the GR index is the first step needed to determine the volume of the shale from a gamma ray log:

\[
I_{GR} = \frac{GR_{log} - GR_{min}}{GR_{max} - GR_{min}}
\]

Where:

- \( I_{GR} \): gamma rays index
- \( GR_{log} \): gamma ray reading of formation
- \( GR_{min} \): minimum gamma ray (clean sand)
- \( GR_{max} \): maximum gamma ray (shale).

The GR log has several nonlinear empirical responses as well as a linear response. The nonlinear responses are based on geographic area or formation age. (Asquith et al., 2004). The nonlinear responses, in increasing optimism (lower calculated shale volume), is:

Larionov (1969) for older rocks (Asquith et al., 2004):

\[
V_{sh} = 0.33 \times \left(2^{2(I_{GR})} - 1\right)
\]
Hilchie (1978) suggests that for shale to significantly affect log-derived water saturation, shale content must be greater than 10 to 15%.

**Porosity determination**

Total porosity for the Nahr-Umr Formation was determined directly from neutron log and indirectly through the RHOB using equation (3) in the depths where the proportion of shale was less than (10%) (Dressr Atlas, 1979).

\[
\phi_D = \frac{\rho_{ma} - \rho_f}{\rho_{ma} - \rho_b} 
\]

Where:
\(\phi_D\): Porosity derived from the density log.
\(\rho_{ma}\): matrix density \{2.68 gm/cm\(^3\) for sandstone (Schlumberger, 1998)\}.
\(\rho_b\): formation bulk density.
\(\rho_f\): density of the fluid \{1.1 g/cm\(^3\) for the saline water Shlebr (Schlumberger, 1998)\}.

In the zones where shale volume more than (10%), the equation (4) can be used to remove shale effective.

\[
\phi_{Dc} = \left[\frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_f}\right] - \left[\frac{\rho_{ma} - \rho_{sh}}{\rho_{ma} - \rho_f}\right] \cdot V_{sh} 
\]

Where:
\(\rho_{sh}\): density of nearby shale

The equation by Tiab and Donaldson (1996) can be used at the depth intervals where the shale volume more than 10%:

\[
\phi_{Nc} = \phi_N - (\phi_{Nsh} \cdot V_{sh}) 
\]

Where:
\(\phi_N\): porosity derived from neutron log.
\(\phi_{Nc}\): porosity derived from neutron log corrected the impact of shale.
\(\phi_{Nsh}\): neutron porosity of the adjacent shale.

The primary porosity can be calculated from the sonic log by linear relationship known as the Wyllie time-average equation (Wyllie et al., 1958), which is used in clean depths.

\[
\phi_s = \frac{\Delta t_{log} - \Delta t_{ma}}{\Delta t_f - \Delta t_{ma}} 
\]

Where:
\(\phi_s\): sonic- derived porosity.
Δt log: interval transit time in the formation.
Δt_{ma}: interval transit time in the matrix (55.5 μsec/ft (Schlumberger, 1998))
Δt_{f}: interval transit time in the fluid in the formation (freshwater mud = 189 μsec/ft; saltwater mud = 185 μsec/ft (Schlumberger, 1998)).

For the zones containing shale more than (10%), the equation (7) can be used to remove shale effect.

\[ \phi_{sc} = \left[ \frac{\Delta t_{log} - \Delta t_{ma}}{\Delta t_f - \Delta t_{ma}} \right] - \left[ \frac{\Delta t_{sh}}{\Delta t_f - \Delta t_{ma}} \right] * V_{sh} \]  .................................................... 7

\( \Delta t_{sh} \) : the interval transit time in nearby shale (usec/ft).

The effective porosity was calculated for the intervals that have shale content less than 10% according to equation (8), and that have shale content more than 10% according to equation (9)

\[ \phi_{N.D} = \frac{\phi_N + \phi_D}{2} \]  .................................................... 8

\[ \phi_{N.Dc} = \frac{\phi_{Nc} + \phi_{Dc}}{2} \]  .................................................... 9

Where:
\( \phi_{N,D} \): effective porosity calculated from neutron and density logs.

The secondary porosity was calculated for the depth intervals that have shale content less than 10% by equation (10), and that have shale content more than 10% by equation (11) (Schlumberger, 1997)

\[ SPI = \phi_{N.D} - \phi_s \]  .................................................... 10

\[ SPI = \phi_{NDc} - \phi_{Sc} \]  .................................................... 11

Where:
SPI: Coefficient of secondary porosity index.

**Determination of Water saturation**

Water saturation was determined in the invaded and uninvaded zones at depths where the shale content is less than (15%) by using Archie's equation (1942):

\[ S_w = \left( \frac{F * R_w}{R_t} \right)^{1/n} \]  .................................................... 12

\[ S_{xo} = \left( \frac{F * R_{mf}}{R_{xo}} \right)^{1/2} \]  .................................................... 13
Where:

$S_w$: Water saturation in the uninvaded zone; $S_{xo}$: water saturation in the invaded zone.

$R_t = \text{true or deep resistivity of uninvaded zone.}$

$R_w = \text{resistivity of the formation water.}$

$R_{mf} = \text{resistivity of mud filtrate at formation temperature.}$

$R_{xo} = \text{resistivity of flushed zone.}$

$n = \text{saturation exponent } = 2.$

$F = \text{formation factor.}$

The formation factor was determined by the following formula (Archie, 1942):

$$ F = \frac{a}{\phi^m} \quad \ldots \ldots \ldots \ldots \ldots \quad 14 $$

Where:

$a$: tortuosity factor $= 0.81$

$m$: cementation factor $= 2$

The parameters $a$, $m$, $n$ were calculated by the pickett plot method (Asquith et al., 2004).

At the depths where the content of the shale is more than (10%), water saturation was determined by Simandoux (1963) (Asquith et al., 2004). This equation is considered the most accurate equation due to its scientific efficiency, and it has been proven by experience that it is better than others and used in our oil fields:

$$ S_w = \left[ \frac{0.4 \times R_w}{\phi^2} \right] \times \left[ \left( \frac{V_{sh}}{R_{sh}} \right)^2 + \left( \frac{5 \times \phi^2}{R_t \times R_w} \right) \right] - \left( \frac{V_{sh}}{R_{sh}} \right) \quad \ldots \ldots \ldots \quad 15 $$

Where: $R_{sh} = \text{true or deep resistivity of nearby shale.}$

**Calculation of bulk volume water and hydrocarbon movability**

The bulk volume water in the uninvaded zone (BVw) and in the invaded zone (BVxo) is calculated by equations (16, 17) (Schlumberger, 1998):

$$ BV_w = S_w \times \phi_{N,D} \quad \ldots \ldots \ldots \ldots \ldots \quad 16 $$

$$ BV_{xo} = S_{xo} \times \phi_{N,D} \quad \ldots \ldots \ldots \ldots \ldots \quad 17 $$

The bulk hydrocarbon volume (BVh) was calculated from equation (18) (Schlumberger, 1998).

$$ BV_h = S_h \times \phi_{N,D} \quad \ldots \ldots \ldots \ldots \ldots \quad 18 $$
Movable hydrocarbon saturation (MOS) can be calculated from the equation of Spain (1992):

\[
\text{MOS} = S_{xo} - S_w
\]

**Quik look methods interpretation**

There are several methods used to determine hydrocarbon-bearing formation and to indicate hydrocarbon movability as following:

**Ratio method:** The ratio method used to identify hydrocarbon from the difference between \(S_{xo}\) and \(S_w\) as equation 20:

\[
\frac{S_w}{S_{xo}} = \left[\left(\frac{R_{xo}}{R_t}\right) / \left(\frac{R_{mf}}{R_w}\right)\right]^{2}
\]

Where: \(\frac{S_w}{S_{xo}} = \text{moveable hydrocarbon index (MHI)}\)

When the \(S_w/S_{xo}\) value is equal to 1 (i.e., \(S_w = S_{xo}\) or its curves are identical) in the permeable zone, the zone will produce water or be non-productive regardless of water saturation. If the value of \(S_w/S_{xo}\) is less than (1), this indicates that the range is permeable and contains some hydrocarbons and the hydrocarbons have been flushed or washed by invasion. Thus, the zone contains a hydrocarbon product as shown in

**Rxo/ Rt:** The Rxo/Rt ratio can be used to identify the hydrocarbon bearing formations and an indicator of the moveable hydrocarbon. If both (Sp) and (Rxo/ Rt) curves are coincide in a permeable zone, then the zone most probably produces water. If the Rxo/ Rt is lower than SP then the zone should produces hydrocarbons. The value of Rxo/ Rt less than the amplitude of the SP indicate the presence of moveable hydrocarbons

**R_o and R_t (side by side technique):** When the \(R_o\) and \(R_t\) curves are corresponds, the zone is water-bearing but when the \(R_t\) value is greater than the value of \(R_o\) (i.e., the \(R_t\) curve deviation to the right of the \(R_o\)-curve) the zone is hydrocarbons-bearing and with the deflection increase of the \(R_t\) curve to the right of the \(R_o\) curve the hydrocarbon saturation increases.

**Determination of permeability**

The permeability was calculated by using the Wyllie and Rose formula (Wyllie and Rose, 1950)) as one of the most accurate methods used according to Equation (21) and chart (Fig. 2), because the study wells did not contain routine core analysis, the
permeability values calculated in this method were compared with the results of core analysis of other fields.

\[ K = \left[ C \times \left( \frac{\emptyset^3}{S_{wirr}} \right) \right]^2 \]

Where:
- \( K \) = permeability, \( \emptyset \) = porosity
- \( C \) = constant, its value equal 250 for medium oil and 79 for dry gas.
- \( S_{wirr} \) = irreducible water saturation.

The chart presented in Figure (2) used to estimate permeability and Bulk volume water (BVW), where the y-axis represents the value of irreducible water saturation (\( S_{wirr} \)), while the x-axis is the porosity value (\( \emptyset \)). The dark curves represent the permeability (md) and the light curves hyperbolic curves (\( S_{wirr} \times \emptyset \)) represent the lines of equal to the value of the bulk volume water (BVW). The permeability of 0.1 md is the minimum for oil production.

![Chart of porosity (Ø) versus irreducible water Saturation (Swirr) for estimating permeability and determining bulk volume water (Schlumberger, 1998) (Chart K-3)](chart.png)
**Relationship between Permeability and porosity**

Figure (2) represents the relationship between porosity and irreducible water saturation (Swirr) to determine the productive zones. If the values for bulk volume water (BVW = $\emptyset \times Swirr$) constant or very close to constant, the zone at irreducible saturation (i.e., produces oil without water), when the values for bulk volume water (BVW) values are slightly different the zone produces oil with water. But when the values for bulk volume water (BVW) significantly different the zone produces only water (Asquith et al., 2004).

The relationship between porosity and permeability (Fig. 3) was used to determine the performance of flow units. Martin et al. (1997) used the $\{r35 = \text{pore throat radius at (35%) mercury saturation}\}$ to identify flow units. The flow units are classified by the size of the pores throats using the designations (Fig. 3), of: Megaport $>$10 micron (tens of thousands of barrels of oil per day), macroport (2 – 10 micron) (thousands of barrels of oil per day), mesoport (0.5 – 2 micron) (hundreds of barrels of oil per day) and microport ($<$ 0.5 micron) (non reservoir).

![Fig. 3: Empirical model based on regression attributed to Winland, from Kolodzie (1980) Labls for four ranges of r35 a taken from Martin et al. (1977) in (Martin et al., 1997)](image_url)
RESULTS AND DISCUSSION

According to the results of the computer process interpretation (CPI), the formation is divided into three main reservoir unit (Fig. 7, 8 and 9):

Upper Nahr-Umr reservoir unit (NRA)

This unit included four reservoir subunits (S11, S12, S13 and S14) Superated by barrier of shale (B11, B12, B13 and B14) (Fig. 10). These reservoir subunits were characterized by different reservoir properties in the correlation section between the wells (west-east). The Table (1) show that the reservoir subunit (S11) has medium reservoir characteristics, at the well (Lu-5) west of the field, where most of its production was water only and its flow unite was (Mesoport) and then improves in the wells (Lu-36, Lu-18) which produces was oil without water and its flow unit was (Macroport – Megaport). The reservoir subunit (S12) has low permeability and good porosity in the wells (Lu-5, Lu-18), while the properties of this subunit improves significantly in the well (Lu-36), and its main production was water only in all the section wells and its flow unit was (Mesoport – Megaport). The reservoir subunit (S13) was varied in their reservoir characteristics as they improved greatly in the well (Lu-36) where most of its production was oil without water and its flow unit (Macroport – Megaport) (i.e., good-very good reservoir). The reservoir subunit (S14) is improved in the middle of the field in the wells (Lu-18, Lu-36), they are considered as medium-very good reservoirs, and produces oil without water and its flow unit was (Mesoport – Megaport), whereas its characteristics are less to the west of the field in the well (Lu-5), where most of its production was water only and its flow unit was (Mesoport) as illustrated in (Fig. 4).

Middle Nahr-Umr reservoir unit (NRB)

This unit included three subunit reservoir (S21, S22 and S23) Superated by barrier of shale (B21, B22, B23 and B4) (Fig. 10). The Table (2) show that the subunit (S21) reservoir properties was medium in the well (Lu-36), and its productivity was oil without water and its flow unit (Macroport) (i.e., good reservoir unit). In the west and middle of the field at wells (Lu-5, Lu-18) the reservoir characteristics are less and productivity was water only, flow unit was (Mesoport – Macropor). The subunit (S22) had excellent characteristics at well (Lu-36), its productivity was oil without water and its flow unit was (Megaport), whereas it was of medium properties in the west of the field at well (Lu-5), its productivity was water only, its flow unit was (Mesoport –
Macroport). The subunit reservoir (S23) is considered the best reservoir subunit of the Middle reservoir Nahr-Umr reservoir unit. The Middle Nahr-Umr reservoir unit was had a very good reservoir properties in all the wells of the section, its improving at the well (Lu-36), whereas its productivity was oil without water and the flow unit was (Mesoport – Macroport) as shown in Figure (5).

**Lower Nahr-Umr reservoir unit (NRC)**

This unit included five reservoir subunits (S31, S32, S33, S34 and S35) Superated by barrier of shale (B31, B32, B33, B34 and B35) (Fig. 10). Table (3) Show that the reservoir subunits (S31, S32) in the section wells were characterized by medium to good reservoir characteristics that improve at well (Lu-36), their productivity was oil without water and their flow unit was (Macroport – Megaport) at the wells (Lu-18, Lu-36), while their productivity was water only and their flow unit was (Mesoport) at the well (Lu-5). The reservoir characteristics for other units are less improved, as their productivity was water only and their flow unit was (Microport – Macroport) except the subunit (S35) its productivity was oil without water and its flow unit was (Macroport – Megaport) at well (Lu-36) as demonstrated in Figure (6).

Table 1: shows the petrophysical properties of the reservoir subunits of the upper Nahr-Umr reservoir unit in the study wells

<table>
<thead>
<tr>
<th>Well No.</th>
<th>Petrophysical properties</th>
<th>S11</th>
<th>S12</th>
<th>S13</th>
<th>S14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lu-5</td>
<td>Ø (%)</td>
<td>0.20</td>
<td>0.15</td>
<td>0.19</td>
<td>0.16</td>
</tr>
<tr>
<td></td>
<td>K (md)</td>
<td>30.173</td>
<td>4.53</td>
<td>39.33</td>
<td>23.79</td>
</tr>
<tr>
<td></td>
<td>Sh (%)</td>
<td>0.38</td>
<td>0.30</td>
<td>0.63</td>
<td>0.50</td>
</tr>
<tr>
<td></td>
<td>Vsh (%)</td>
<td>0.17</td>
<td>0.24</td>
<td>0.28</td>
<td>0.28</td>
</tr>
<tr>
<td></td>
<td>Thickness (m)</td>
<td>13.3</td>
<td>4</td>
<td>3</td>
<td>13</td>
</tr>
<tr>
<td>Lu-36</td>
<td>Ø (%)</td>
<td>0.24</td>
<td>0.23</td>
<td>0.26</td>
<td>0.24</td>
</tr>
<tr>
<td></td>
<td>K (md)</td>
<td>115.62</td>
<td>383.45</td>
<td>334.23</td>
<td>177.04</td>
</tr>
<tr>
<td></td>
<td>Sh (%)</td>
<td>0.55</td>
<td>0.60</td>
<td>0.64</td>
<td>0.62</td>
</tr>
<tr>
<td></td>
<td>Vsh (%)</td>
<td>0.05</td>
<td>0.19</td>
<td>0.16</td>
<td>0.19</td>
</tr>
<tr>
<td></td>
<td>Thickness (m)</td>
<td>9.48</td>
<td>2.55</td>
<td>11</td>
<td>17.7</td>
</tr>
<tr>
<td>Lu-18</td>
<td>Ø (%)</td>
<td>0.22</td>
<td>0.20</td>
<td>0.17</td>
<td>0.14</td>
</tr>
<tr>
<td></td>
<td>K (md)</td>
<td>147.59</td>
<td>6.20</td>
<td>17.17</td>
<td>2.24</td>
</tr>
<tr>
<td></td>
<td>Sh (%)</td>
<td>0.69</td>
<td>0.13</td>
<td>0.44</td>
<td>0.44</td>
</tr>
<tr>
<td></td>
<td>Vsh (%)</td>
<td>0.03</td>
<td>0.08</td>
<td>0.23</td>
<td>0.24</td>
</tr>
<tr>
<td></td>
<td>Thickness (m)</td>
<td>7.85</td>
<td>9</td>
<td>8.4</td>
<td>11.6</td>
</tr>
</tbody>
</table>
Table 2: shows the petrophysical properties of the reservoir subunits of the middle Nahr-Umr reservoir unit in the study wells

<table>
<thead>
<tr>
<th>Well No.</th>
<th>Petrophysical properties</th>
<th>S21</th>
<th>S22</th>
<th>S23</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lu-5</td>
<td>Ø (%)</td>
<td>0.15</td>
<td>0.16</td>
<td>0.23</td>
</tr>
<tr>
<td></td>
<td>K (md)</td>
<td>1.17</td>
<td>34.12</td>
<td>582.15</td>
</tr>
<tr>
<td></td>
<td>$S_h$ (%)</td>
<td>0.29</td>
<td>0.67</td>
<td>0.64</td>
</tr>
<tr>
<td></td>
<td>$V_{sh}$ (%)</td>
<td>0.25</td>
<td>0.21</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>Thickness (m)</td>
<td>2.75</td>
<td>10</td>
<td>19.4</td>
</tr>
<tr>
<td>Lu-36</td>
<td>Ø (%)</td>
<td>0.18</td>
<td>0.24</td>
<td>0.30</td>
</tr>
<tr>
<td></td>
<td>K (md)</td>
<td>0.376</td>
<td>2204.21</td>
<td>16823.97</td>
</tr>
<tr>
<td></td>
<td>$S_h$ (%)</td>
<td>0.61</td>
<td>0.79</td>
<td>0.86</td>
</tr>
<tr>
<td></td>
<td>$V_{sh}$ (%)</td>
<td>0.16</td>
<td>0.07</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td>Thickness (m)</td>
<td>3.8</td>
<td>7.4</td>
<td>7.5</td>
</tr>
<tr>
<td>Lu-18</td>
<td>Ø (%)</td>
<td>0.15</td>
<td>---</td>
<td>1.18</td>
</tr>
<tr>
<td></td>
<td>K (md)</td>
<td>6.63</td>
<td>---</td>
<td>148.49</td>
</tr>
<tr>
<td></td>
<td>$S_h$ (%)</td>
<td>0.41</td>
<td>---</td>
<td>0.80</td>
</tr>
<tr>
<td></td>
<td>$V_{sh}$ (%)</td>
<td>0.18</td>
<td>---</td>
<td>0.09</td>
</tr>
<tr>
<td></td>
<td>Thickness (m)</td>
<td>4</td>
<td>---</td>
<td>10.75</td>
</tr>
</tbody>
</table>

Table 3: shows the petrophysical properties of the reservoir subunits of the lower Nahr-Umr reservoir unit in the study wells

<table>
<thead>
<tr>
<th>Well No.</th>
<th>Petrophysical properties</th>
<th>S31</th>
<th>S32</th>
<th>S33</th>
<th>S34</th>
<th>S35</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lu-5</td>
<td>Ø (%)</td>
<td>0.24</td>
<td>0.22</td>
<td>0.22</td>
<td>0.21</td>
<td>0.19</td>
</tr>
<tr>
<td></td>
<td>K (md)</td>
<td>27.92</td>
<td>10.67</td>
<td>8.32</td>
<td>8.18</td>
<td>5.19</td>
</tr>
<tr>
<td></td>
<td>$S_h$ (%)</td>
<td>0.18</td>
<td>0.05</td>
<td>0.00</td>
<td>0.03</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td>$V_{sh}$ (%)</td>
<td>0.02</td>
<td>0.02</td>
<td>0.01</td>
<td>0.01</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>Thickness (m)</td>
<td>4.6</td>
<td>13</td>
<td>19</td>
<td>45</td>
<td>25</td>
</tr>
<tr>
<td>Lu-36</td>
<td>Ø (%)</td>
<td>0.25</td>
<td>0.26</td>
<td>0.26</td>
<td>0.22</td>
<td>0.22</td>
</tr>
<tr>
<td></td>
<td>K (md)</td>
<td>9558.65</td>
<td>124.22</td>
<td>58.58</td>
<td>22.16</td>
<td>16.90</td>
</tr>
<tr>
<td></td>
<td>$S_h$ (%)</td>
<td>0.80</td>
<td>0.49</td>
<td>0.41</td>
<td>0.33</td>
<td>0.33</td>
</tr>
<tr>
<td></td>
<td>$V_{sh}$ (%)</td>
<td>0.04</td>
<td>0.03</td>
<td>0.01</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>Thickness (m)</td>
<td>11.3</td>
<td>13.2</td>
<td>14</td>
<td>58</td>
<td>19</td>
</tr>
<tr>
<td>Lu-18</td>
<td>Ø (%)</td>
<td>0.22</td>
<td>0.21</td>
<td>0.22</td>
<td>0.20</td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td>K (md)</td>
<td>564</td>
<td>373.28</td>
<td>8.32</td>
<td>4.62</td>
<td>5.90</td>
</tr>
<tr>
<td></td>
<td>$S_h$ (%)</td>
<td>0.86</td>
<td>0.81</td>
<td>0.03</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>$V_{sh}$ (%)</td>
<td>0.04</td>
<td>0.02</td>
<td>0.01</td>
<td>0.01</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>Thickness (m)</td>
<td>5.5</td>
<td>22</td>
<td>4</td>
<td>86</td>
<td>16</td>
</tr>
</tbody>
</table>
Fig. 4: Charts of ($\bar{\Omega}$) versus (Swirr) for estimating permeability and determining (BVW) and Empirical model for four ranges of r35 for reservoir subunits of upper Nahr-Umr reservoir unit for well (Lu-5)
Fig. 5: Charts of ($\bar{\Omega}$) versus (Swirr) for estimating permeability and determining (BVW) and Empirical model for four ranges of r35 for reservoir subunits of middle Nahr-Umr reservoir unit for well (Lu-5)
Fig. 6: Charts of (Ø) versus (Swirr) for estimating permeability and determining (BVW) and Empirical model for four ranges of r35 for reservoir subunits of lower Nahr-Umr reservoir unit for well (Lu-5)
Fig. 7: CPI of Nahr Umr Formation in Luhais field (Lu-36)

Fig. 8: CPI of Nahr-Umr Formation in Luhais field (Lu-18)
Fig. 9: CPI of Nahr-Umr Formation in Luhais field (Lu-36)

Fig. 10: Correlation Profile of reservoir units and subunits for Nahr-Umr Formation in (Lu-5, Lu-36, and Lu-18)
CONCLUSIONS

- Based on the interpretation of well logs and the description of cores in addition to the relationships between porosity and permeability, Nahr-Umr Formation can be divided into three main reservoir units (Upper Nahr-Umr reservoir unit (NRA), middle Nahr-Umr reservoir unit (NRB) and lower Nahr-Umr reservoir unit (NRB)). Upper Nahr-Umr reservoir unit (NRA) divided into four reservoir subunits (S11, S12, S13, S14), the middle Nahr-Umr reservoir unit (NRB) divided into three reservoir subunits (S21, S22, S23) and lower Nahr-Umr reservoir unit (NRC) divided into five reservoir subunits (S31, S32, S33, S34, S35).

- The best of these reservoir subunits in most of the study wells (S11, S14, S23, S31 and S32): these reservoir subunits with good petrophysical specifications and producing oil without water and the flow units were (Macroport - Megaport), (Mesoport – Macroport), (Mesoport – Macroport), (Macroport – Megaport) respectively (i.e., these Subunits are considered economical flow units).

REFERENCES


