Reservoir Properties of the Upper Sand Member of the Zubair Formation in North Rumaila Oil Field

Hadeer Al-Aradi¹, Fahad Alnajm² and Amer Al-Khafaji³,*

¹ Gifted School, Basra Education Department, Ministry of Education, Basra, Iraq
² Department of Geology, College of Science, University of Basra, Basra, Iraq
³ Applies Geology Department, College of Science, University of Babylon, Hilla, Iraq

Abstract

The Zubair Formation is main prolific reservoirs in the Rumaila oilfield in southern Iraq. The petrophysical assessment of the Zubair Formation was carried out using a suite of open-hole logs from eight wells along with the Rumaila North oil fields, in Basra. Based on the neutron, density and Gamma Ray logs, the Upper Sand Member of the Zubair Formation is divided into the alternate units of the sand and shale and defining their boundaries. Based on the obtained results, the Upper Sand Member was divided in to three main pay units: AB, DJ, and LN, separated by two insulating shale units designated C and K. The unit DJ was subdivided into four secondary reservoir units: D, F, G, H, and the LN unit, which is split into L, M, and N. High porosity, high oil saturation and a high net-to-gross ratio were found in the petrophysical investigation. The porosity types are good (from 15 to 20%), very good (20-25%) and excellent (more than 25%) except wells R-559 and R-256, which has medium permeability, all the wells have good to excellent permeability. The net pay for the reservoir unit thickness ranges from 5 to 59m in all wells, resulting in significant hydrocarbon productivity due to strong hydrocarbon saturation, good effective porosity, and low shale volume.

Keywords: North Rumaila Oilfield; Zubair reservoir; Petrophysics properties; Net pay; Upper Sand Member; South Iraq

1. Introduction

Rumaila oilfield is a super-giant oil field in Basra Mesopotamian Basin, southern Iraq, around 50 kilometers west of Basra and 32 kilometers from the Kuwait border. It has estimated reserves of 17 billion barrels (Beydoun, 1988). The oilfield was discovered in the year 1953 by the Basrah Petroleum Company (BPC) and is regarded as the world's biggest oilfield ever discovered in Iraq, and the third supergiant oilfield in the world. (Christopher, 2010). The West Qurna, North Rumaila, and South Rumaila domes are detached by shallow saddles in the supergiant field (Fig.1).

Rumaila North oilfield has two main producing reservoirs with great remaining unproduced intervals resources. The two main productive reservoirs are the Upper Cretaceous (Cenomanian-Turonian) shallow marine carbonate Mishrif Formation and the second is Lower Cretaceous (Hauterivian-Aptian) Zubair Formation (Owen & Nasr, 1958). This study will focus on the Aptian Upper Sandstone Member (USSM) of the Zubair Formation, which is thought to be the main producing unit in

DOI: 10.46717/igj.55.1C.8Ms-2022-03-27
the North Rumaila Oilfield in southern Iraq (Aqrawi et al., 2010), and to define its reservoir units using bore-hole log data, as well as to evaluate the hydrocarbon potential of lithological units predicated on petrophysical properties.

Fig. 1. Location map of studied area showing oil fields, southern Iraq, modified from Al-Khafaji et al. (2020) and Wells et al. (2019)

The aim of the study is to re-evaluate the reservoir of the Upper Sandstone Member of the Zubair Formation, in Rumaila North oil field, determine the reservoir units, and calculate the petrophysical parameters, and consequently the reservoir unit’s evaluation.

2. Geological and Stratigraphic Setting

The North Rumaila Oilfield is located within the Zubair sub-zone, this sub-zone is distinguished by the presence of several longitudinal folds. These fold tendencies are North-South and NW to SE, containing huge oil reservoirs in Basra province, and are finally enclosed in Late Cretaceous, with linear and narrow anticlines (Jassim & Goff, 2006). The Zubair Formation deposited in the Early Cretaceous during the AP8 sedimentary Cycle (Thamama Group), and during Late Tithonian-Aptian secondary cycle (Barremian - Aptian (131-113 Ma)). The formation extends regionally in Iraq, Kuwait, Saudi Arabia, Iran and Syria, and is a succession of generally oil-producing sandstone and shale units (Harris et al., 2012). In the Zubair oil field, the typical section of the Zubair Formation was determined in the Zu-24 well, with a thickness of 389.33m divided into five members. These five members of the formation were found fixed and specific in the northern Rumaila field and extending to the West Qurna field, and they represent different stages of the sedimentary history of the field (Mustafa, 1973).

The Zubair Formation in general consists of siltstone, alternating shale, and sandstone. In the type section, the Formation is divided into five lithological Members composed of sand and shale. These Members are Upper Shale (USM), Upper Sandstone (USSM), Middle Shale (MSM), Lower Sandstone (LSSTM), and Lower Shale (LSM) (Fig. 2). The shale proportion in the formation rapidly decreases to the Southwest, while the sandstone decreases to the northeast (Jassim & Goff, 2006), (Wells et al., 2019).
The overall Zubair Formation was formed through the deposition of interbedded shales and sandstone in delta and fluvial settings (Harris et al., 2012) (Al-Muhailan et al., 2013). The Upper Sandstone Member was deposited in the tidal/estuarine environment where sand channels accumulate and spread everywhere through the formation (Azim et al., 2019). However, the sandstone bottom was forged in an environment dominated by a fluvial/mouth bar-dominated environment (Harris et al., 2012). The Zubair Formations in southern Iraq were deposited by an environment dominated by a fluvial-dominated and the delta was affected by tides during a period of increased sediment supply from behind the coastal areas.

3. Materials and Methods

The purpose of this work is to create a precise stratigraphic section, sedimentary framework, and petrophysical properties for the Upper Sandstone Member of the Zubair Formation, in Rumaila North oil field, south Iraq. The method is based on combining wire log data and their interpretations with based on geological data and core description data provided from the Basra Oil Company. Along with the North Rumaila structure, eight wells were chosen to investigate the Lower Cretaceous Zubair reservoir properties and estimate hydrocarbon potential; R-152, R-167, R-172, R-181, R-249, R-256, R-554, and R-559 (Fig.3).
Log data were quantitatively and qualitatively processed and proved comparable for petrophysical evaluation. Because wireline logging allows for the determination of the composition and physical characterization of the rocks surrounding the well, it enables a proper technique for investigating the subsurface at a lower cost.

4. Results and Discussion

The reservoir, in general, is the unit zone, which is of economic relevance because it provides storage capacity for hydrocarbons and water. Porosity, permeability, and reserved economic hydrocarbon must all be present in a good reservoir unit (Ellis, 2007). Many petrophysical properties, such as porosity, permeability, Shale volume, water saturation is determined for each well in the examined oil field, and the full interpretation of each well is analyzed separately. When conducting a quantitative interpretation of the data of the well logs, several factors that affect the response of the logs must be taken into account, including the size of the hole, the volume of clay, the thickness of the layer, and others. Therefore, several corrections must be made before evaluating the formation. In this study, the petrophysical characterization of the formation were calculated by applying their equations in Excel, such as porosity (total, effective and secondary), shale volume Vsh, water and hydrocarbon saturation Sw, Sh, total water volume BWV and total hydrocarbon volume BVO (Aversana, 2011). Thus, it was possible to divide the reservoir formation in these wells into several units and compare them to find out which is the best reservoir and in which direction the petrophysical characteristics improve, which leads as a result to the prediction of the best sites for drilling and production.

4.1. Qualitative analysis of the Upper Sandstone Member

4.1.1. Identification of lithology and prospect reservoir units

The gamma-ray log shows a low response in front of clean sandy rocks (less than 30 API) and a high response in front of shale intervals (70-150), with the average values (30-70) referring to dirty sand layers, while the low porosity values (less than 5%) indicate to the tight rocks (Fig.4A). The neutron
and density log, on the other hand, responds to shale and dirty sand by recording an increase in neutron porosity and medium density, but the neutron porosity is lower than neutron porosity of Shale in front of sand rocks as depicted in (Fig.4B). The data from the wells show that their lithology was between clean sand, Dirty sand and shale with just a small amount of tight sand found.

**Fig.4.** Examples of relationship between GR & ΦN well logs (A) and Relationship between Density & ΦN well logs (B) of the R-172 well, used to determine the lithology of the USSM of Zubair Formation

### 4.1.2. Determination of the permeable and impermeable layers

The boundaries and thickness of the permeable and impermeable layers were determined using caliper and Sp log. zones of a mud cake (permeable zones) are indicated by low caliper log readings smaller than the diameter of the well, whereas high caliper log readings more than the diameter of the well indicate areas of collapse and cavitation's, which occur mainly of the Shale (Impermeable Layers). (Hilchie, 1978).

In case of deviation in the SP log from the Shale Base Line (Sh. B. L), indicate permeable layers. The deviation is to the left because Rmf > Rw, which is the common case in all wells. Maximum deflection of the SP log indicates the presence of a clean sand layer that has been saturated with water SSP (Fig.5B). The presence of the gas, in addition lithology can be demonstrated using the relationship between the neutron φ(N) and Sonic / Acoustic log. (Fig.5A).

**Fig.5.** (a): Relationship between Sonic & ΦN well logs, (b): Relationship between SP & ΦN well logs show the permeable and Impermeable layers

### 4.1.3. Determination of the hydrocarbons and water-bearing zones

The resistance is a function of the type and quantity of the fluid, so these zones were determined using the resistivity log and the relationship between Rxo, which denotes areas near the wellbore (invaded zone), Rt, which stands for Un Invaded Zone, and Ri, which denotes the transitional zone between them. The relationship between GR and Rt, Rt and N log also gives the amount of hydrocarbon saturation and water saturation in addition to the Source Rocks as shown in (Fig.6B, and 6D). Through the relationship between Rt and SP (Fig.6A) and the relationship between GR and Rt (Fig. 6C), Rt and
Rxo (Fig. 6B), Rt and N log (Fig. 6D), found that most of the reservoir layers in all wells contain a high percentage of hydrocarbons and a small percentage contain water except for the R-167 well, which appears to contain a large proportion of water due to its position in the crest of structure.

Fig. 6. Examples of many cross plots of (a) The relationship between Rt and Sp, and (b) the relationship between Rt and Rxo, displaying the percentage of high hydrocarbon-bearing permeable area. (c) The relationship between GR and Rt, and (d) the relationship between Rt & N log showing the amount of hydrocarbon saturation and water saturation in addition to Source Rocks in R-172 well.

According to the above, the USSM of Zubair Formation in the studied wells was divided into alternating layers of clean sand, dirty sand and shale (Fig. 7). And based on the interpretation of a quick look at the data from the well logs and cross section, the possible reservoir intervals were identified (Figs. 6 and 7), the R-172, R-181, R-249, R-554, R-559, and R-152 wells are considered good hydrocarbon reservoirs due to an increase in sandy area and an improvement in porosity and hydrocarbon saturation. As a result, we infer that the reservoir characteristics improve in the North Rumaila oil field structure’s center and south. The R-256 well is similarly classified as a medium reservoir in terms of porosity and hydrocarbon content, while well R-167 indicated, the water content of the field grew as it towards the southwest.

4.2. Qualitative Analysis of the Upper Sandstone Member

It includes the study of petrophysical properties and knowledge of their values, such as shale volume, porosity, oil saturation, and permeability to divide the formation into reservoir units and know the best ones. The following is the process for calculating petrophysical parameters:
Fig. 7. Well log curves for Upper Sand Member of Zubair Formation in Well-172, as an example, to determine the lithological units. (SS: clean sand; D: Dirty sand)

4.2.1. Calculation of shale volume (Vsh)

The shale volume assessment was carried out to assess the number of radioactive materials or shale found in the reservoir unite and to designate zones of significance. The presence of shale in a percentage of greater than 10-15% of the total rock volume affects porosity and water saturation values (Bassiouni, 1994). Shale content can be calculated using a variety of logs, including GR, SP, N, and R. (Schlumberger, 1998). The GR log is the best because of its sensitivity to radioactive elements in shale, so Shale volume was calculated with it according to the following equation:

\[
IGR = \frac{GR \text{ log} - GR \text{ min}}{GR \text{ max} - GR \text{ min}}
\]

\[
V_{sh} = 0.33(2^{2*IGR} - 1)
\]

4.2.2. Calculation of shale volume (Vsh)

Porosity is a performance parameter for reservoir rock characterization because it describes the amount of open space that is filled with a liquid (hydrocarbon or water). These porosity logs are studied to determine the zones of void space that are interconnected and thus capable of transmitting fluids (effective porosity), and the integration of all of these characteristics and their relationships with the water or hydrocarbon gives the porosity development and reservoir identification. The porosity is defined as the percentage of void volume to total rock volume, as shown in the equation below;

\[
\text{Porosity } \Phi = \left( \frac{\text{Pore Volume}}{\text{Bulk Volume}} \right) \times 100
\]

The neutron porosity is given directly from the log reading and represents the effective porosity while the depths containing the shale are corrected for the log readings through an equation (Tiab & Donaldson, 1996):

\[
\Phi_{N \text{ corr}} = \Phi_{N} - (V_{sh} \times \Phi_{N \text{ sh}})
\]

The porosity of the density is calculated by (Wyllie, et al., 1958) equation:

\[
\Phi_{D} = \frac{(\rho_{ma} - \rho_{b})}{(\rho_{ma} - \rho_{f})}
\]
Where ØDcorr. = corrected porosity, ρma = density of matrix

While the depths containing the shale are corrected for the log readings through an equation (Atlas, 1979):

\[ \phi_{Dcorr.} = \frac{(\rho_{ma} - \rho_b)}{(\rho_{ma} - \rho_f)} \times (\frac{(\rho_{ma} - \rho_{sh})}{(\rho_{ma} - \rho_f)}) \times V_{sh} \] (6)

The total porosity within a reservoir interval can be estimated using a combination of neutron–density (Dolan, 1990):

\[ \phi_{N.D} = \frac{(\phi_N + \phi_D)}{2} \] (7)

Where \( \phi_N \) = Neutron porosity, \( \phi_D \) = Density porosity

Primary porosity can be estimated by sonic logs (Baker, 1992):

\[ \phi_S = \frac{(\Delta t_{log} - \Delta t_{ma})}{(\Delta t_f - \Delta t_{ma})} - \frac{(\Delta t_{sh} - \Delta t_{ma})}{(\Delta t_f - \Delta t_{ma})} \times V_{sh} \] (9)

While the depths containing the shale are corrected for the log readings through an equation as (Atlas, 1979):

\[ \phi_S = \frac{(\Delta t_{log} - \Delta t_{ma})}{(\Delta t_f - \Delta t_{ma})} \times V_{sh} \] (9)

Where \( \phi_S \) = sonic derived porosity, sonic log (\( \Delta t \)). Secondary porosity is calculated by an equation: (Schlumberger, 1998):

\[ SPI = \phi_{N.D} - \phi_S \] (10)

Where SPI = Secondary porosity Index, \( \phi_s \) = Sonic porosity

By observing the porosity values in all the wells of the study area, it was found that the porosity mostly ranges between a good (from 15 to 20%), very good (20-25%) and excellent range (more than 25%) according to the classification of (North, 1985) (Fig.10).

4.2.3. Permeability estimation

Permeability means the ability of rocks with good effective porosity to flow fluids under the differential pressure gradient (Chillinger, et al., 2005) Porosity and resistivity logs are the two main well log data used to assess permeability, because it is significantly associated with permeability, the porosity log is typically favored over the resistivity log (Ellis, 2007).

Based on grain size, mineralogy, pore dimensions, and water saturation, the (Timur, 1968), (Tixier, 1949); (Wyllie & Rose, 1950) models was used to predict the permeability of each identified reservoir rock. The permeability to the main reservoir units was calculated using the relationship between Sw and porosity for each reservoir unit in each well and then applying Wyllie ‘s equation (Wyllie et al., 1958), then the pore throat was calculated by graphing the relationship between permeability and porosity (Fig.8).

\[ K = \left[ a_{wr} \times \left( \frac{(\phi_{ef})^3}{Swirr} \right) \right]^{1/2} \] (11)

Where; K: Permeability which is measured in milli Darcy (mD), a wr: the hydrocarbon density constant of 250 for medium oil and 79 for dry gas, Swirr: saturation of non-displaceable water, and Φef: effective porosity (%). According to the Levenson (1972) permeability classification (Table 1), all units had a range of permeability from good to Excellent, with the exception of wells R-559 and R-256, which had medium permeability. Pore throat ranged in size from small to quite large. The average permeability values derived using the Wyllie et al. (1958) equation for the study wells is shown in Table 1.
Fig.8. Cross plots as example in R-172 well showing the Irreducible water saturation and the determination of the size of the pore throat of the reservoir units in the wells of the study area.

Table 1. Permeability values and their classification according to Leverson (1972) for the units of the Zubair formation in the study wells

<table>
<thead>
<tr>
<th>Well</th>
<th>Unit</th>
<th>Average of Permeability (mD)</th>
<th>Leverson (1967)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB</td>
<td></td>
<td>86.06</td>
<td>Good</td>
</tr>
<tr>
<td>R-152</td>
<td>DJ</td>
<td>49.00</td>
<td>Good</td>
</tr>
<tr>
<td>LN</td>
<td></td>
<td>132.64</td>
<td>Very Good</td>
</tr>
<tr>
<td>R-167</td>
<td>LN</td>
<td>2224.11</td>
<td>Very Good</td>
</tr>
<tr>
<td>AB</td>
<td></td>
<td>89.88</td>
<td>Good</td>
</tr>
<tr>
<td>LN</td>
<td></td>
<td>15.26</td>
<td>Good</td>
</tr>
<tr>
<td>R-181</td>
<td>AB</td>
<td>118.54</td>
<td>Very Good</td>
</tr>
<tr>
<td>LN</td>
<td></td>
<td>14.3</td>
<td>Good</td>
</tr>
<tr>
<td>R-249</td>
<td>AB</td>
<td>22.18</td>
<td>Good</td>
</tr>
<tr>
<td>DJ</td>
<td></td>
<td>4.76</td>
<td>Moderate</td>
</tr>
<tr>
<td>LN</td>
<td></td>
<td>1745.06</td>
<td>Excellent</td>
</tr>
<tr>
<td>R-559</td>
<td>DJ</td>
<td>4.73</td>
<td>Moderate</td>
</tr>
</tbody>
</table>

4.2.4 Hydrocarbon and water-saturation

Porosity and resistivity logs are used to calculate the water saturation ratio, which is the proportion of water volume to pore volume. Water saturation is critical because hydrocarbon saturation estimated from it. It is critical to determine the type of fluid in the reservoir units, whether it contains hydrocarbons, water, or both. The zone should have been porous and have higher resistivity values than water-bearing rocks for a reservoir to hold hydrocarbons (Bassiouni, 1994). The resistivity log was employed in this work to distinguish hydrocarbon and other fluids bearing intervals. In this work, Archie’s model is used to calculate the water saturation of reservoir units, according to the following equation:

\[ S_w = \left( \frac{a \times R_w}{R_f \times \phi^m} \right)^{\frac{1}{n}} \]  \hspace{1cm} (12)

Where \( S_w \) = water saturation, \( R_f \) = true formation resistivity, \( R_w \) = formation water resistivity at formation temperature, \( \phi \) = Total porosity, \( a \) = tortuosity exponent, \( n \) = saturation exponent, \( m \) = cementation exponent.

\[ S_{xo} = \sqrt{\frac{(a \times Rmf)}{(Rxo \times \phi^m)}} \] \hspace{1cm} (13)
The hydrocarbon saturation (SH) is the proportion of pore volume filled with hydrocarbon in a formation. The hydrocarbon saturation was calculated by deducting the value of water saturation value from 100 percentage, according to the equation below:

\[ SH = (100 - Sw) \% \] (14)

4.2.5. Calculate the movability of hydrocarbons index

The hydrocarbon is not moveable if the \( Sw/Sxo \) value is equal to or greater than 1.0; if the value is less than 0.7, the hydrocarbon is moveable (Atlas, 1979) Archie's formula was used to calculate the hydrocarbon movability index, which was determined as a ratio of the uninhibited zone to the flushed zone using the equation bellow:

\[ HC \text{ mov index} = SW/Sxo \] (15)

Where; \( Sxo \) = water saturation of the flushed zone, \( Sw \) = water saturation of the uninhibited zone.

The total water volume \( BVW \) is multiplying of the total porosity and water saturation, and it can be determined using (Bassiouni, 1994), and the (Schlumberger, 1998) equations in both Invaded and Uninvaded zone:

\[ BVW = Sw \times \emptyset t \] (16)

\[ BVxo = Sxo \times \emptyset t \] (17)

The total hydrocarbon volume \( BVh \) is calculate from an equation:

\[ BVh = Sh \times \emptyset t \] (18)

Also, the movable oil saturation and the residual oil saturation was calculated from an equation (Schlumberger, 1998):

\[ MOS = Sxo - Sw \] (19)

\[ ROS = 1 - Sxo \] (20)

Where: \( Rw \) = Resistivity of water formation, \( Sw \) = Water saturation

The reservoir in all analyzed wells implies a higher proportion of void space occupied by hydrocarbon and consequently with low water saturation, except for the R-167 well, which appears to contain a large percentage of water (Fig.10).

4.2.6. Net pay

All of the wells studied have sand and shaly sandstone portions (inside the reservoir units). It should be observed, however, that while the sand region accounts for a minor percentage of the whole, the Shaly sandstone section accounts for the majority of the total, and the amount of shale is lower (non-reservoir units). The net pays for reservoir thickness in all wells ranges from 5 to 59m (except R-167), with strong hydrocarbon saturation, good effective porosity, and low shale volume, resulting in significant hydrocarbon productivity (Table 2).

4.2.7. Reservoir units

Based on the results, the Upper Sandstone Member in the studied wells was divided into three main reservoir units, separated by two insulating layers of shale, and seven secondary reservoir units. A relationship has been applied between shale volume and effective porosity within each unit in well studied to show how the clays distributed, the results showed that the clays were distributed in a structural, laminated and a small percentage is dispersed form in the reservoir units (Fig.9). The petrophysical results of these units were also clarified in more detail in (Fig.10) and these units are:
• **AB unit**

This unit is mainly composed of sand, in addition to shale overlapping with sandstone. This unit extends in all studied wells and its thickness ranges between 4-8 meters. By comparing this unit in all wells, we find the best in well R-249 because of its large thickness and good reservoir properties.

![Fig.9. The relationship between Vsh and PHIND ef showing Clay distribution the AB, DJ, and LN reservoir units of the USSM in Well R-172](image)

• **C unit**

An insulating layer composed of shale, as the well logs show, separates the reservoir unit AB above and the reservoir unit DJ below, and its thickness ranges between 4-6 meters in the studied wells and contains a high hydrocarbon saturation rate in all wells except for well R-256.

• **DJ unit**

It mainly composed of sandstone with thin layers of shale, so it is divided into four secondary units as below. Its thickness is about 55-60 meters in the wells studied, except for the well of R-249, which has a thickness of about 75 m. The effective porosity of this unit is high in all wells especially in R-152, R-181, except R-554. As for the value of SH, it appears high in all wells except the R-167 well which shows great water saturation. The secondary units of this unit are (1) D subunit; It consists of sandstone in the form of intertwined side layers with thin layers of shale that extends laterally in a limited way. (2) F subunit; consists of sandstone and shaly sand. (3) G subunit; composed of fine sand content with shale. (4) H subunit; very similar to the layer G above it.

• **K unit**

An insulating layer of Shale separating the DJ and LN reservoir units, its thickness ranges between 4-7 m, in the study wells and the hydrocarbon saturation in it is high, except in the well of R-249.

• **LN unit**

Consisting of sandstone and shaly sand with thin layers of shale, the lower boundary of this unit ending with MSM. Its thickness ranges in the studied wells between 45-70 m. The effective porosity appears in wells R181 and R-559 higher than the rest of the wells. The results of SH also show the
The presence of a medium to good amount of hydrocarbon, except for the R-167 well, which is few. As for the ratio of Vsh, it appears distributed along the unit length in all wells and increases near the bottom (upper of Middle Shale Member).

Table 2. Summary of the results of several computed petrophysical parameters for the wells studied

<table>
<thead>
<tr>
<th>Well</th>
<th>Unit</th>
<th>Depth m</th>
<th>Thickness (m)</th>
<th>Net Pay Thickness (m)</th>
<th>Vsh Average</th>
<th>PHIND ef Average</th>
<th>SH Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-152</td>
<td>AB</td>
<td>3180.3-3186.9</td>
<td>6.58</td>
<td>5</td>
<td>0.29</td>
<td>0.12</td>
<td>0.64</td>
</tr>
<tr>
<td></td>
<td>DJ</td>
<td>3190.1-3245.0</td>
<td>54.89</td>
<td>45</td>
<td>0.20</td>
<td>0.13</td>
<td>0.68</td>
</tr>
<tr>
<td></td>
<td>LN</td>
<td>3250.0-3289.4</td>
<td>39.37</td>
<td>32</td>
<td>0.16</td>
<td>0.14</td>
<td>0.41</td>
</tr>
<tr>
<td>R-181</td>
<td>AB</td>
<td>3219.5-3226.5</td>
<td>7.01</td>
<td>7</td>
<td>0.20</td>
<td>0.14</td>
<td>0.63</td>
</tr>
<tr>
<td></td>
<td>DJ</td>
<td>3230.1-3289.9</td>
<td>59.81</td>
<td>59</td>
<td>0.09</td>
<td>0.16</td>
<td>0.84</td>
</tr>
<tr>
<td></td>
<td>LN</td>
<td>3298.5-3366.9</td>
<td>68.38</td>
<td>30</td>
<td>0.23</td>
<td>0.14</td>
<td>0.30</td>
</tr>
<tr>
<td>R-249</td>
<td>AB</td>
<td>3175.1-3185.5</td>
<td>10.41</td>
<td>6</td>
<td>0.28</td>
<td>0.13</td>
<td>0.61</td>
</tr>
<tr>
<td></td>
<td>DJ</td>
<td>3187.5-3261.2</td>
<td>73.69</td>
<td>56</td>
<td>0.12</td>
<td>0.07</td>
<td>0.68</td>
</tr>
<tr>
<td></td>
<td>LN</td>
<td>3265.7-3333.9</td>
<td>68.19</td>
<td>30</td>
<td>0.24</td>
<td>0.06</td>
<td>0.35</td>
</tr>
<tr>
<td>R-256</td>
<td>AB</td>
<td>3178.1-3183.4</td>
<td>5.25</td>
<td>5</td>
<td>0.23</td>
<td>0.1</td>
<td>0.33</td>
</tr>
<tr>
<td></td>
<td>DJ</td>
<td>3187.2-3252.5</td>
<td>65.23</td>
<td>40</td>
<td>0.24</td>
<td>0.08</td>
<td>0.46</td>
</tr>
<tr>
<td></td>
<td>LN</td>
<td>3258.5-3282.3</td>
<td>73.73</td>
<td></td>
<td>0.13</td>
<td>0.07</td>
<td>0.08</td>
</tr>
<tr>
<td>R-554</td>
<td>AB</td>
<td>3086.9-3092.6</td>
<td>5.71</td>
<td>5</td>
<td>0.16</td>
<td>0.07</td>
<td>0.55</td>
</tr>
<tr>
<td></td>
<td>DJ</td>
<td>3097.2-3156.0</td>
<td>58.8</td>
<td>40</td>
<td>0.20</td>
<td>0.04</td>
<td>0.57</td>
</tr>
<tr>
<td></td>
<td>LN</td>
<td>3159.8-3218.0</td>
<td>58.2</td>
<td>28</td>
<td>0.21</td>
<td>0.07</td>
<td>0.33</td>
</tr>
<tr>
<td>R-559</td>
<td>AB</td>
<td>3168.6-3174.5</td>
<td>5.94</td>
<td>5</td>
<td>0.18</td>
<td>0.09</td>
<td>0.49</td>
</tr>
<tr>
<td></td>
<td>DJ</td>
<td>3179.0-3237.1</td>
<td>58.06</td>
<td>40</td>
<td>0.11</td>
<td>0.09</td>
<td>0.48</td>
</tr>
<tr>
<td></td>
<td>LN</td>
<td>3242.2-3311.7</td>
<td>69.45</td>
<td>17</td>
<td>0.23</td>
<td>0.13</td>
<td>0.43</td>
</tr>
<tr>
<td>R-167</td>
<td>AB</td>
<td>3389.0-3400.0</td>
<td>11</td>
<td>0</td>
<td>0.04</td>
<td>0.10</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>DJ</td>
<td>3407.0-3460.0</td>
<td>53</td>
<td>2</td>
<td>0.08</td>
<td>0.10</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>LN</td>
<td>3466.4-3520.0</td>
<td>53.6</td>
<td>5</td>
<td>0.11</td>
<td>0.11</td>
<td>0.12</td>
</tr>
<tr>
<td>R-172</td>
<td>AB</td>
<td>3089.6-3095.0</td>
<td>5.4</td>
<td>5</td>
<td>0.22</td>
<td>0.14</td>
<td>0.52</td>
</tr>
<tr>
<td></td>
<td>DJ</td>
<td>3099.7-3156.0</td>
<td>56.3</td>
<td>56</td>
<td>0.24</td>
<td>0.10</td>
<td>0.57</td>
</tr>
<tr>
<td></td>
<td>LN</td>
<td>3161.0-3210.0</td>
<td>49</td>
<td>48</td>
<td>0.21</td>
<td>0.10</td>
<td>0.47</td>
</tr>
</tbody>
</table>

This unit is divided into three sub-units: (1) L subunit; represents the accumulation of sandstone bodies horizontally overlapping with thin parts of the shale. (2) M subunit; composed of a thin accumulation of sandstone with an increase in shale especially towards the base. (3) N subunit; represents the lower part of the Upper Sandstone Member USSTM and consists of sandstone, this part grades downward to the Middle Shale Member MSM.

Fig.10. An example of the Interpretation of the computed petrophysical parameters of the Upper Sand Member and its sub-units in Well-172
4.2.8. Statistical Analysis

The three basic reservoir units of the Upper Sandstone Member were also statistically analyzed as shown in Fig. 11 to find out the best unit in terms of porosity and hydrocarbon saturation. The DJ reservoir unit is of great importance because it contains a high proportion of the hydrocarbons promise.

![Fig.11. Statistical analysis for all sub-units of the Upper Sandstone Member in R-172 well](image)

The Zubair Formation's main production unit is the DJ reservoir unit. Except for the R-167 well, which has high water saturation and little oil saturation, the DJ and LN units have good porosity and hydrocarbon saturation in all wells. The AB unit has good hydrocarbon saturation in all wells except the R-167 and R-256 wells. The petrophysical study results also found high porosity, good permeability, high oil saturation in all wells, except for well R-167 which have high water saturation. Accordingly, the R-172, R-181, R-249, R-554, R-559, and R-152 wells have hydrocarbon-bearing reservoir units that have the potential for commercial oil production and accumulation.

5. Conclusions

The quantitative and qualitative explanations for the Upper Sandstone Member within the Zubair were identified by examining petrophysical parameters and computing their values (shale volume, porosity, permeability, and oil saturation). The results showed that the clays are distributed in a structural form in all reservoir units in wells, but they do not take from the size of the pores and therefore do not affect the porosity. The permeability-porosity relationship was calculated using the diagram of the relationship between Pore's throat and permeability, and the permeability ranges from good to excellent. Through the interpretation of a quick look and by using different cross-plots such as neutron-density-$\phi$N, GR- $\phi$N show that the reservoir units lithology ranges from sandstone, shaly sandstone to shale in all study wells. By considering all petrophysics properties parameters from the log data analysis performed in this study, such as Vsh, PHIND, Sw, SH, and K, the Upper sand member of the Lower
Cretaceous Zubair Formation of the North Rumaila oil field was divided into three main reservoir units. They are named AB, DJ, and LN, separated by two insulating units of shale, named C, and K. The DJ unit was then divided into four secondary reservoir units, namely: D, F, G, H, while the unit LN was divided into three secondary potential units, which are: L, M, and N.

Acknowledgements
The authors would like to extend their sincere thanks and appreciation to the Basra Oil Company for providing them with samples and data. Thanks due to the Department of Geology, University of Basra for assistance in completing the work in its laboratories. The authors are very grateful to the reviewers, Editor in Chief Prof. Dr. Salih M. Awadh, the Secretary of Journal Mr. Samir R. Hijab, and the Technical Editors for their great efforts and valuable comments.

References
Aversana, P. D., 2011. Joint inversion of rock properties from Sonic, resistivity, and density well-log measurement. Geophysical Prospecting 59(6), 1144 -1154
Christopher, H., 2010. The World's Biggest Oil Reserves. Chances are your energy needs are going to 412 flow from one of these 10 fields in the future. Forbes.
BV First EAGE Workshop on Iraq - Hydrocarbon Exploration and Field Development - Istanbul, Turkey (2012.04.29-2012.05.02)] First EAGE Workshop on Iraq-Hydrocarbon Exploration and Field Development - Stratigraphy and Depositional Environment of the Upper Zubair Sandstone “Main Pay”, West Qurna 1 Field, Iraq.


Wyllie, M. & Rose, W., 1950. Some theoretical considerations related to the quantitative evaluation of the physical characteristics of reservoir rock from electrical log data. Transactions of AIME, 189, 105-118.