

Petrophysical Evaluation and Reservoir Characterization of the Zubair Formation in the Luhais and Rachi oil fields, Southern Iraq

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Abstract—The Barremian succession in the present study is represented by the Zubair Formation which the most significant sandstone reservoir in Iraq. The area of study is located in the Southern part of Iraq at the Luhais and Rachi oil fields, within the Mesopotamian basin.

The thickness of the Zubair Formation is about 450 m in the studied area. It is divided into three lithofacies: - The upper unit is composed mostly of shale layers, the middle unit consists of thick layers of sandstone rocks and the lower ones consist mainly of Shale with less sandstone layers. These units are characterized by three types of petrophysical features according to total porosity/effective porosity: - High-moderate effective porosity rocks (type I), moderate effective porosity rocks (type II) and low-non pores rocks (type III).

The upper unit of the Zubair Formation at the Luhais oil field is characterized by two horizons. The first is showing high resistivity-high gamma ray which represents the upper part; while the lower one is shown low resistivity-low gamma ray. There are two good reservoir horizons with high oil saturation (low water saturation) in this unit at the Rachi oil field and Lu-3 borehole, while at the Lu-12 is appeared as one unconformable horizon.

The middle is characterized by two subzones in the southwestern part of Luhais oil field (Lu-12). The upper one is characterized by high- moderate effective porosity while the lower one is characterized by moderate effective porosity because of presence a low volume of shale. This unit is dominated by low resistivity-low gamma ray with three sub-banded bands of high resistivity-low gamma ray, these appeared in both studied oil fields. The high percentage of water saturation in this unit caused the lack of clarity of the oil saturation, which appears in narrow bands

The lower unit is represented the shale – dominated member of Zubair Formation, with low to non-pores rocks. This appeared in all studied wells. There are limited presences for the high- moderate effective porosity of rock within the sand bands lithofacies appears in these

wells. This unit is characterized by alternative the high resistivity-high gamma ray horizon with the low resistivity-low gamma ray horizon as four cycles. There are two good reservoir horizons with high oil saturation (low water saturation) in this unit with a distribution similar to that found in the upper part.

From the reservoir geology which represent by property modelling, preparing data, construction of three-dimension clump and scale up for the studied oil fields. The Rachi oil field is appeared the better hydrocarbon saturation compared to Luhais oil field, although the Luhais oil field (Lu-3 and Lu-12) is the best of petrophysical properties. This indicates that the Rachi oil field was affected by the structural position as indicated by the model, while the model did not show any structural properties in the field of Luhais. Therefore, the structural and/or stratigraphic positions have the greatest influence on the hydrocarbon accumulation, regardless of petrophysical properties.

Keywords—Petrophysical evaluation, Reservoir characterization, Zubair Formation, and Luhais-Rachi oil fields.

I. INTRODUCTION

- I. The Zubair Formation was introduced by Glynn Jones in 1948 from the Zubair oil field and amended by Nasr and Hudson in 1953 (Bellenet *et al.*, 1959). It is the most significant sandstone reservoir in Iraq, is composed of fluvio- deltaic, deltaic and marine sandstones.
- II. The study area is located in the Southern part of Iraq at the Luhais and Rachi oil fields, within the Mesopotamian basin at the stable shelf. The studied oil fields are located in the southern desert, about 90 km south-west of the city of Basra, which lies about 50 km southwest of the Northern Rumaila oil field (Fig.1).
- III. Rachi oil field in southern Iraq, is located within the administrative border of the province of Basra, just 80 km south-west of the city of Basra southern Iraq.

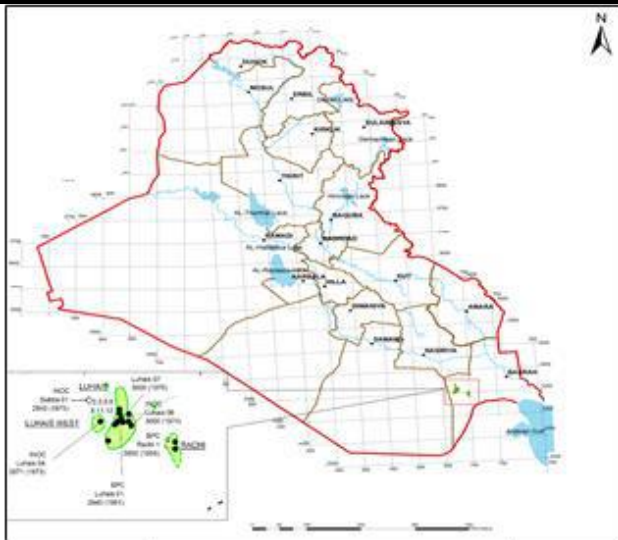


Fig. 1: location of study

The Barremian succession represent a part of The Late Tithonian-Early Turonian Megasequence was deposited in a large intra-shelf basin contemporaneous with a new phase of ocean floor spreading in the Southern Neo-Tethys. Differential subsidence (and resultant thickness changes) occurred across transverse faults. The axis of the intra-shelf basin shifted towards the eastern Mesopotamian Zone into the Tigris Subzone from its previous position on the Salman Zone and western Mesopotamian Zone (Jassim and Goff, 2006).

IV. The progradational Zubair/Ratawiclastic shelf was covered by the Shu'aiba Formation carbonates following backstepping of the Zubair and Ratawi Formations (Fig. 2). Jassim and Buday (2006) suggested that the Zubair Formation depocentre was located at the eastern limit of the Salman Zone, as illustrated by the isopach of the Zubair Formation (Ali and Nasser, 1989 in Aqrawi et al. 2010) (Fig.3).

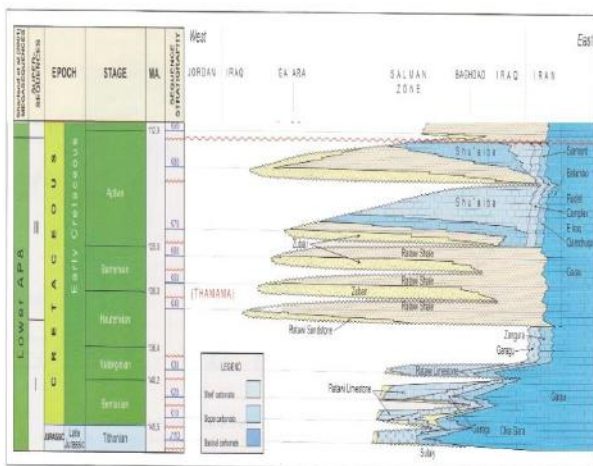


Fig. 2: Early Cretaceous chronostratigraphic section (Aqrawi, et al. 2010)

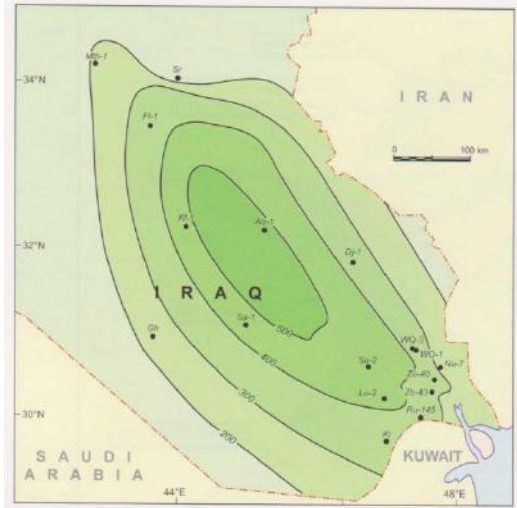


Fig. 3: Isopach map of the Zubair Formation After Ali and Nasser, 1989 in Aqrawi et al. 2010.

V. The upper contact of the formation with the Shuaiba Formation is mostly gradational and conformable. The lower boundary is, however unconformable with Ratawi Formation (Buday, 1980), and this unconformity described by Douban and Al-Medhadi (1999).

II. METHODOLOGY

- Study of available well logs and relate the log response to facies and diagenetic changes for the studied succession intervals (table 1).

Table.1: Zubair Formation subdivisions thickness and occurrence.

Field Name	Well No.	Formation	Units	Top	Bottom	Thickness (m)
Luhais	Lu-3	Zubair	Upper	2720	2807	87
			Middle	2807	3055	248
			Lower	3055	3180	115
Luhais	Lu-12	Zubair	Upper	2730	2790	60
			Middle	2790	3070	280
			Lower	3070	3170	100
Rachi	Rc-1	Zubair	Upper	2870	2930	60
			Middle	2930	3240	310
			Lower	3240	3310	70
Rachi	Rc-2	Zubair	Upper	2880	2925	45
			Middle	2925	3230	305
			Lower	3230	3320	90

- Digitizing well logs using Didger software .
- Using interactive petrophysical software IP (V3.5) and petrel (V.14) for the environmental correction, lithology and mineralogy identification and logs interpretation.
- Study of the well logs and relate the log response to facies and diagenetic changes.
- Building petrophysical models, Facies and structured maps were constructed and the petrophysical properties were distributed throughout well correlation in Mauudud and NahrUmr formations.

III. LITHOFAICES UNIT OF ZUBAIR FORMATION

- The thickness of the Zubair Formation is about 450 m (Table 3-1). it is divided into three lithofacies units by using GR log in Petrel Software.
- The upper member is composed mostly of Shale layers. This member is important in terms of reservoir.
- The middle member consists of thick layers of sand rocks. The
- lower member
 Consists mainly of layers Shale with less sandy layers.Figs (4), (5), and (6).

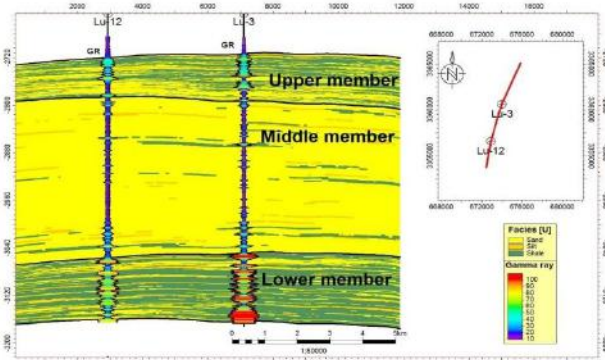


Fig. 4 : Lithofacies Intersection of Zubair formation in luhais oil field shows all members

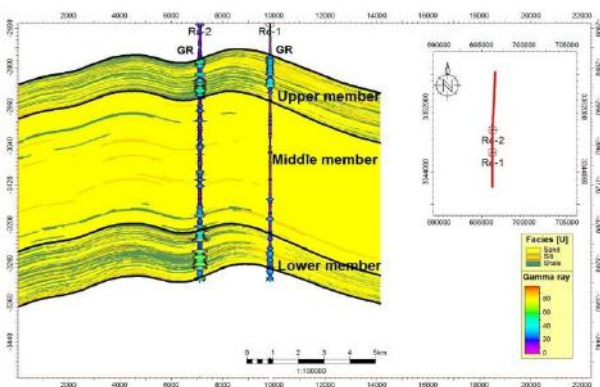


Fig. 5: Lithofacies Intersection of Zubair formation in Rachi oil field shows all members

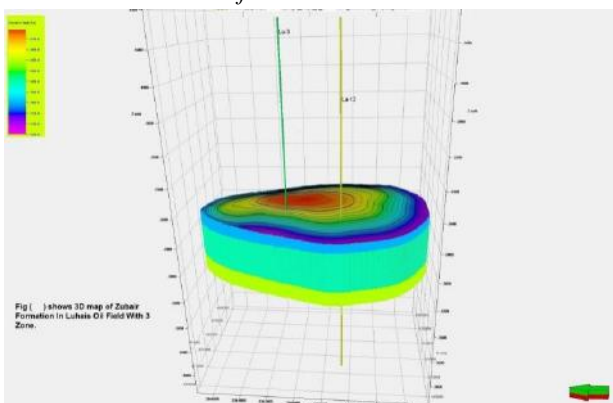


Fig. 6: Shows depth map of Zubair Formation in Luhais Oil Field with three zones.

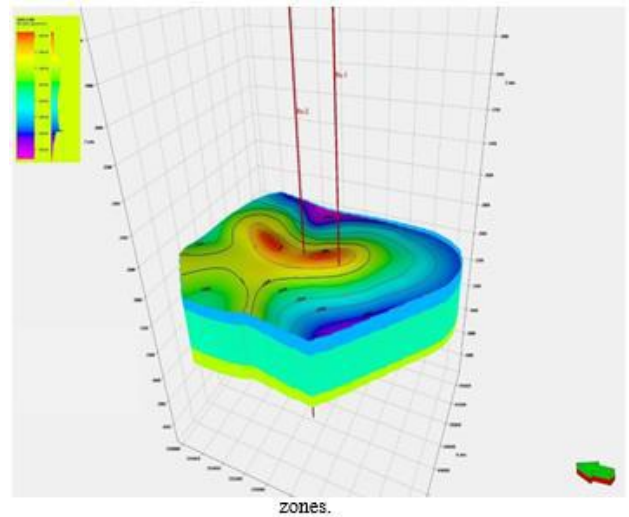


Fig. 7: Shows depth map of Zubair Formation in Rachi Oil Field with three zones.

➤ Upper unit

This zone is characterized by high shale volume in range (30-70%) with the general gamma ray log shape is bell, which refers to relatively decreasing Fig. 7: Shows depth map of Zubair Formation in Rachi Oil Field with three zones.upward in gamma ray value as three cycles (Fig. 3-5). Thickness of the upper unit is approximately (75m) in the Luhais oil field and (55m) in the Rachi oil field (Fig.8).

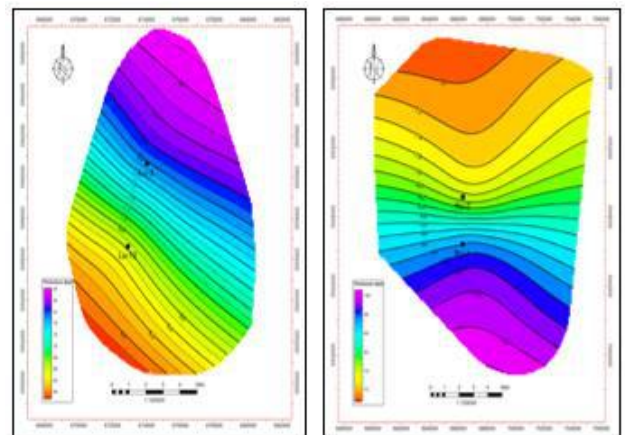


Fig. 8: isopach map shows the upper unit thickness in Luhais and Rachi

➤ Middle unit

This unit is characterized by low gamma ray values with two cycles of fine up-ward (Bell shape) in the lower zone of this part, and coarse up-ward (Funnel shape) in the upper zone divided the serrated shape into two cycle (8-22%) (Fig.9), it appears clearly in all studied boreholes. Thickness of this zone is approximately (265m) in Luhais oil field and (305m) in Rachi oil field (Fig.9).

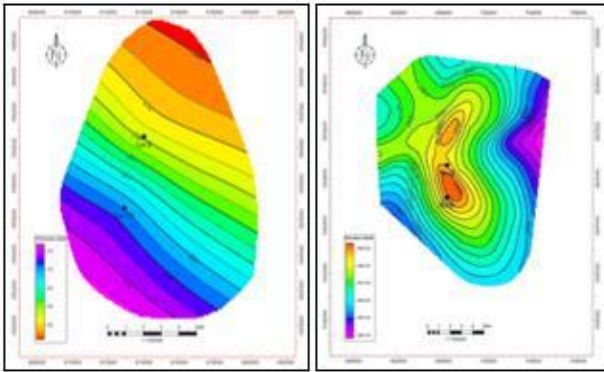


Fig. 9: isopach map shows the middle unit thickness in Luhais and Rachi oil field

➤ **Lower unit**

This zone is divided into two subzones characterized by the bell log shape which refers to decreasing upward with gamma ray values at the lower part (Fig.10). while the upper part is showing six cycles as increasing upward(Funnel). The thickness of this unit is about (110m) in Luhais oil field to (70m) in the Rachi oil field (Fig.10).

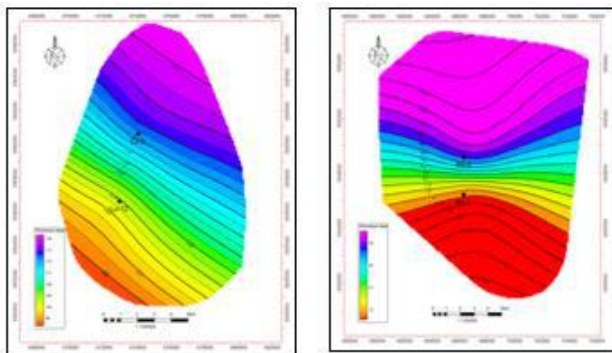


Fig. 10: isopach map shows the middle unit thickness in Luhais and Rachi oil field

IV. PETROPHYSICAL MODEL

The petrophysical model is the determination of the values of the petrophysical properties such as porosity and water saturation on each cell of the triple clasp according to the many statistical methods found in the Petrel software to distribute the petrophysical qualities after the work of its scale up. The Zubair sequence can be divided by the gamma ray and shale value into three zones (upper, middle and lower); therefore, we have an interpretation of the logs porosity and porosity evaluation according to these divisions. The log porosity logs correlation among the studied boreholes showing an approximate matching with these zones. After the application of the wire log porosity procedures and drawing the porosity-depth relationship for each borehole rather than logs reading with depth. These relationships include neutron/density log (total porosity)-depth, sonic porosity-depth and effective porosity-depth

and the porosity evolution and reservoir characterization (Fig.11).

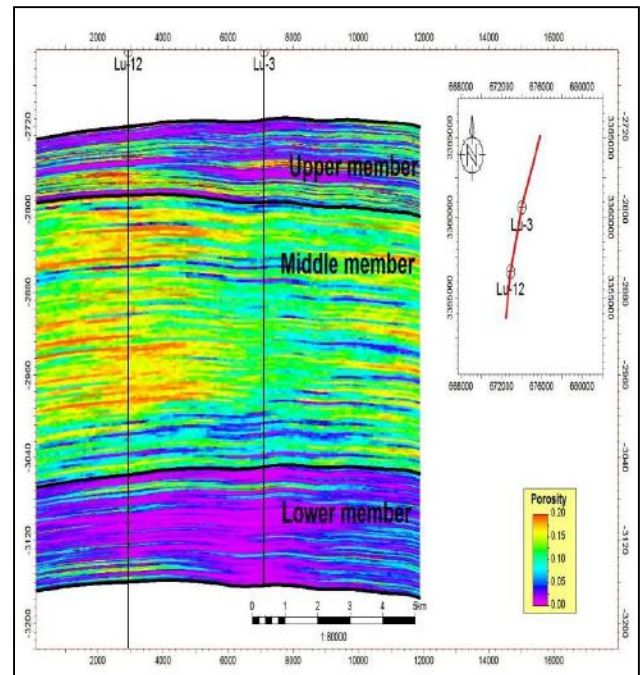


Fig. 11: North South cross section of porosity distributions of Zubair Formation in Luhais Oil Field

These types of porosity logs are studied for:-

1. Determination of the zones of void space that is interconnected and thus able to transmit fluids (effective porosity).
2. Combination of all of these features and their relationships with the water or hydrocarbon give the porosity evolution and reservoir characterization.

These zones are divided in to three types of rocks according to total porosity:-

1. High-moderate effective porosity rocks (type I).
2. Moderate effective porosity rocks (type II).
3. Low-non pores rocks (type III).

❖ **Zone A**

This zone is containing two types of rocks according to total porosity, high-moderate ineffective porosity rocks (type II) and low-non pores rocks (type III).

The type (II) is appeared in the lower part of the upper unit at the Luhais oil field, while its appeared at the upper part of this unit in the Rachi oil field(Figs. 12, 15 and 16). These features are matching with the sand rich rocks and low to moderate shale.

The type (III) is represented the non-porous rocks which appeared in the other part of this unit. This type is distinguished the shale dominated rocks and poor sorted sandstone.

❖ **Zone B**

This zone is characterized by two subzones in the southwestern part of Luhais oil field (Figs. 13, 15 and

16). The upper one characterized by high- moderate effective porosity (type I) while the lower one characterized by moderate effective porosity (type II) because of presence a low volume of shale. These features are not clear to the east near the Lu-3 and to the Rachi oil field, where the moderate effective porosity (type II) is the common type at this zone. This zone is representing the middle part of Zubair Formation within the sand-dominated member.

❖ **Zone C**

The zone (c) is represented the shale – dominated member of Zubair Formation, with low to non-pores rocks (type III). This appeared in all studied wells (Fig. 13,14, 15 and 16). There are limit presences for the high moderate effective porosity type (I) of rock within the sand bands lithofacies appears in these wells.

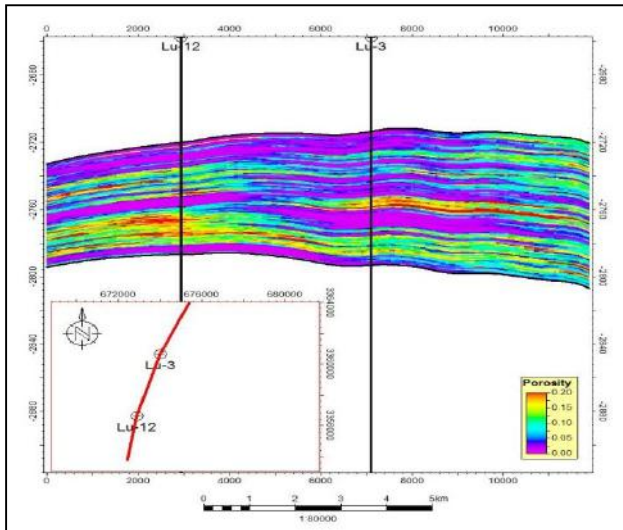


Fig.12: Cross section shows porosity distributions of the upper member of Zubair Formation in Luhais Oil Field

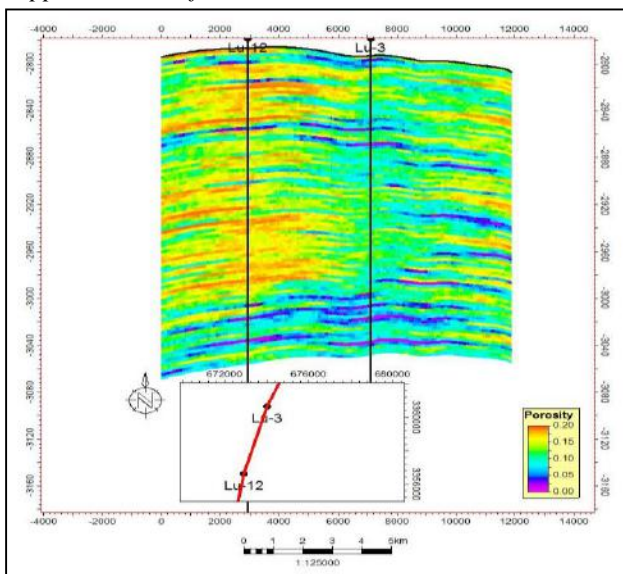


Fig.13: Cross section shows porosity distributions of the middle member of Zubair Formation in Luhais Oil Field

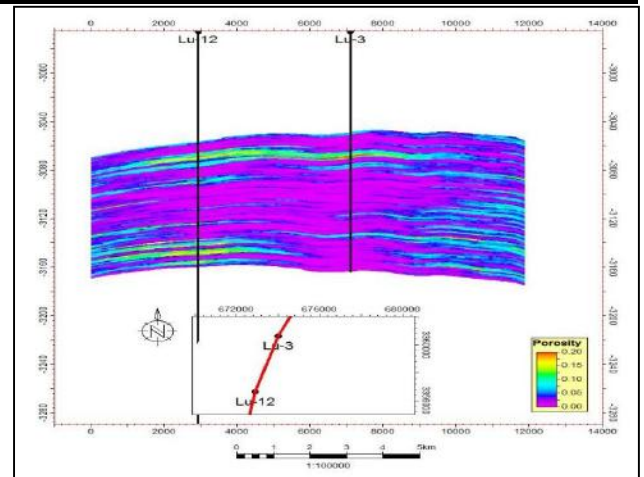


Fig.14: Cross section shows porosity distributions of the lower member of Zubair Formation in Luhais Oil Field

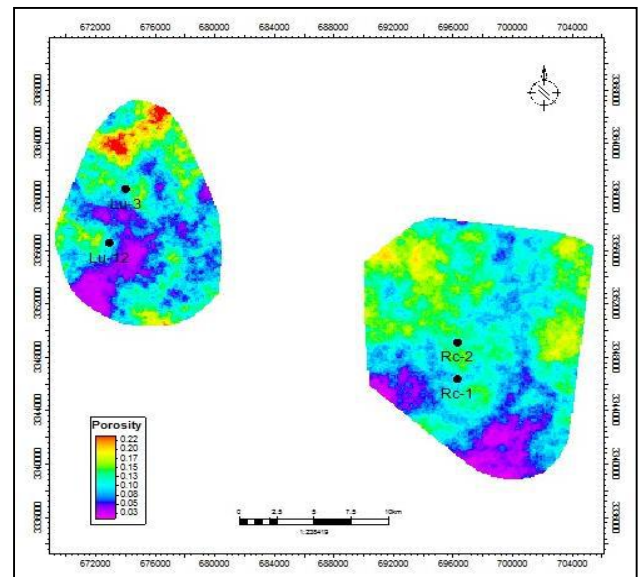


Fig. 15: Map shows porosity distribution of Zubair Formation between Luhais and Rachi fields

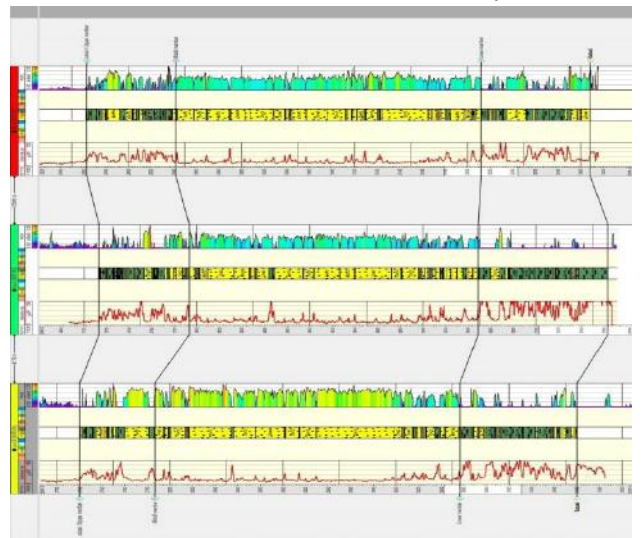


Fig. 16: Cross section shows porosity distribution of Zubair Formation between Luhais and Rachi fields

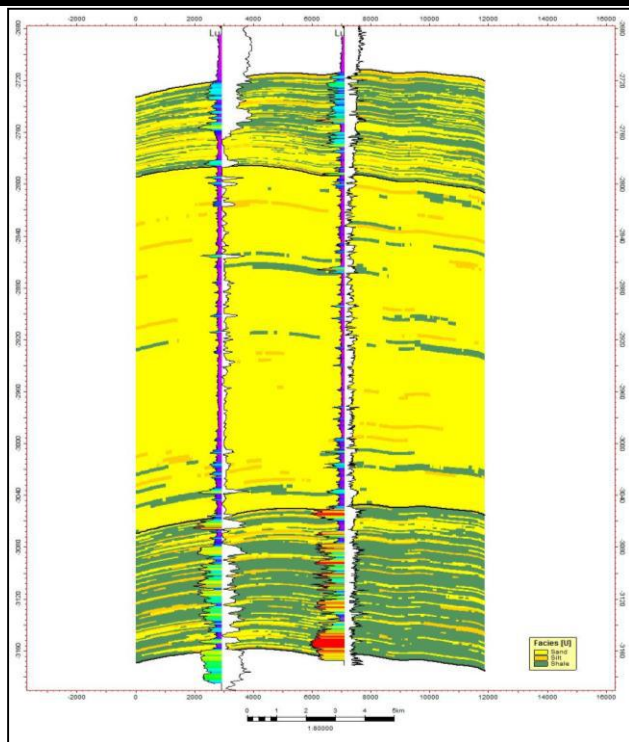


Fig. 17: Cross section shows the gamma ray and resistivity of Zubair Formation in Luhais Oil field.

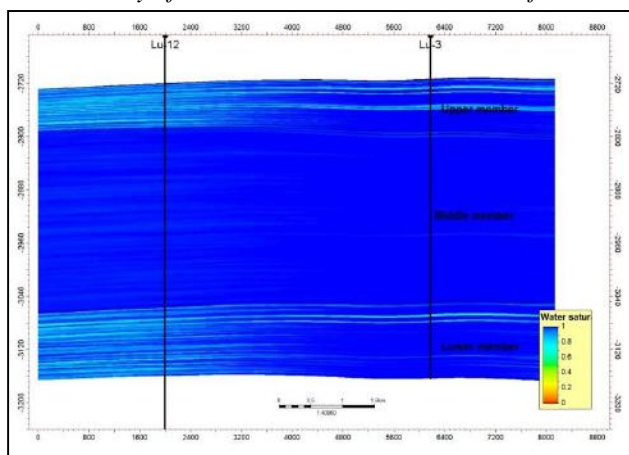


Fig. 18: Cross section shows the water saturation of Zubair Formation in Luhais Oil field.

V. WATER AND HYDROCARBON SATURATION

Fluid saturation are usually obtained from resistivity logs. Different resistivity logs; with variable fluid saturation occur at different distances from the borehole wall. Fluid saturation are estimated from resistivity measurement by the Archie equation. This equation relates the resistivity of the information to the porosity, water saturation and resistivity of the water formation (Archie, 1942).

All water saturation determinations from resistivity logs in clean formations with homogeneous intergranular porosity are based on Archie's water saturation equation (Asquith, and Krygowski, 2004).

According to the relationship of resistivity-gamma ray and porosity there are three types of petrophysics features within the Zubair Formation:

- I. Low resistivity-high gamma ray
- II. High resistivity-high gamma ray
- III. High resistivity-low gamma ray
- IV. Lwo risistivity-low gamma ray

The upper unit of the Zubair Formation at the Luhais oil field is characterized by two horizons. The first is showing high resistivity-high gamma ray which represent the upper part, while the lower ones is shown low resistivity-low gamma ray. There are many subhorizons as bands within the upper horizon as high rissistivity-low gamma ray (Figs.17, 18, and 21). The Rachi oil field is charactrized by defferent subdivisions where appeared three horizons. The first is shown high resistivity-high gamma ray, the second is shown high resistivity-low gamma ray and the last is charachtrized by alternative of high resistivity-high gamma ray and lwo resistivity-low gamma ray (Figs.19, 20 and 21).

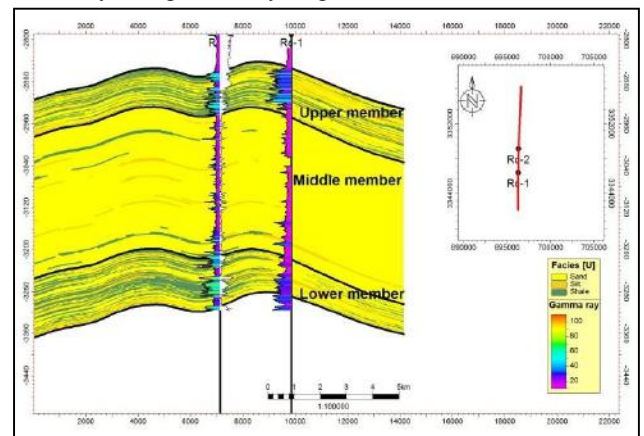


Fig. 19: Cross section shows the gamma ray and resistivity of Zubair Formation in Rachi Oil field.

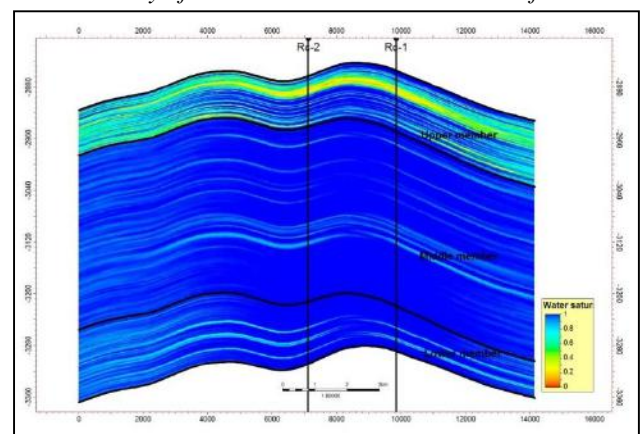


Fig. 20: Cross section shows the water saturation of Zubair Formation in Rachi Oil field.

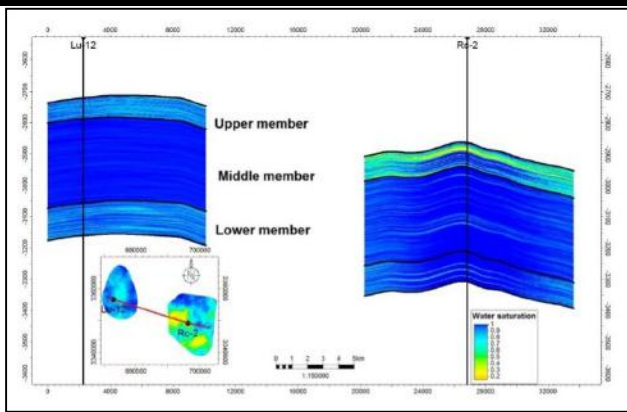


Fig. 21: Cross section shows the water saturation of Zubair Formation in Luhais and Rachi Oil fields.

There are two good reservoir horizons with high oil saturation (low water saturation) in this unit at the Rachi oil field and Lu-3 borehole, while at the Lu-12 is appeared as one uncontinuous horizon.

The middle unit is dominated by low resistivity-low gamma ray with three subsided bands of high resistivity-low gamma ray, these appeared in both studied oil fields (Figs.17, 18, and 21). The high percentage of water saturation in this unit caused the lack of clarity of the oil saturation, which appears in narrow bands.

The lower unit is characterized by alternative the high resistivity-high gamma ray horizon with the low resistivity-low gamma ray horizon as four cycles (Figs.17, 18, and 21). There are two good reservoir horizons with high oil saturation (low water saturation) in this unit with a distribution similar to that found in the upper part (Figs.19, 20, and 21).

VI. RESERVOIR GEOLOGY

Deals with the study of the different reservoir characteristics and the relationship between these characteristics and the lithofacies. In addition, it evaluates the content of hydrocarbons when proven by different measurements and determining reservoir architecture.

The assessment of the composition of Zubair formation in the current study was based on the available geological data in wells study, which includes data surface of the wells, geological reports and final drilling reports in addition to the previous studies in the database of the South Oil Company for an integrated understanding of the work Previous.

Four wells were selected, representing two wells per field, namely Lu-3, Lu-12 in the Luhais field and Rc-1, Rc-2 in Rachi oil field.

The values of the GR log were used to determine the range of shale and Sand by determining the minimum and maximum values, which are the basis for calculating the volume of Shale.

- **Model Properties: Property Modeling**

Is the process of filling the three-dimensional cells of the geological model with the characteristic readings of the logs (Schlumberger, 2013). There are several statistical methods and equations used in the distribution process. The model of the properties is divided into the amniotic model and the petrophysics model (porosity, water saturation and permeability).

- **Preparing data**

The first step in the Petrel software is the import of the available information to the software. The information included the coordinates of the wells of Luhais and Rachi for Al-Zubair Formation, the top of formations and lithofacies units of these wells and logs includes (Neuron, Density, Gamma Ray, deep and shallow resistor logs) as well as the Electrofacies in Petrel to build the model for Zubair formation.

- **Construction of three-dimension clump (Pillar Gridding)**

The construction of the clump depends on the depth map on which the model is built. This map is taken from the study of interpretations as in the present study. If it is not available, it can be drawn from the top formations provided that there are a good number of wells (Figs. 22 and 23).

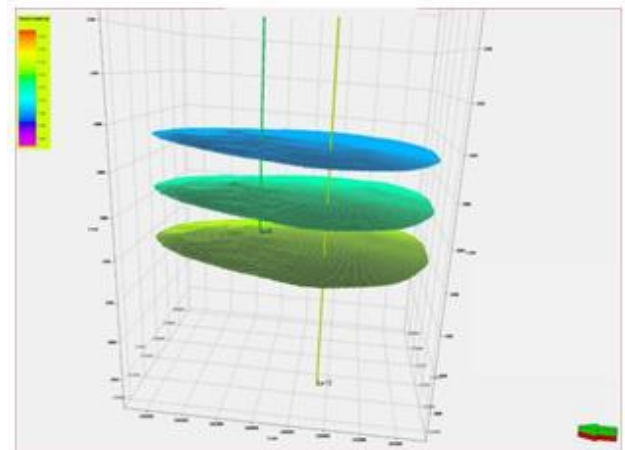


Fig. 22 : Shows Pillar Gridding 3D of Zubair Formation in Luhais Oil Field

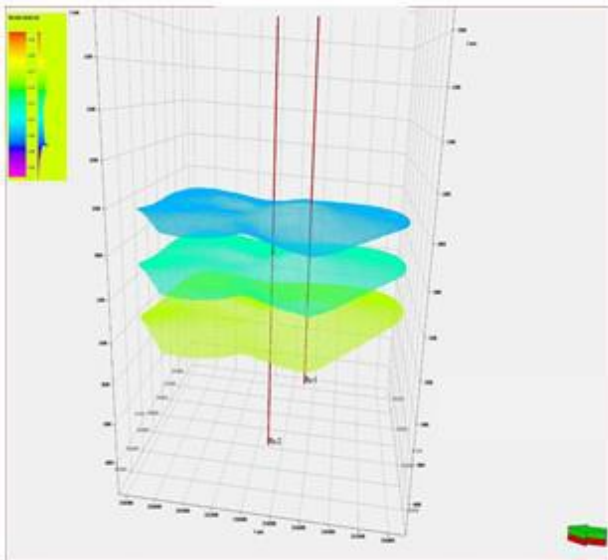


Fig.23: Shows Pillar Gridding 3D of Zubair Formation in Rachi Oil Field

- **Scale up**

Is the process of converting the reading of the logs to the shape of the three dimensional cell to fit with the reading of the logs to the gap, where (J & I) of the clamp know the horizontal and vertical size, Layer defines the thickness of the cell three-dimensional (Fig. 24) and (Fig. 25).

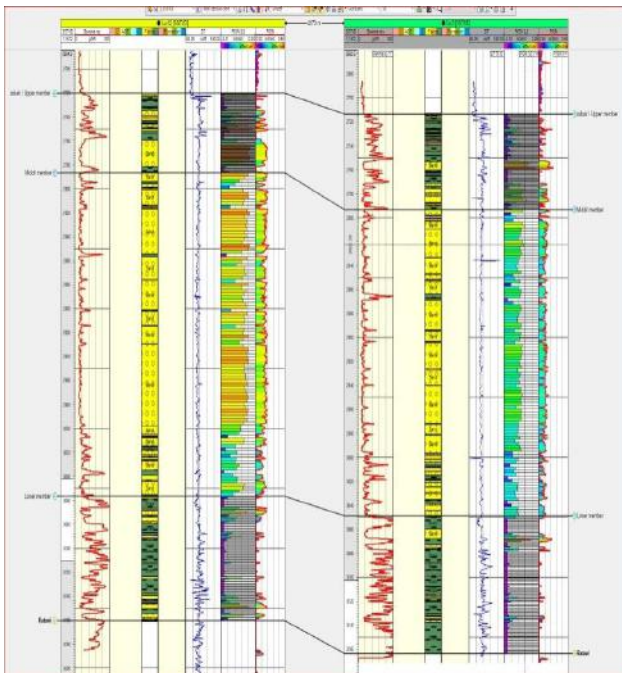


Fig. 24: Cross section shows the scale up process of Zubair Formation in Luhais Oil field.

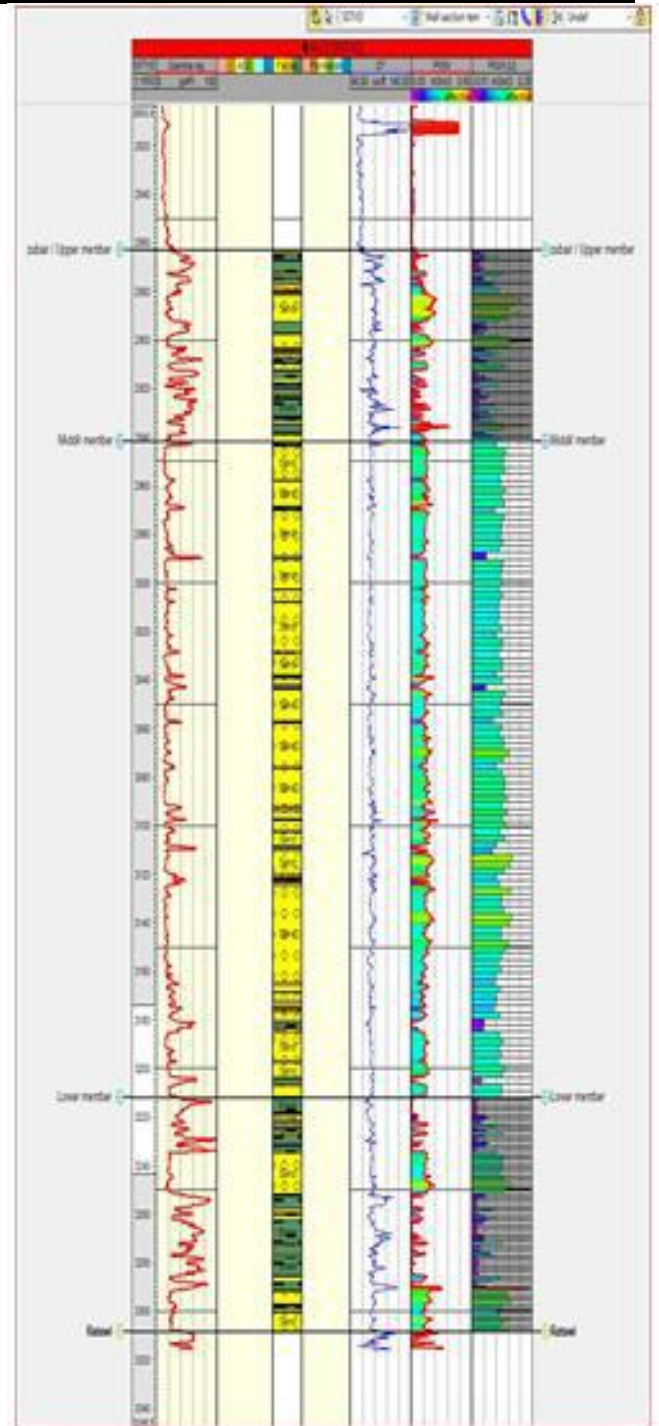


Fig. 25: Cross section shows the scale up process of Zubair Formation in Rachi Oil field.

VI. CONCLUSION

The thickness of the Zubair Formation is about 450 m in the studied area. It is divided into three lithofacies:- The upper unit is composed mostly of shale layers, the middle unit is consists of thick layers of sandstone rocks and the lower ones is consists mainly of shale with less sandstone layers.

These subdivisions are characterized by three types of petrophysical features according to total porosity/effective

porosity: -

4. High-moderate effective porosity rocks (type I).
5. Moderate effective porosity rocks (type II).
6. Low-non pores rocks (type III).

❖ Zone A

This zone is containing two types of rocks according to total porosity, high-moderate ineffective porosity rocks (type II) and low-non-pores rocks (type III).

The type (II) is appeared in the lower part of the upper unit at the Luhais oil field, while its appeared at the upper part of this unit in the Rachi oil field. These features are matching with the sand rich rocks and low to moderate shale.

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❖ Zone B

This zone is characterized by two subzones in the southwestern part of Luhais oil field (Lu-12). The upper one characterized by high- moderate effective porosity (type I) while the lower one characterized by moderate effective porosity (type II) because of presence a low volume of shale. These features are not clear to the east near the Lu-3 and to the Rachi oil field, where the moderate effective porosity (type II) is the common type at this zone.

This zone is representing the middle part of Zubair Formation within the sand-dominated member.

The middle unit is dominated by low resistivity-low gamma ray with three subbanded bands of high resistivity-low gamma ray, these appeared in both studied oil fields. The high percentage of water saturation in this unit caused the lack of clarity of the oil saturation, which appears in a narrow bands

❖ Zone C

The zone (c) is represented the shale – dominated member

of Zubair Formation, with low to non-pores rocks (type III). This appeared in all studied wells. There are limit presences for the high moderate effective porosity type (I) of rock within the sand bands lithofacies appears in these wells.

The lower unit is characterized by alternative the high resistivity-high gamma ray horizon with the low resistivity-low gamma ray horizon as four cycles. There are two good reservoir horizons with high oil saturation (low water saturation) in this unit with a distribution similar to that found in the upper part.

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