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Petro physical Evaluation and Reservoir Characterization of the Zubair Formation in Majnoon oil field, 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 Majnoon oil field, 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 is consisting of thick layers of sandstone rocks and the lower ones is consisting 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 Majnoon oil field is characterized by two horizons. The first is showing high resisitivity-high gamma ray which represent the upper part, while the lower part show low resisitivity-low gamma ray. There is a good reservoir horizon with high oil saturation (low water saturation) in this unit at the Majnoon oil field is appeared as a non-continuous horizon. The middle member is dominated by low resistivity-low gamma ray. The high percentage of water saturation in this unit caused the lack of clarity of the oil saturation, which appears in a narrow band. The lower member of Zubair Formation is distinguished by shale dominated rocks and poor sorted sandstone. This shows high resisitivity-high gamma ray. There are many sub horizons as bands within the lower horizon as high resistivity-low gamma ray. There is a good reservoir horizon with high oil saturation (low water saturation) in this unit.*

Keywords*— *Petrophysical evaluation, Reservoir characterization, Zubair Formation, and Majnoon oil field.

I. INTRODUCTION

The Zubair Formation was introduced by Glynn Jones in 1948 from the Zubair oil field and amended by Nasr and Hudson in 1953 (Bellen et al., 1959). It is the most significant sandstone reservoir in Iraq, is composed of fluvio- deltaic, deltaic and marine sandstones.

The study area is located in the Southern part of Iraq at the Mjnoon oil field, within the Mesopotamian basin at the stable shelf. The studied oil fields are located in Southern Iraq approximately 60 Km. Northwestern of Basra city, close to the Iranian border and extending North to Missan province "Fig. 1".

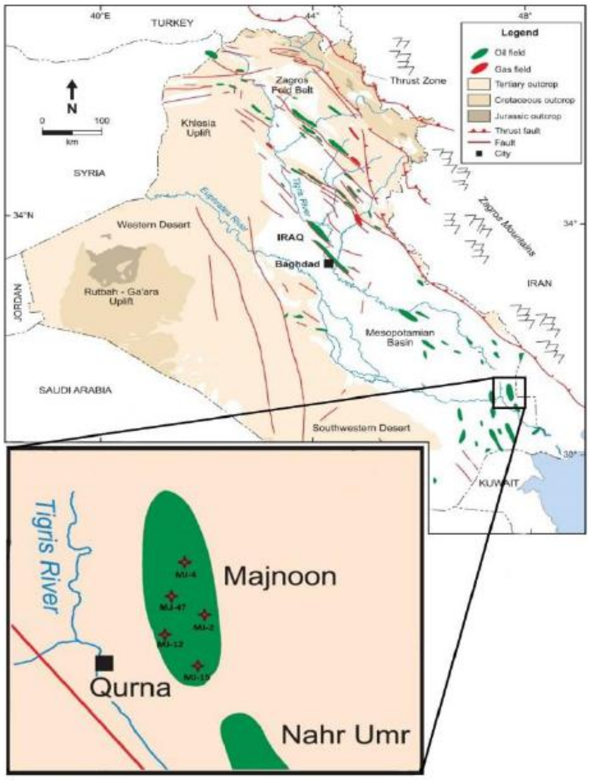

Fig. 1: Location of the study area (Modified after Abeed, et. Al, 2013).

The Barremain 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).

The progradational Zubair/Ratawi clastic shelf was covered by the Shu'aiba Formation carbonates following backstopping of the Zubair and Ratawi Formations "Fig. 2".

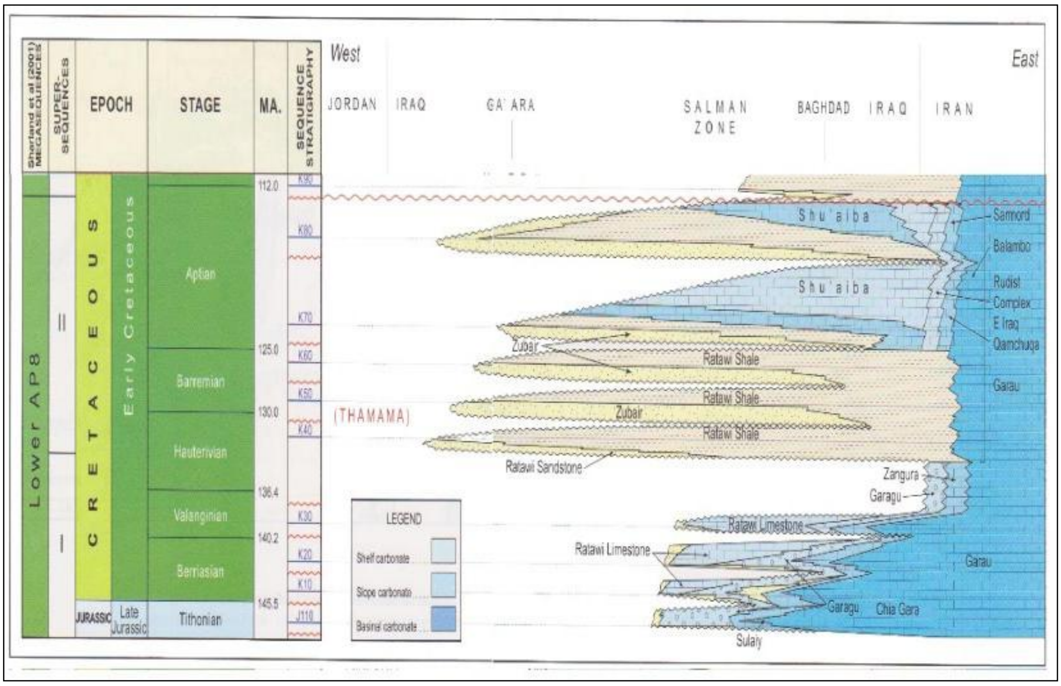

Fig. 2: Early Cretaceous chronostratigraphic section (Aqrawi, et al. 2010).

Jassim and Guff (2006) suggested that the Zubair Formation depocenter 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".

The upper contact of the formation with the Shuaiba Formation are mostly gradational and conformable. The lower boundary is, however unconformable with Ratawi Formation (Buday, 1980) and this unconformity is 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".
- Digitizing well logs using Didger software.
- Using interactive petro physical 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 petro physical models, Facies and structured maps reconstructed and the petro physical properties were distributed throughout well correlation in Zubair formation.

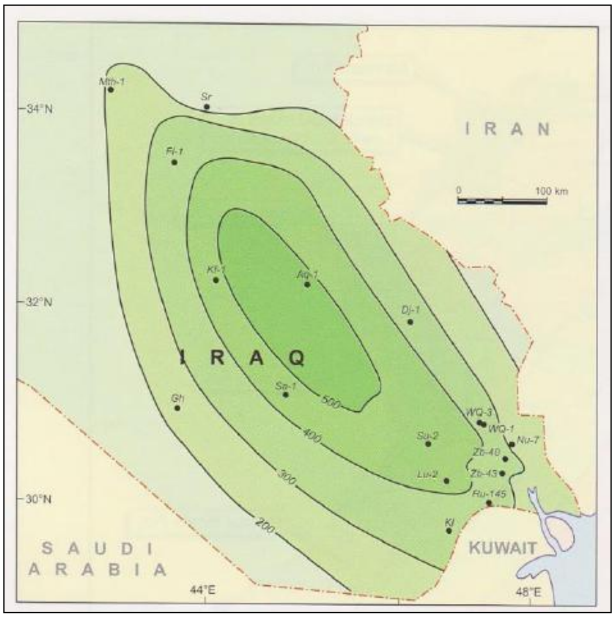

Fig. 3: Isopach map of the Zubair Formation (After Ali and Nasser, 1989 in Aqrawi et al. 2010).

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Table.1: Zubair Formation subdivisions thickness and occurrence.

Well no.	Formation	Top (m)	Bottom (m)	Longitude	Latitude
MJ-2	*Zubair Fn.*	*3452*	*3665*	*E751906.1*	*N3436141.1*
MJ-4	*Zubair Fn.*	*3465*	*3650*	*E749948.3*	*N3444259.2*
MJ-12	*Zubair Fn.*	*3524.5*	*3725*	*E747940*	*N3436300*
MJ-15	*Zubair Fn.*	*3478*	*3690*	*E752574.3*	*N3432726.8*
MJ-47	*Zubair Fn.*	*3373*	*3615*	*E747650*	*N3449300*

III. LITHOFAICES UNIT OF ZUBAIR FORMATION

The thickness of the Zubair Formation is about 225m "Table 2". It is divided into three lithofacies units by using GR & SP logs in Petral Software.

Table.2: Zubair Formation subdivisions thickness and occurrence.

Field Name	Well No.	Formation	Units	Top	Bottom	Thickness (m)
Majnoon	Mj-2	Zubair	Upper Middle Lower	3452 3450 3509	3450 3509 3665	2 59 156
Majnoon	Mj-4	Zubair	Upper Middle Lower	3465 3477 3525	3477 3525 3650	12 48 125
Majnoon	Mj-12	Zubair	Upper Middle Lower	3524.5 3530 3593	3530 3593 3725	5.5 63 132
Majnoon	Mj-15	Zubair	Upper Middle Lower	3478 3487 3542	3487 3542 3690	9 55 148
Majnoon	Mj-47	Zubair	Upper Middle Lower	3373 3405 3485	3405 3485 3615	32 80 130

The upper member is composed mostly of Shale layers. The middle member consists of thick layers of sand rocks. The lower member consists mainly of layers Shale with less sandy layers. "Fig. 4" shows the correlation of facies distribution for Zubair Formation in the wells (MJ-47, MJ-2, Mj-4, MJ12 & MJ-15) in Majnoon oil field.

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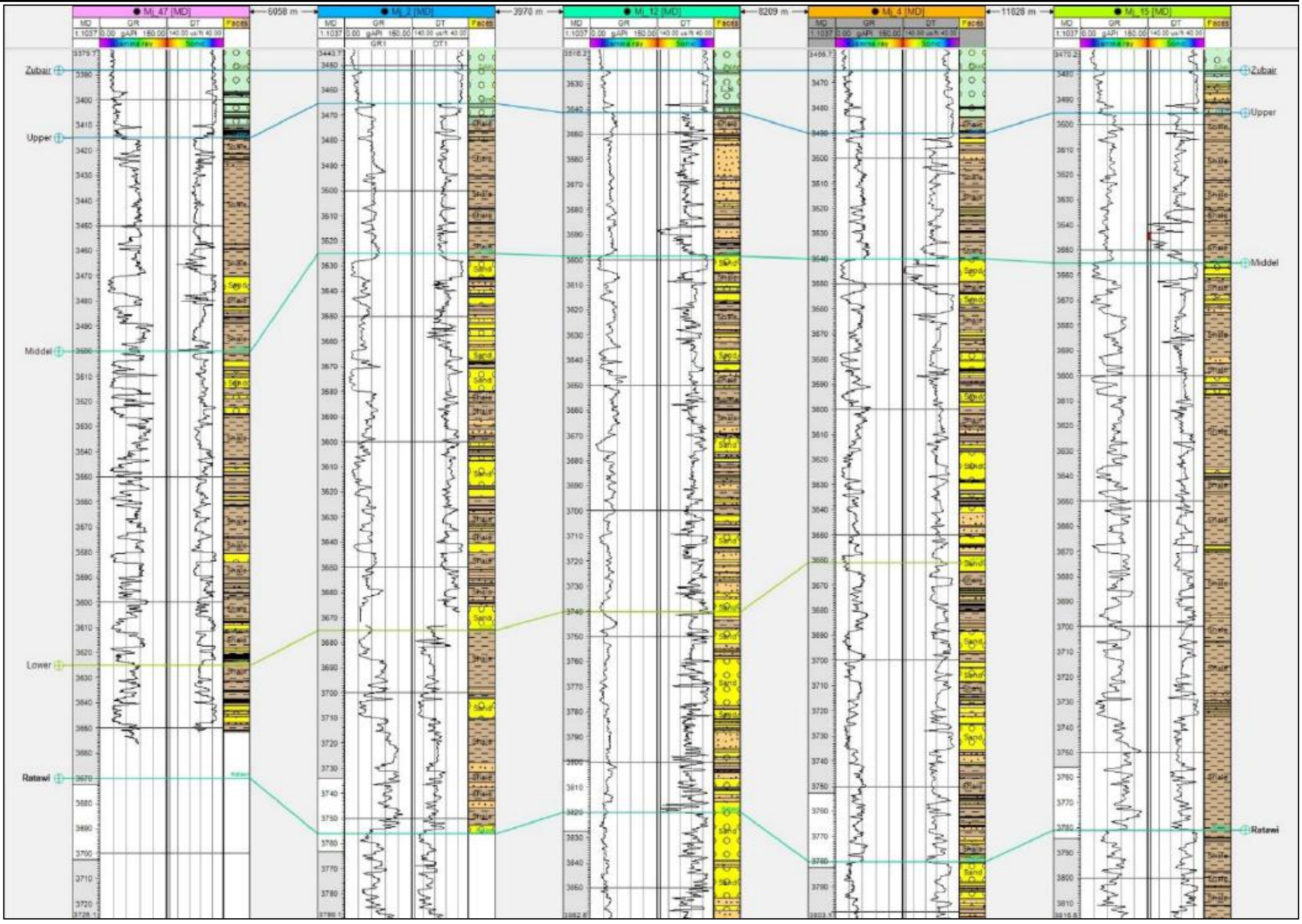

Fig. 4: The correlation of facies distribution of Zubair Formation in Majnoon Oil Field.

3.1 Lower member:

This zone is characterized by GR log values with many cycles as decreasing upward (bell shape) and grain size increasing. This unit also has (a funnel shape) in some positions. The thickness of this member is about (130m) in Majnoon oil field. "Fig. 5" shows the facies distribution through this member.

3.2 Middle member:

This zone is characterized by low gamma ray values with many cycles of fine to coarse sand (cylindrical shape of GR log) in the upper zone of this unit, and coarse up-ward (hour-glass shape) in some positions. Thickness of this zone is approximately (60m) Majnoon oil field. "Fig. 6" shows the facies distribution through this member.

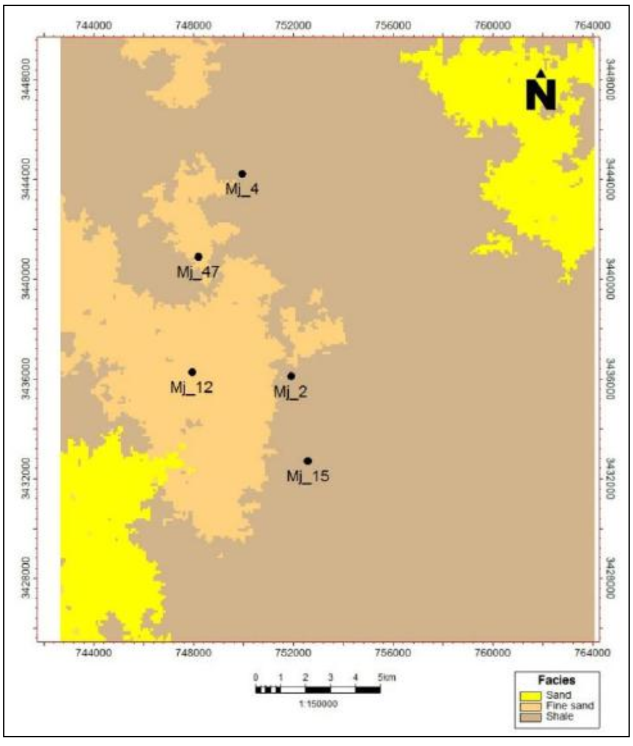

Fig. 5: Facies distribution map through the lower member of Zubair Formation in Majnoon oil field.

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3.3 Upper member:

This unit is characterized by high shale volume and the general GR log is almost forming a serrated shape, which refers to relatively increasing upward in gamma ray values. Thickness of the upper unit is approximately (10m) in the Majnoon oil field. "Fig. 7" illustrates the facies distribution through this unit.

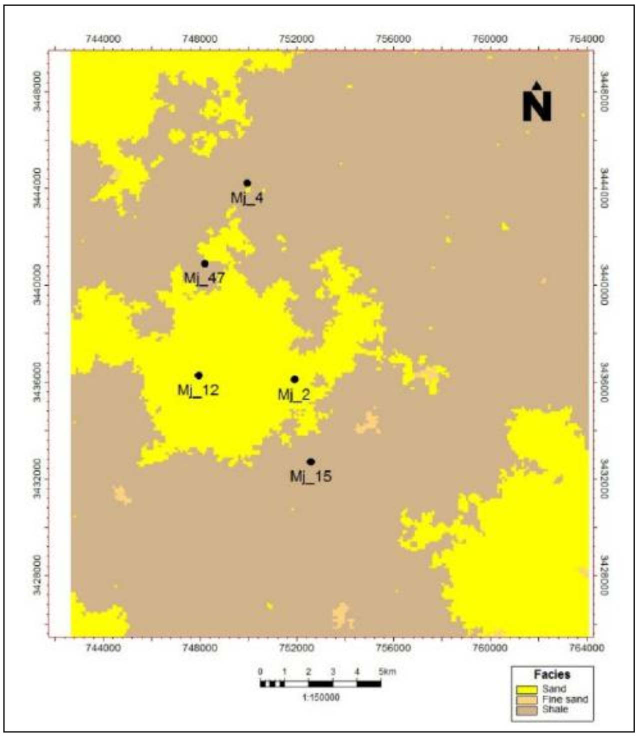


Fig. 6: Facies distribution map through the middle unit of Zubair Formation in Majnoon oil field.

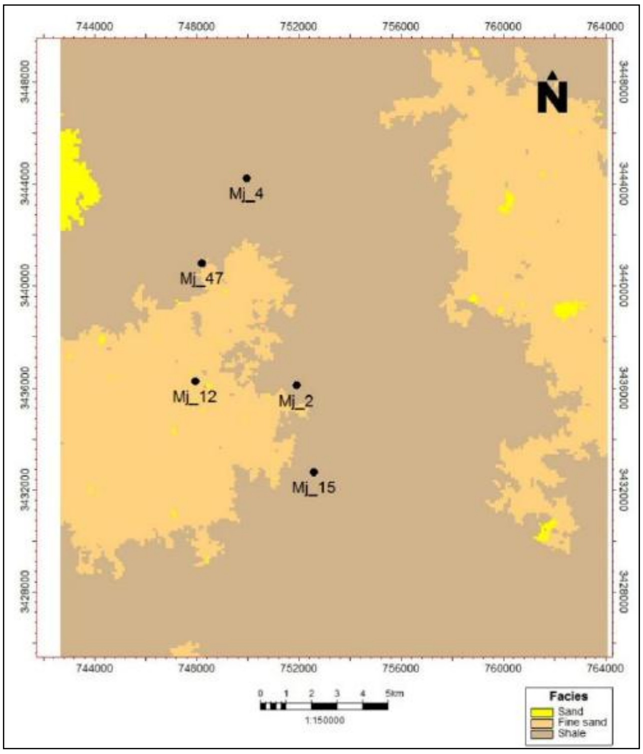
These units are well shown in "Fig. 8" which draw the facies variations profile along W-E of the study area passing through Mj-2 and Mj-12 wells. While "Fig. 9" shows the lithofacies intersection along N-S in Majnoon Oil Field passing through Mj-4, Mj-2 and Mj-15 wells.

IV. Porosity distribution:

The porosity of a rock is a measure of the amount of internal space that is capable of holding fluids. it is important because it represents a potential storage volume for hydrocarbons (Asquith and Gibson, 1982).

4.1 primary porosity:

This type is formed by syndepositional processes which contains visual and non-visual pores between the grains, so the spaces between the fragments of solid material deposited as sediment are the "primary" porosity. Porosity value can be obtained from the Sonic (Acoustic) log



(Asquith and Gibson, 1982).

Fig. 7: Facies distribution map through the upper unit of Zubair Formation in Majnoon oil field.

4.2 Secondary porosity:

This is formed after depositional processes. This type contains the pores which are created by dissolution processes and it be symmetrical formed by selective dissolution, which is called (moldic voids), or asymmetrical called (vuggy voids) or (channels) or (caverns). It may also be intercrystalline voids formed by dolomitization processes or fractures voids formed by different physical stresses (Asquith and Gibson, 1982).

4.3 Effective porosity:

The amount of internal space of void in a given volume of rock is a masseur of the amount of fluids a rock withholds and if this pore is interconnected and able to transmit fluids is called (Asquith and Gibson, 1982).

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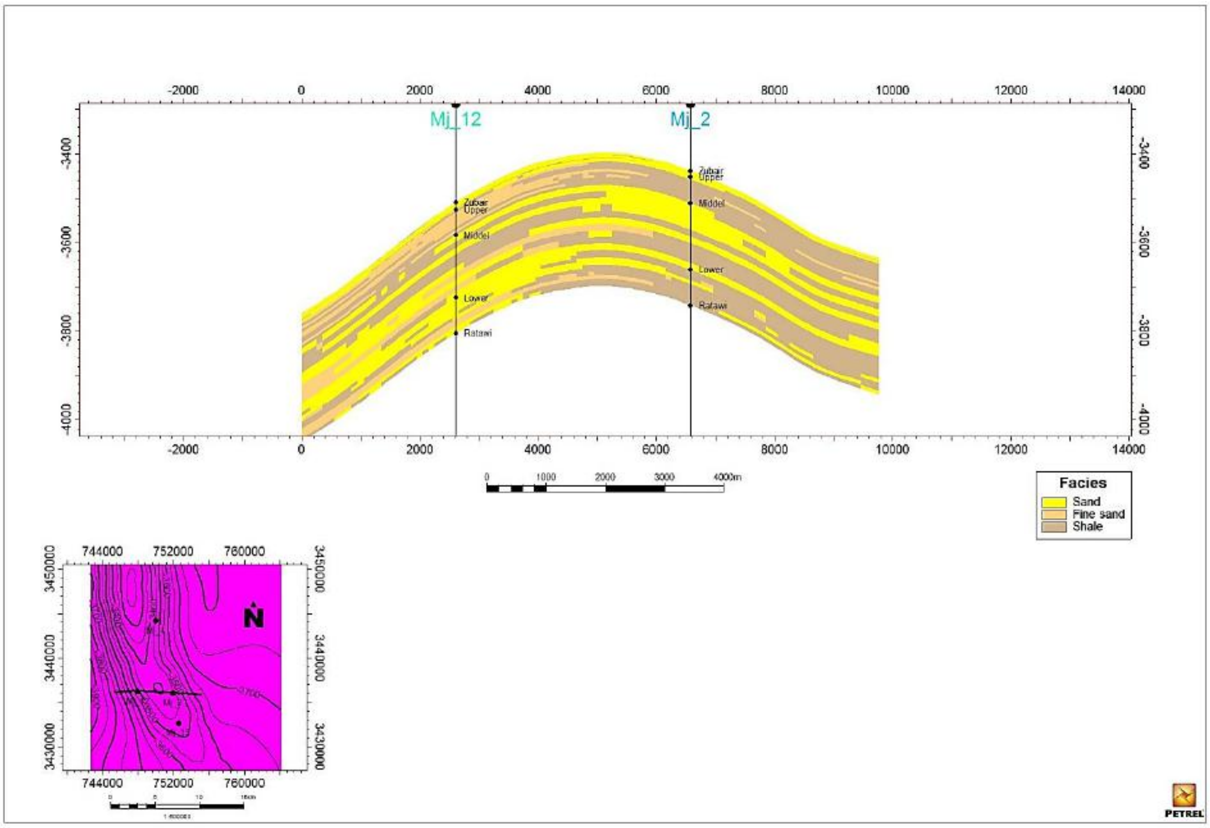

Fig. 8: Lithofacies intersection of Zubair formation along W-E trend in the study area.

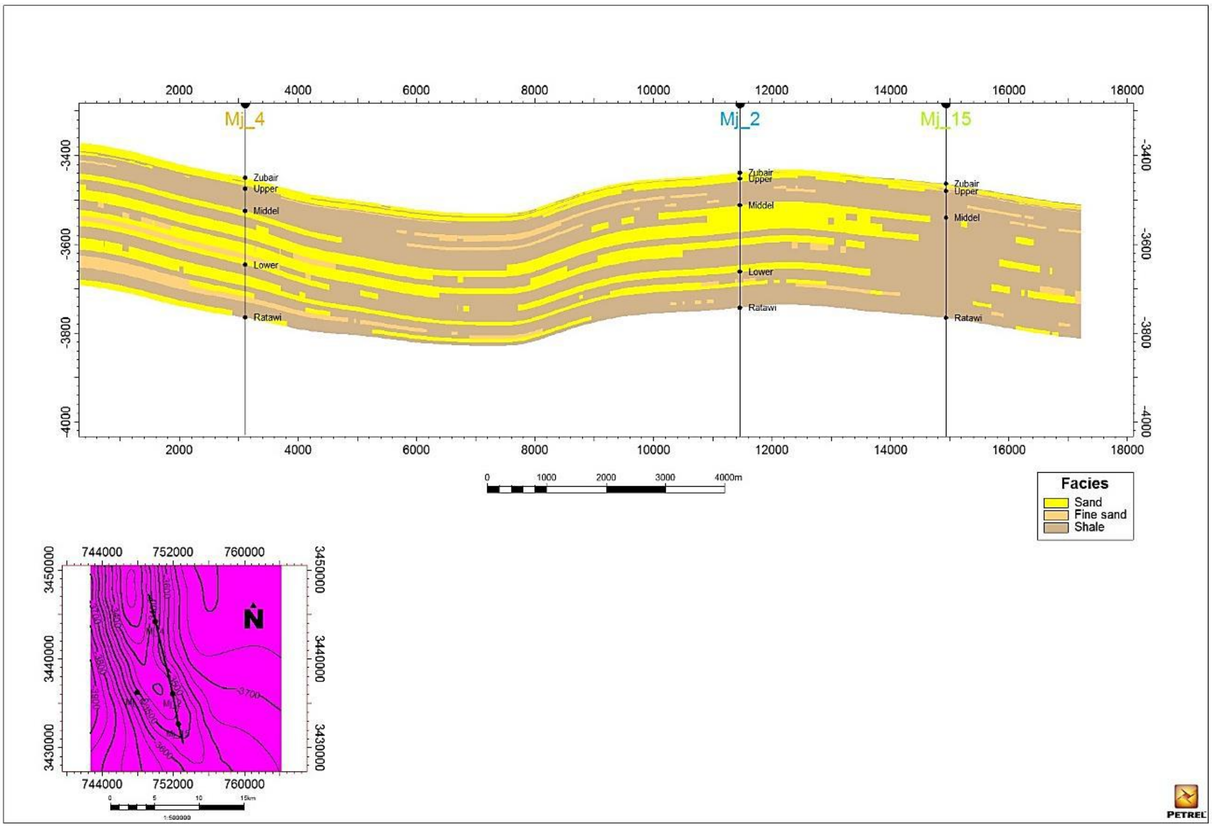

Fig. 9: Lithofacies intersection of Zubair formation along N-S trend in the study area.

The porosity of Zubair Formation sandstones declines towards the east of the Balambo-Garau Basin. Porosities of 30% in the Salman Zone decline to about 15% close to the border with Iran. Permeabilities in the formation range from 20 to 1800 mD with a mean of 700 mD (Jassim and Al- Gailani, 2006).

A better understanding of the relationships between porosity development, diagenesis, and sequence stratigraphy of the Zubair Formation is crucial to developing new play concepts. In all wells, the stacking pattern of rock-fabric units and diagenesis are systematic within systems tracts. Therefore, distribution of porosity and permeability is closely related to relative sea-level changes. For example, deltaic - shallow marine facies deposited during sea-level fall (low stand system tract) are porous and permeable. The same attributes can be observed in the upper part of the highstand systems tracts. In contrast, higher porosities largely occur within highstand systems tracts in shoal environments where the effects of relative sea-level fall. Thus, they are characterized by high primary porosity.

The various stages in the history of the depositional sequences of the Zubair Formation with late diagenetic processes modified the above logical interpretation of porosity development in the facies. The low stand systems tracts of the sequence have low sonic log values indicating high porosity due to the coarse grains of silt and sand. In the other sequence of the lower part of high system tract, the facies have lower porosity values because of the shale facies with low permeability.

V. Petrophysical model:

The above petrographic observations are in terms of rock-fabric units. These units can be most effectively converted into petrophysical parameters and into reservoir models.

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 porosity log (sonic log) in the studied boreholes showing an approximate matching with these zones. After the Petral application of sonic log drawing the porosity-depth relationship for each borehole rather than logs reading with depth. The sonic (porosity) log is studied to determination of the zones of void space that is interconnected and thus able to transmit fluids (effective porosity).

These zones are divided in to three types of rocks according to total porosity "Fig. 10":

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

5.1 Lower member:

The lower zone is represented the shale – dominated member of Zubair Formation, with low to non-pores rocks (type III). This appeared in all studied wells "Fig. 11 & 12". There are many presences of the moderate porosity type (II) of rock within the sand bands lithofacies appears in these wells. 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 Majnoon oil field. 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 lower part of this member. This type is distinguished the shale dominated rocks and poor sorted sandstone. This shows high resisitivity-high gamma ray. There are many sub horizons as bands within the lower horizon as high resistivity-low gamma ray. There is a good reservoir horizon with high oil saturation (low water saturation) in this unit.

5.2 Middle member:

This zone is characterized by two subzones. The upper one characterized by high-moderate active porosity (type I) while the lower one characterized by moderate active porosity (type II) and low to non-pores rocks (type III) because of the high ratio of shale "Fig. 13 & 14".

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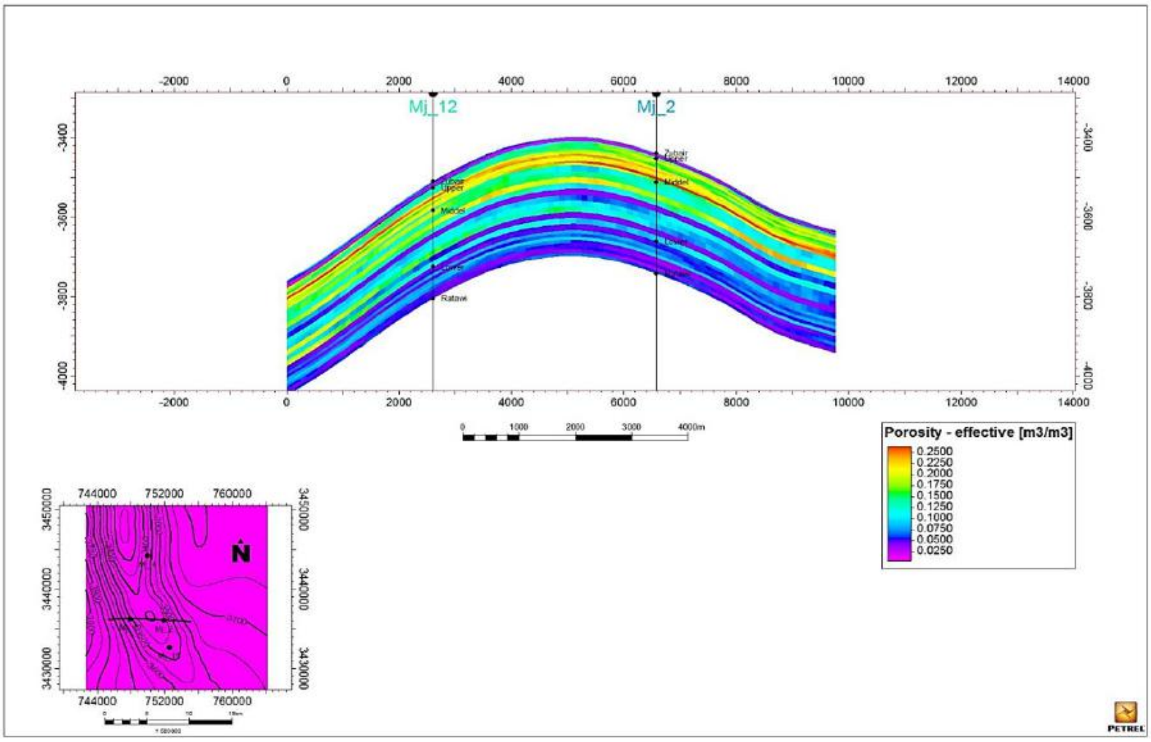

Fig. 10: East-West cross section porosity distribution of Zubair Formation.

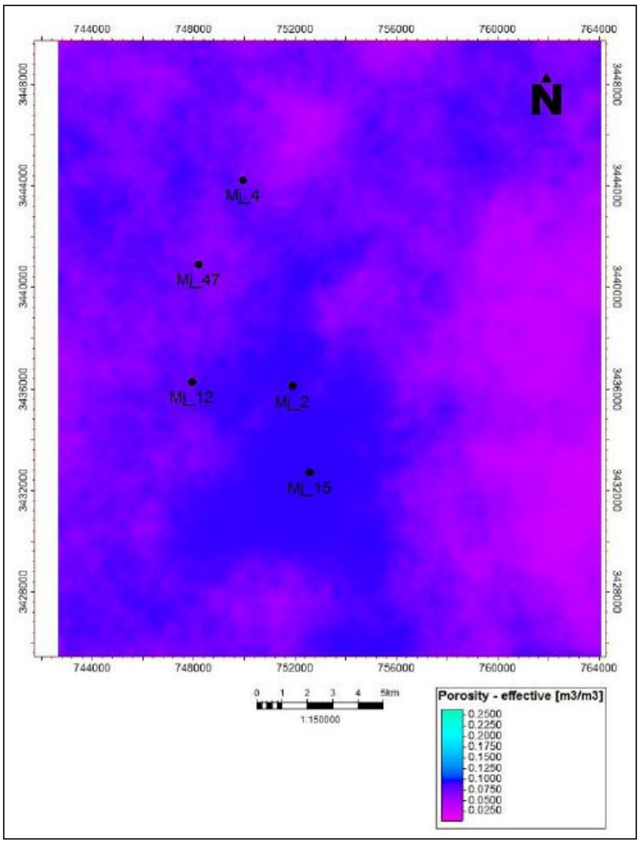

Fig. 11: Porosity distribution map through the lower member of Zubair Formation.

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

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This zone is characterized by two subzones in the southwestern part of Majnoon oil field. The upper part is characterized by high- moderate effective porosity (type I) while the lower part is characterized by moderate effective porosity (type II) because of presence a low volume of shale.

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. The high percentage of water saturation in this unit caused the lack of clarity of the oil saturation, which appears in a narrow band.

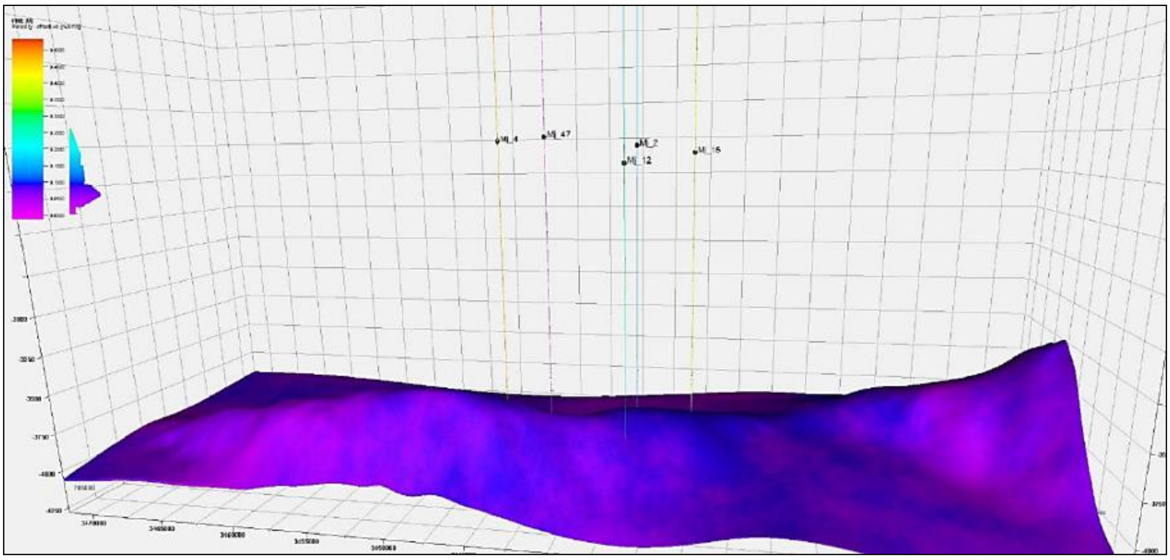

Fig. 12: 3D model of porosity distribution through the lower zone of Zubair Formation.

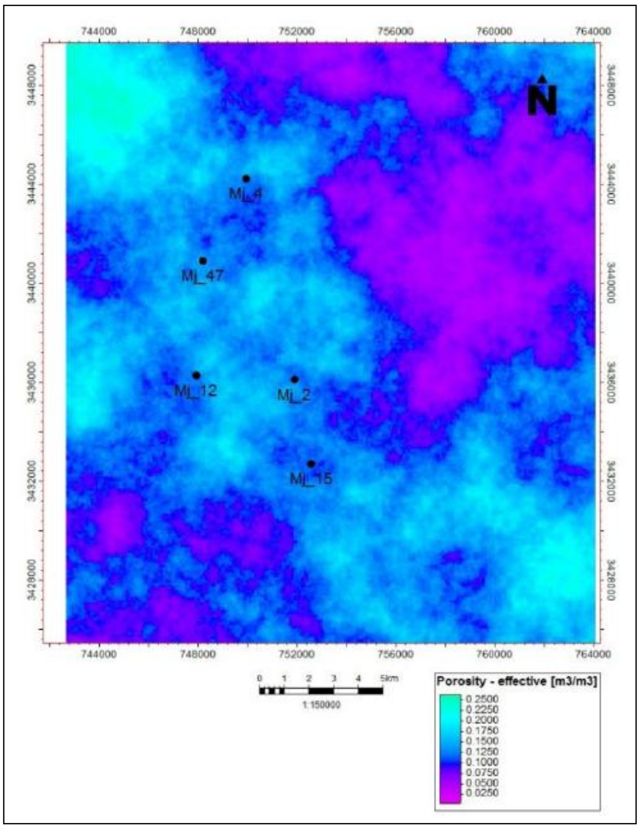

Fig. 13: Porosity distribution map through the lower zone of Zubair Formation.

5.3 Upper member:

This zone is containing high-moderate active porosity rocks (type I) because of well sorted coarse grains. This type is appeared through the upper unit at Majnoon oil field "Fig. 15 & 16". These features are matching with the sand rich rocks and low to moderate

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shale. There are limit presences for the high moderate effective porosity type (I) of rock within the sand bands lithofacies appears in these wells. The upper unit is characterized by alternative the high resistivity-low gamma ray horizon. There is good reservoir horizon with high oil saturation (low water saturation) in this unit.

VI. MODEL PROPERTIES (PROPERTY MODELING)

It is the process of filling the three-dimensional cells of the geological model with the characteristic readings of the logs (Sclumberger, 2013). The facies model is constructed according to the facies variations (horizontally and vertically) that interpreted from the well logs.

6.1 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 Majnoon oil field for Zubair Formation, the top lithofacies units of these wells and logs as well as the electrofacies in Petrel to build the model for Zubair formation.

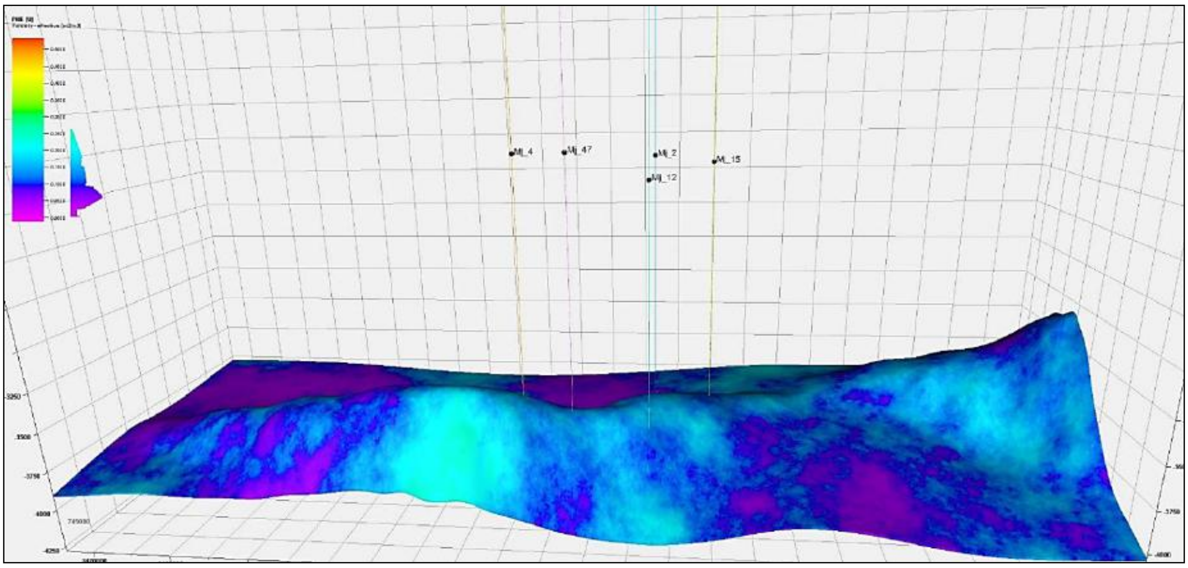

Fig. 14: 3D model of porosity distribution through the middle zone of Zubair Formation.

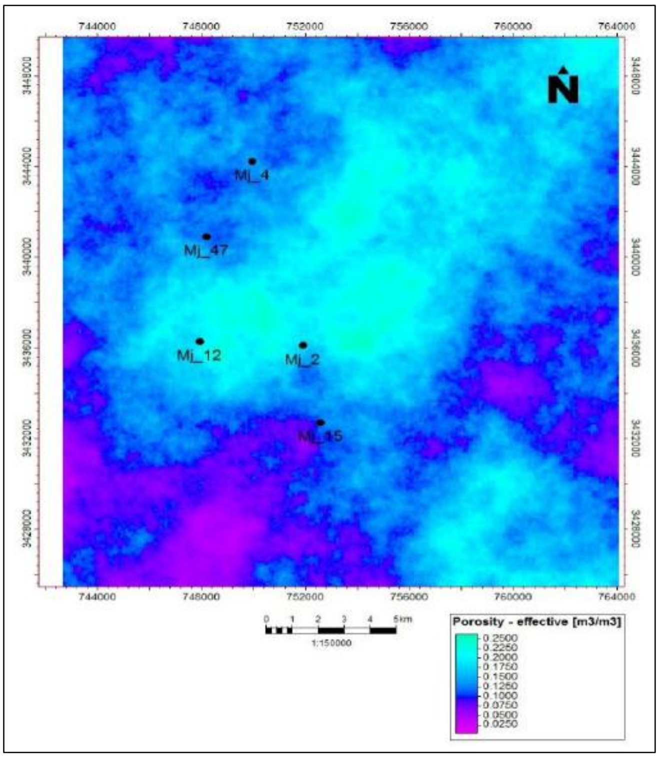

Fig.15: Porosity distribution map through the lower zone of Zubair Formation.

6.2 Construction of three-dimensional lithofacies model:

The construction of the clamp (Pillar Gridding) is the basic process to build the 3D model, it 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 as shown in "Fig. 17".

The other important process is the scale up which convert the reading of the logs to the shape of the three dimensional cell to fit with the reading of the logs to the gap of the clamp to know the horizontal and vertical thicknesses of the cell three-dimensional cells.

Finally, the three dimensional model can be constructed with the lithofacies variations through three zones in Zubair Formation as shown in "Fig. 18".

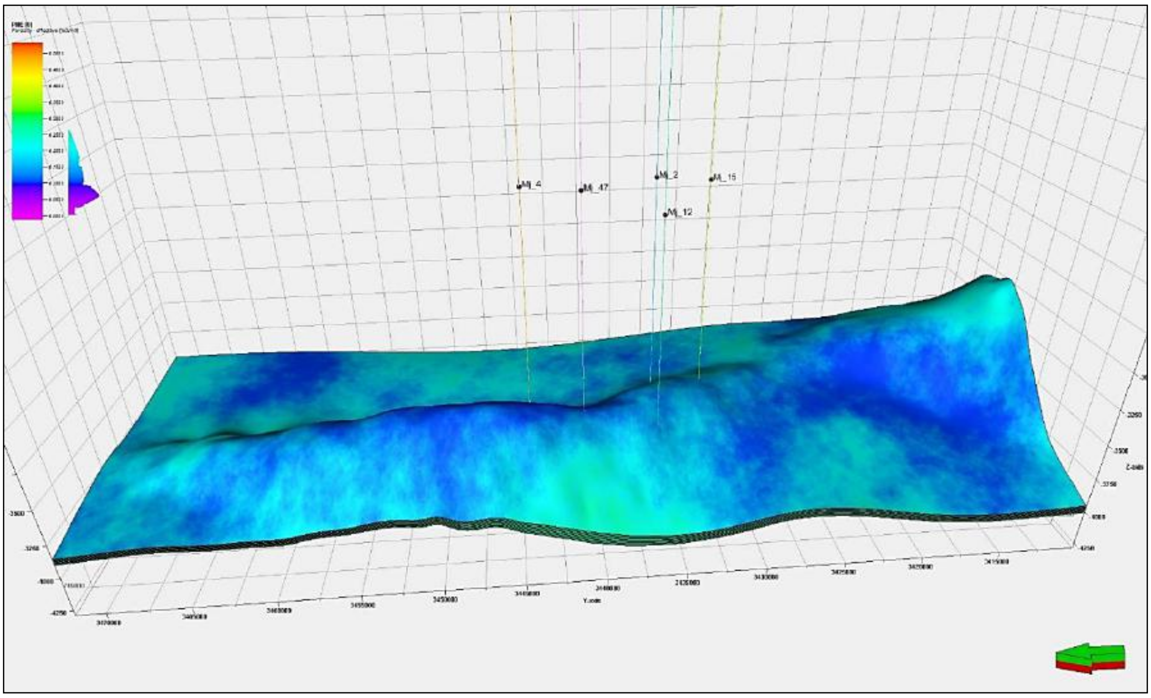

Fig. 16: 3D model of porosity distribution through the upper zone of Zubair Formation.

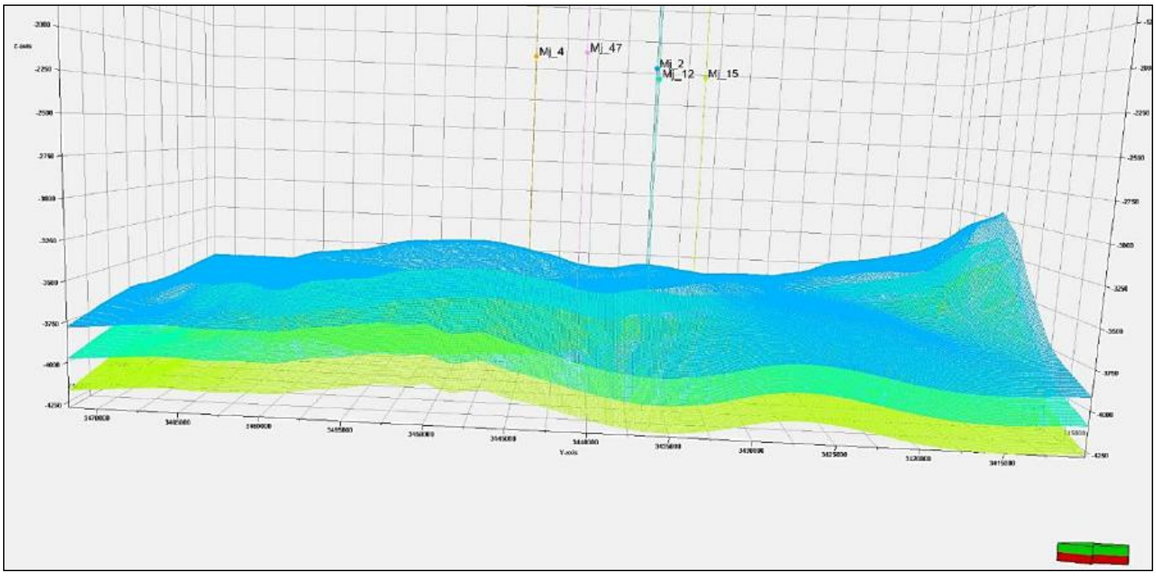

Fig. 17: 3D Pillar Gridding clamp of Zubair Formation in Majnoon Oil Field.

VII. CONCLUSIONS

The thickness of the Zubair Formation is about 200 m in the studied area. The sedimentary basin analysis is studied by understanding the mechanism of tectonics and climate in the Barremian succession, and studying the sediment supply sources and the basin porosity distribution to give an enhanced basin modeling.

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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 porosity log (sonic log) in the studied boreholes showing an approximate matching with these zones. The structural and/or stratigraphic position have the greatest influence on the degree of diagenetic and developed of petrophysical properties.

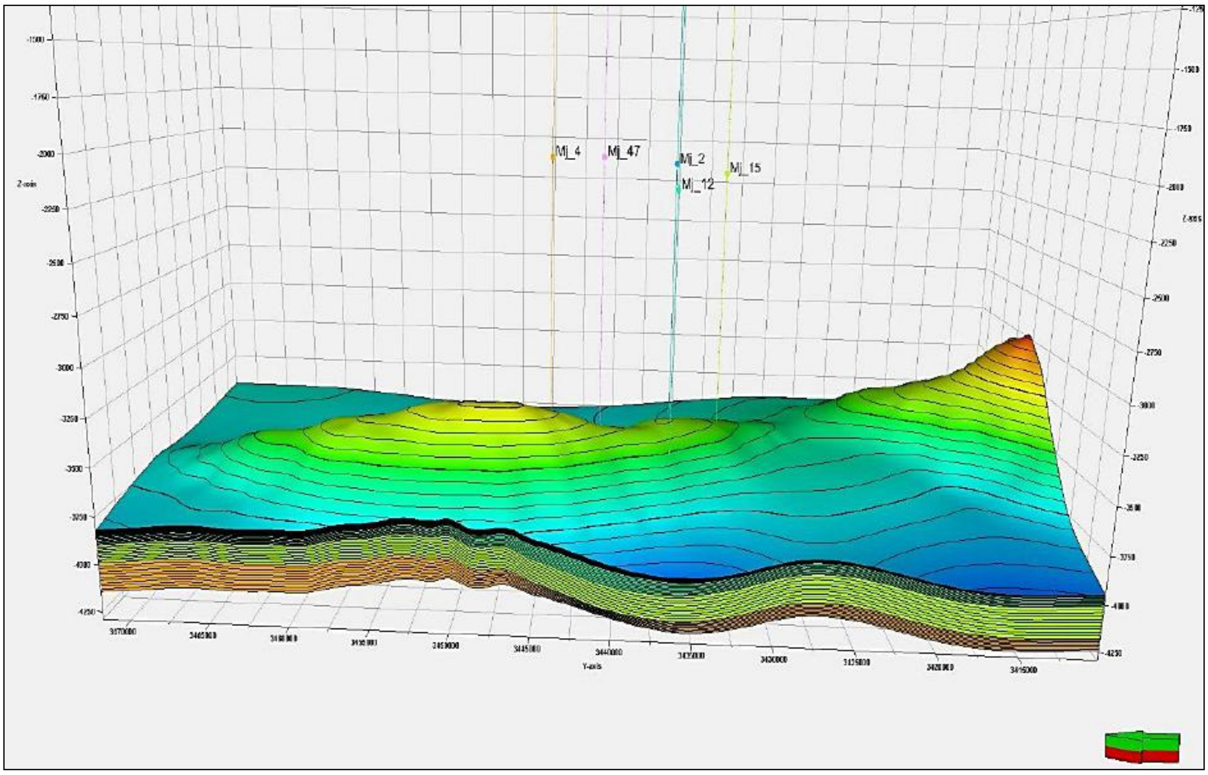

Fig. 18: Three dimensional model of Zubair Formation in Majnoon Oil Field.

The lower member of Zubair Formation is distinguished by shale dominated rocks and poor sorted sandstone. It has a high gamma ray with very low porosity. There are many sub horizons as bands within the lower horizon as high porosity-low gamma ray within the sand membesr. There is a good reservoir horizon with high effective porosity (low shale volume) in this unit. The middle member is dominated by high porosity-low gamma ray. The high volume of effective porosity in this unit caused the lack of clarity of the oil show, which appears in a narrow band. The upper unit is characterized by alternative the high porosity-low gamma ray horizon. There is good reservoir horizon with high oil show (low water saturation) in this unit.

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