



ISSN: 0067-2904

## 3D Reservoir Modeling of Buzurgan Oil Field, Southern Iraq

Munef Mahjoob Mohammed<sup>1\*</sup>, Hameed Mahmood Salih<sup>2</sup>, Kadhim Hmood Mnaty<sup>3</sup>  
<sup>1</sup>Department of Petroleum & Refining Engineering, College of Petroleum & Mining Engineering, University of Mosul, Mosul, Iraq.

<sup>2</sup>North Oil Company, Ministry of Oil, Iraq.

<sup>3</sup>Missan Oil Company, Ministry of Oil, Iraq.

Received: 28/1/2021

Accepted: 21/5/2021

### Abstract

This study aims to set up a 3D static model to characterize and evaluate Mishrif Formation which represents the main reservoir in Buzurgan Oilfield, southern Iraq. Six wells have been selected to set up structural, facies and petrophysical models of Mishrif reservoir by using Petrel Software. The structural model has been built based on the structural contour map of the top of Mishrif Formation, which derived from seismic interpretation, and by using different static algorithms in Petrel Software. The structural model showed that the Buzurgan Oilfield represents an anticlinal fold with two domes north and south separated by a depression. The petrophysical model included the porosity model and water saturation model. The results of petrophysical models showed lateral and vertical variations in the porosity and water saturation characteristics of the Mishrif reservoir. The integration between the structural and petrophysical models illustrated that the main productive zones in Mishrif reservoir are MB21, MC1 and MC2 units.

**Keywords:** Reservoir modeling, Mishrif Formation, Buzurgan oil field, Petrophysical modeling.

### تصميم موديل مكمني ثلاثي الابعاد لحقل البزركان النفطي، جنوب العراق

منيف محجوب محمد<sup>1\*</sup>، حميد محمود صالح<sup>2</sup> وكاظم حمود مناتي<sup>3</sup>

<sup>1</sup>قسم هندسة النفط والتكرير، كلية هندسة النفط والتعدين، جامعة الموصل، العراق

<sup>2</sup>شركة نفط الشمال، وزارة النفط، العراق

<sup>3</sup>شركة نفط ميسان، وزارة النفط، العراق

### الخلاصة

تهدف الدراسة الحالية الى تصميم موديل جيولوجي ثلاثي الابعاد لغرض توصيف وتقييم الخصائص المكمنية لتكوين المشرف والذي يمثل المكمن الرئيسي لحقل البزركان النفطي في جنوب العراق. تم اختيار ستة ابار نفطية لغرض تشكيل الموديل التركيبي، موديل السحنات وموديل الخصائص البتروفيزيائية لمكمن المشرف وباستخدام برنامج Petrel. الموديل التركيبي تم تصميمه بالاعتماد على الخارطة التركيبية للحد العلوي لتكوين المشرف والتي رسمت بالاعتماد على المسوحات الزلزالية. أظهر الموديل ان حقل البزركان يمثل طية محدبة تمتد باتجاه شمال غرب-جنوب شرق وتتألف من قبتين شمالية وجنوبية يفصل بينهما منخفض. بالنسبة للموديل البتروفيزيائي فقد تضمن تصميم موديلات لخصائص المسامية وتشبع الماء. أظهرت نتائج الموديل

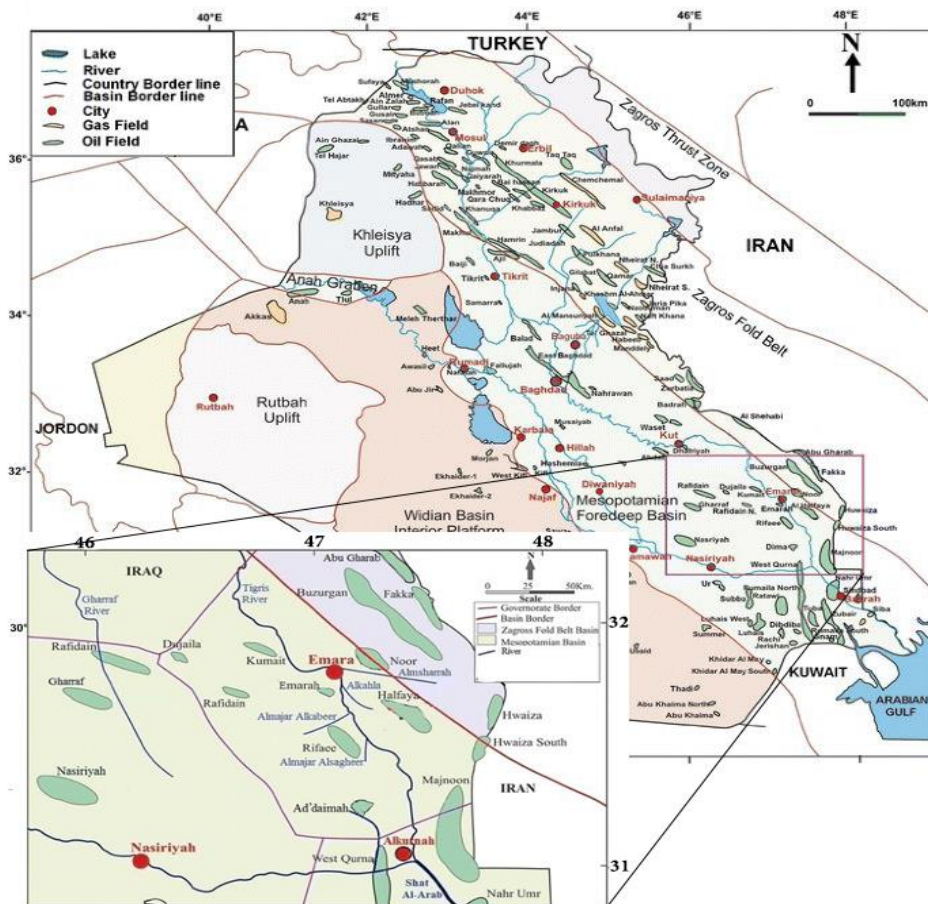
\*Email: m.m.mohammed@uomosul.edu.iq

البتروفيزيائي وجود تغييرات جانبية وعمودية في خصائص المسامية وتشبع الماء لمكمن المشرف. التكامل مابين  
 الموديل التركيبي والموديل البتروفيزيائي أظهر أن المناطق الإنتاجية الرئيسية في مكمن المشرف تشمل الوحدات  
 الطباقية ( MB21, MC1, MC2 ).

**1. Introduction**

Reservoir modelling plays an essential role in producing and developing hydrocarbon reserves, due to it captures the heterogeneity in reservoir characteristics, especially permeability which will impact reservoir performance. A reservoir model is a series of two-dimensional maps and well correlations, an inverted seismic volume defining the distribution of lithology and fluids in a section or a three-dimensional geocellular grid [1]. Buzurgan oil field is located in the southeastern part of Iraq, about 40 km to the northeast of Amara city in Misan Governorate (Figure 1). The oil field was discovered in 1970, and its development started in 1976.

This study aims to set up a 3D static model of the Buzurgan oil field to define the areal distribution of the main properties of Mishrif reservoir such as porosity, permeability, and water saturation. This static model will form the basis for the dynamic modelling of the field to simulate the fluid flow through the reservoir.

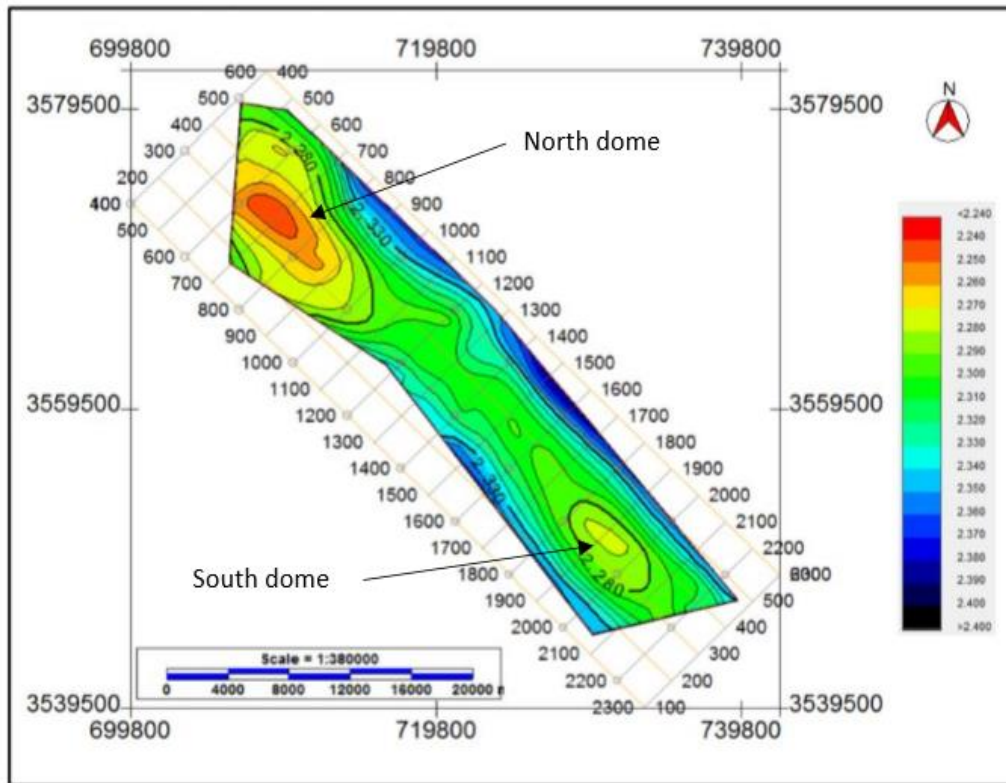


**Figure 1-** Location map of Buzurgan oil field, modified from [2]

**1. Geological setting**

The study area forms part of the unstable platform – Mesopotamian Basin zone [3]. The structure of the Buzurgan oilfield is an asymmetrical anticline fold extending towards NW-SE, and it has two domes north & south separated by a saddle, as shown in Figure 2, [4]. Mishrif Formation represents the main oil reservoir in Buzurgan oilfield, and the formation mainly consists of limestone and dolomite with interbedded shale, especially at the top of the formation. The depositional environment of Mishrif formation represents a carbonate

platform ramp [5]. Mishrif Formation consists of shallow open-marine, organic detrital limestone, rudist, coral-reef and lagoonal facies [6].



**Figure 2-** Structural contour map of the top of Mishrif Formation [4].

## 2. Materials and Methods

The data used in this study include well tops and well logs for eleven wells in the Buzurgan oil field and the structural contour map of the top of the Mishrif Formation. To achieve the aim of the study, the methodology that has been used was divided into five approaches:

### a- Stratigraphic modelling:

The stratigraphic modelling aims to define the stratigraphic scheme using well data, which form the basis for well-to-well correlation. The stratigraphic column in the Buzurgan oil field comprises Tertiary and Upper Cretaceous deposits (Figure 3). In this study, the tops for six wells have been used to set up the stratigraphic model of the Mishrif Formation. The stratigraphic correlation of the formation was made using Strater version 5 software.

### b- Structural modelling:

This type of modelling aims to reconstruct the geometrical and structural properties of the Mishrif reservoir by defining the structural map of the top of the reservoir. The objective of the structural modelling is to accumulate the large-scale heterogeneities such as faults or unconformities that affect fluid flow within the reservoir. The main input data for the structural modelling are seismic and well data. In this study, the data for eleven wells and the structural top map of Mishrif Formation that derived from the seismic interpretation were used to construct the structural model of Buzurgan oil field, and by using Petrel 2014 and Didger version 5 softwares.

	Age	Formation	Lithology	Note	
Tertiary	Pliocene	Bakhtiary	Marly clay + Gypsum + Sandy clay		
	Upper Miocene	Upper Fars	Gravel Sand + Siltstone + Anhydrite + Shale		
	Middle Miocene	Lower Fars – MB5		Shale + Anhydrite + Limestone + Dolomite	
		Lower Fars – MB4		Shale + Anhydrite + Salt + Limestone	
		Lower Fars – MB3		Anhydrite + Salt + Shale	
		Lower Fars – MB2		Salt	
		Lower Fars – MB1		Anhydrite + Shale + Dolomite	
	Burdigalian	Jeribe/Euphrates	Limestone + Dolomite	Asmari Formation	
	Aquitanian to Oligocene	Upper Kirkuk	Sand + Siltstone + Shale + Dolomite		
		M-L Kirkuk	Sand + Siltstone + Shale		
Eocene to Paleocene	Jaddala	Limestone + Marl + Chert + Shale			
	Aaliji	Marl + Limestone			
Cretaceous	Lower Maastrichtian	Shiranish	Chalky Limestone		
		Hartha	Chalky Limestone		
	Campanian to Santonian	Sadi	Limestone + Marl		
	Coniacian to Turonian	Tanuma	Shale + Marl + Limestone	Unconformity	
		Khasib	Limestone + Shale		
	Lower Turonian to Upper Cenomanian	Mishrif	Limestone		
		Rumaila	Limestone		
	Lower Cenomanian	Ahmedi	Marl + Limestone		
Mauddud					
	Nahr Umr				

**Figure 3-** The stratigraphic column of the Buzurgan oil field, modified from [7].

c- Facies modelling:

The facies modelling aims to define the lateral variation in the lithology. The modelling was established based on the lithological section from wells and the petrophysical properties calculated from well logs interpretation. This type of modelling needs to do a microscopic analysis to define the facies, but unfortunately, the data is unavailable. Therefore, the facies modelling was based on the lithology information available from wells and logs.

d- Petrophysical modelling:

This modelling is based upon the quantitative interpretation of well logs to define the main petrophysical characteristics of the Mishrif reservoir, such as porosity, permeability and water saturation. The performance of well logs was done by using Techlog 2011 Software.

### 3. Stratigraphic Modeling

Mishrif Formation represents the main reservoir in Buzurgan oil field. The formation consists of eight stratigraphic units (MA, MB11, MB12, MB21, MB22, MB23, MC1, MC2), which are separated by eight compacted zones [8]. The well tops for eleven wells in the Buzurgan oil field were used to build the stratigraphic model of the Mishrif Formation. A stratigraphic correlation of Mishrif Formation was constructed by using Strater software to show the lateral variation in stratigraphic units of the formation, Figure 4. The stratigraphic correlation illustrated vertical and lateral variations in the thickness of stratigraphic units of Mishrif Formation along the axis of the Buzurgan structure (Figure 4).



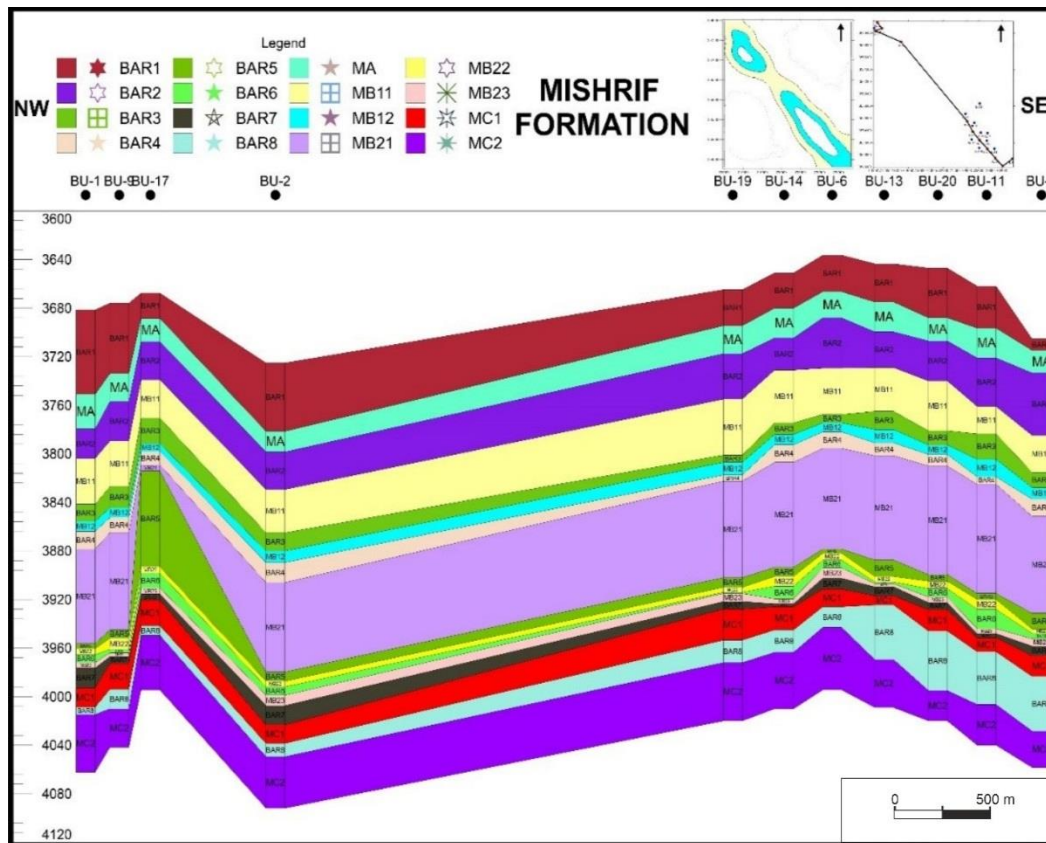
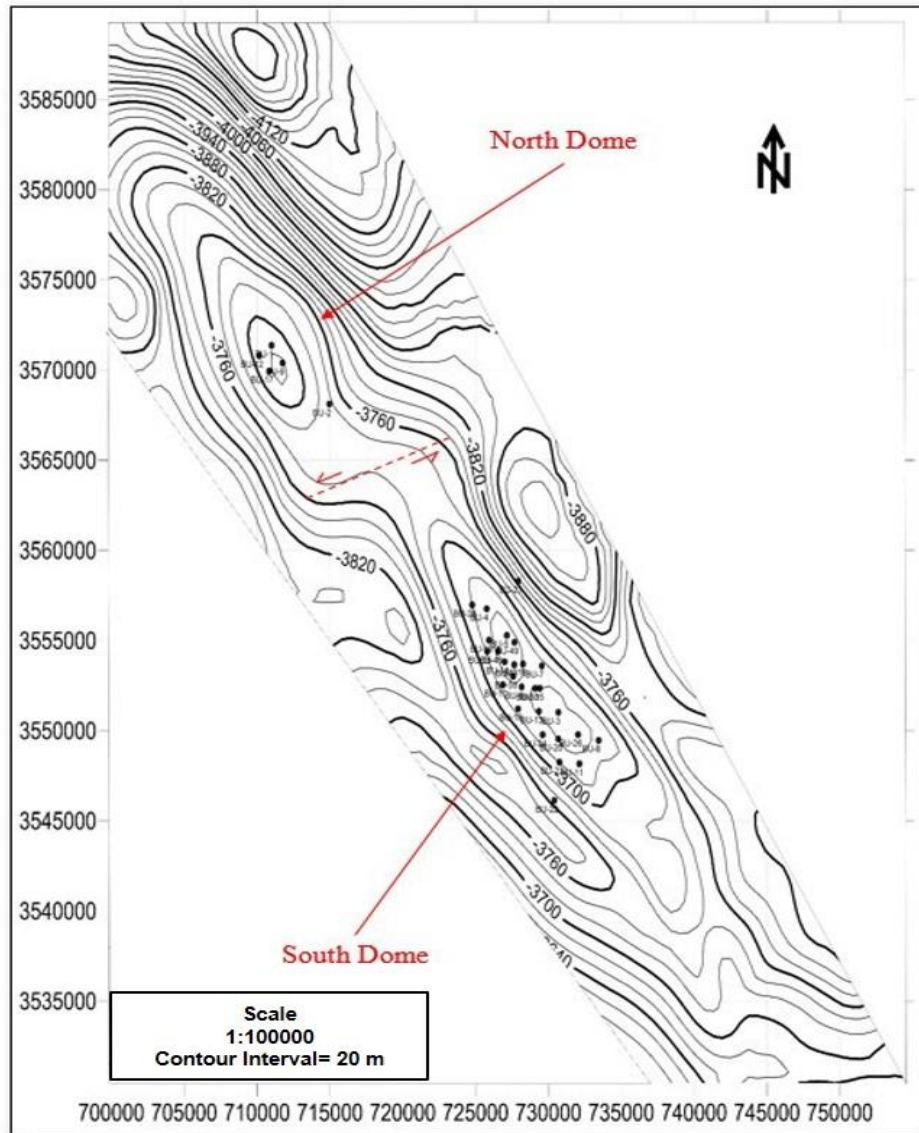


Figure 4- Stratigraphic correlation of Mishrif Formation by using Strater software.

#### 4. Structural Modeling

Structural modeling represents the first step in the reservoir modeling workflow and probably the most crucial in describing the large-scale geology of the oil field [1]. The objective of the structural modeling is to construct a reservoir framework that captures the large scale heterogeneities such as faults or unconformities that affect fluid flow in the reservoir. The main inputs of the structural modelling are structural contour map and well tops. The structural model of the Buzurgan oil field was constructed based on the structural contour map of the top of the Mishrif reservoir that has been derived from seismic interpretation by Missan Oil Company. The structural contour map was digitized, calibrated according to the UTM coordinates system, and adjusted according to well locations by using Didger software. The new structural map of the top of Mishrif reservoir showed a shifting in the fold axis between the north and south domes of Buzurgan structure, Figure 5. This shifting in the Buzurgan structure axis may refer to a strike-slip fault between the two domes as shown in Figure 5.



**Figure 5-** Structural contour map of the top of Mishrif reservoir, digitised by Didger software, modified from [9].

Structural modelling represents structural contour map of the Mishrif Formation zones by applying different statistic algorithms in Petrel software such as convergent interpolation, isochore interpolation and kriging interpolation. In the structural model, five contour maps have been generated of the top of Mishrif Formation that includes top of MB2 zone, top of MC1 zone, top of MC2 zone, and the base of MC2 zone.

The Mishrif Formation was divided into four zones (MA-MB1, MB2, MC1 & MC2), and each zone has been subdivided into a number of layers based on the petrophysical properties of each zone as shown in Figure 6.

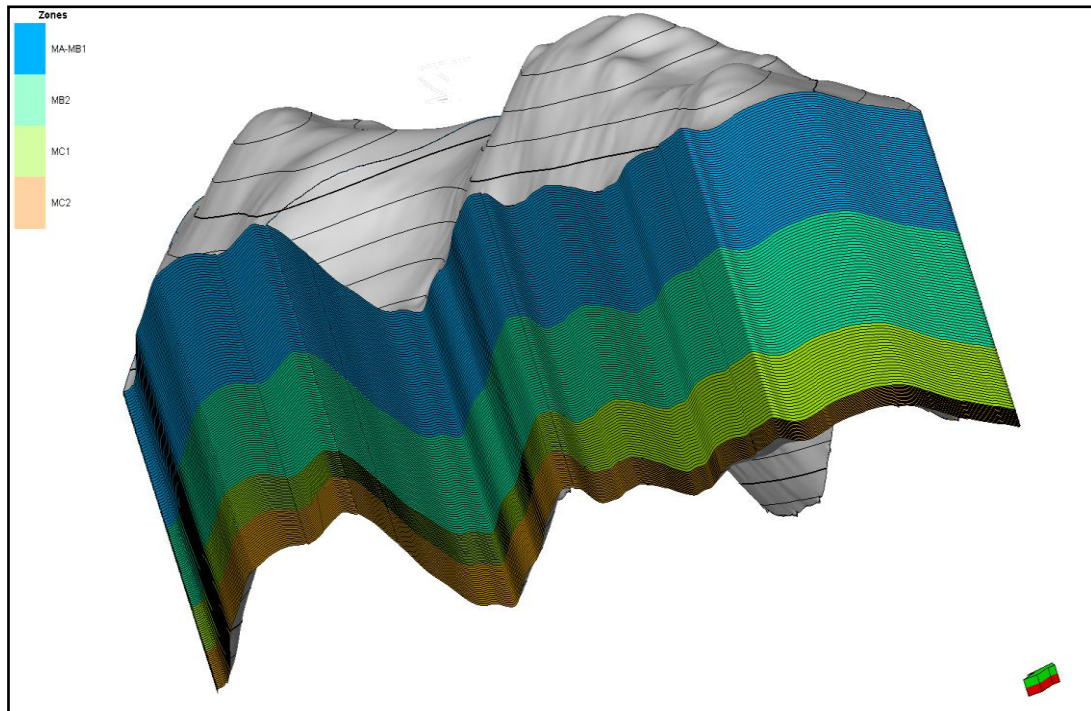


Figure 6- Three-dimensional model shows the zones and layers of Mishrif Formation.

### 5. Scale-up of Well Logs

The scale-up process of well logs averages the values to the cells in the 3D grid penetrated by the wells. Many statistical methods are used to scale up of reservoir properties, such as arithmetic mean and harmonic mean. Figure 7 shows the scale up of porosity property of Mishrif reservoir in Buzurgan oil field.

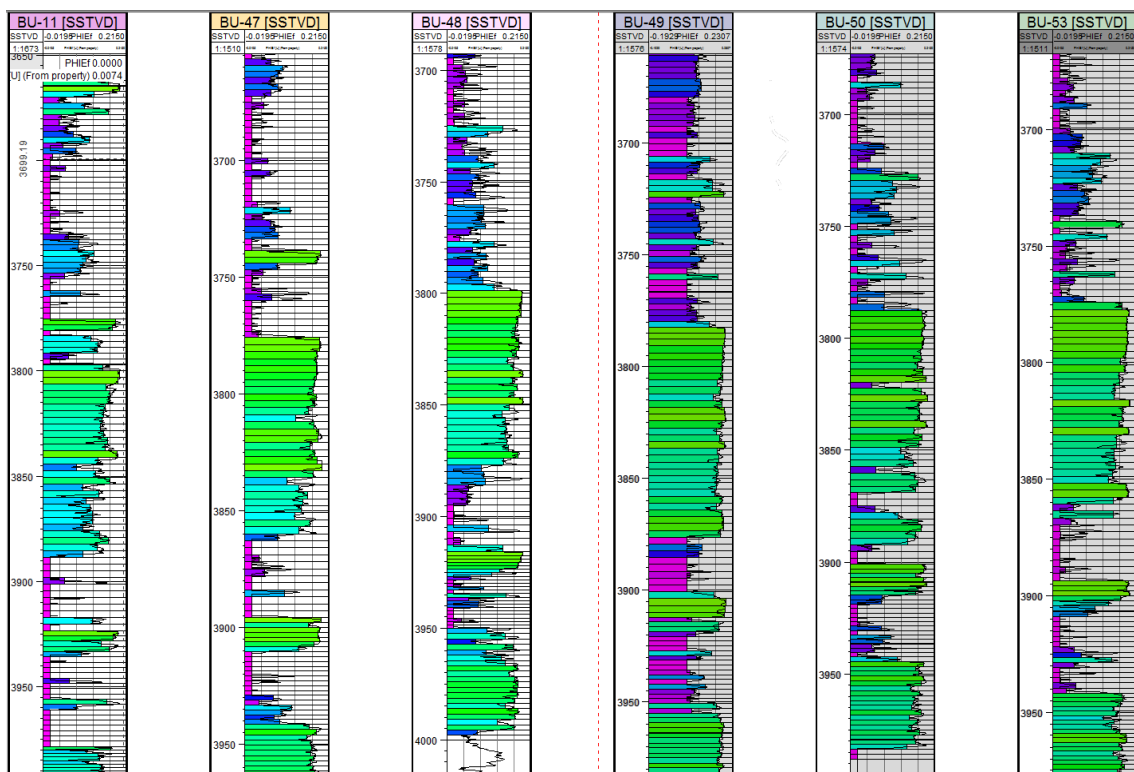


Figure 7- Scale up of porosity property of Mishrif Formation in Buzurgan oilfield.



### 6. Facies Modeling

Facies modelling was set up by using the truncated Gaussian simulation algorithm. The truncated Gaussian simulation transforms the upscaled facies into normal score space before calling the Gaussian simulation. The continuous simulated data at each cell will then be transformed back to facies code. Based on the M-N cross plot, the lithology of the Mishrif Formation has been determined as limestone and dolomite with a cap rock of shale. The 3D facies model of the Mishrif reservoir is shown in Figure 8 and Figure 9. The facies model shows that the most dominant lithology of the Mishrif Formation is Limestone.

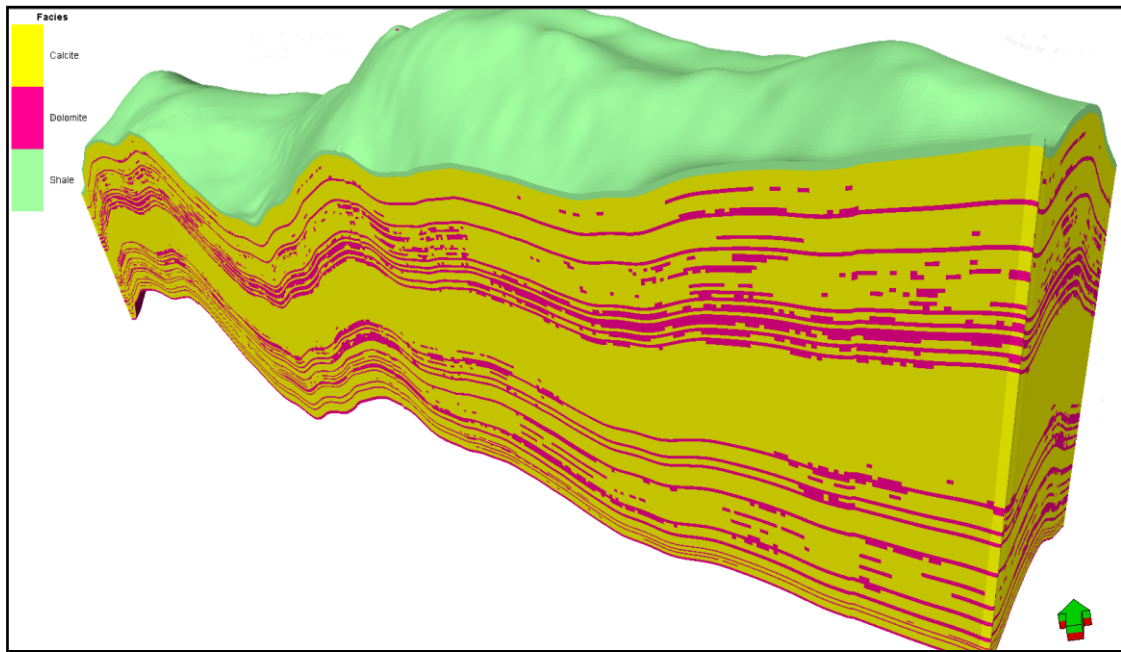


Figure 8- 3D facies model of Mishrif reservoir in Buzurgan oil field.

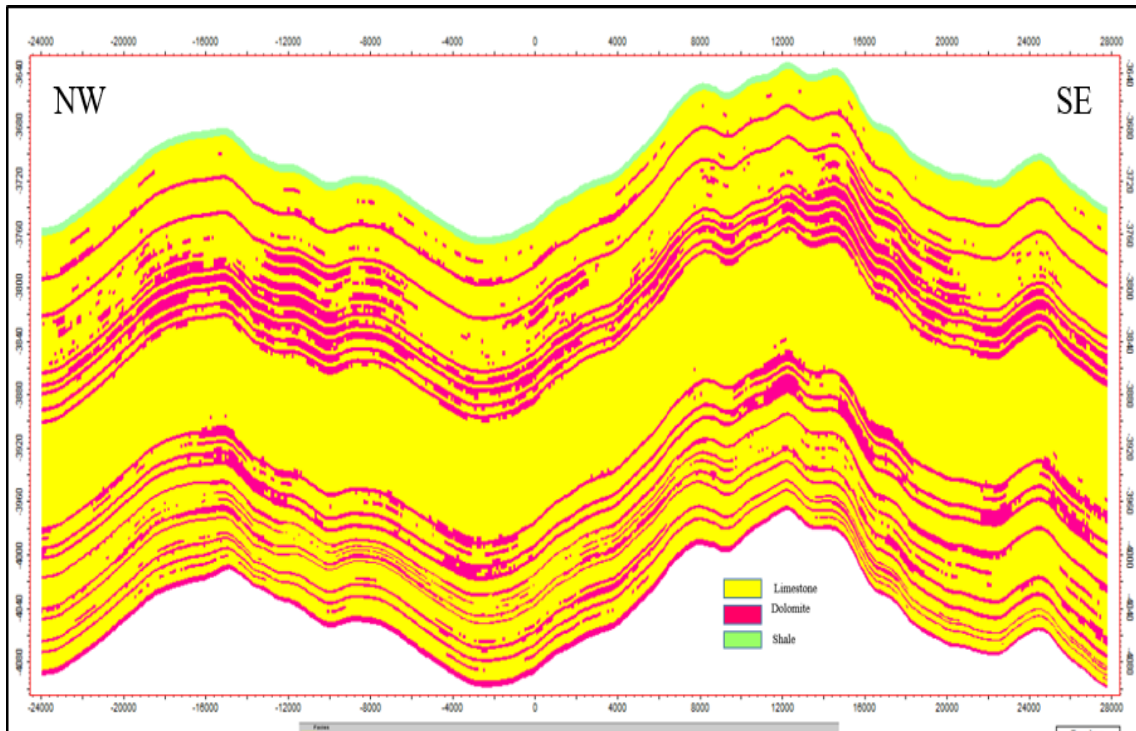


Figure 9- 2D cross section along with the facies model of Mishrif reservoir.



### 7. Petrophysical Modeling

The main aim of the petrophysical modelling is to capture the heterogeneity of the petrophysical properties of the reservoir, such as porosity, permeability and water saturation. In this study, the petrophysical modeling included building porosity and water saturation models for Mishrif reservoir in Buzurgan oil field using different modelling algorithms.

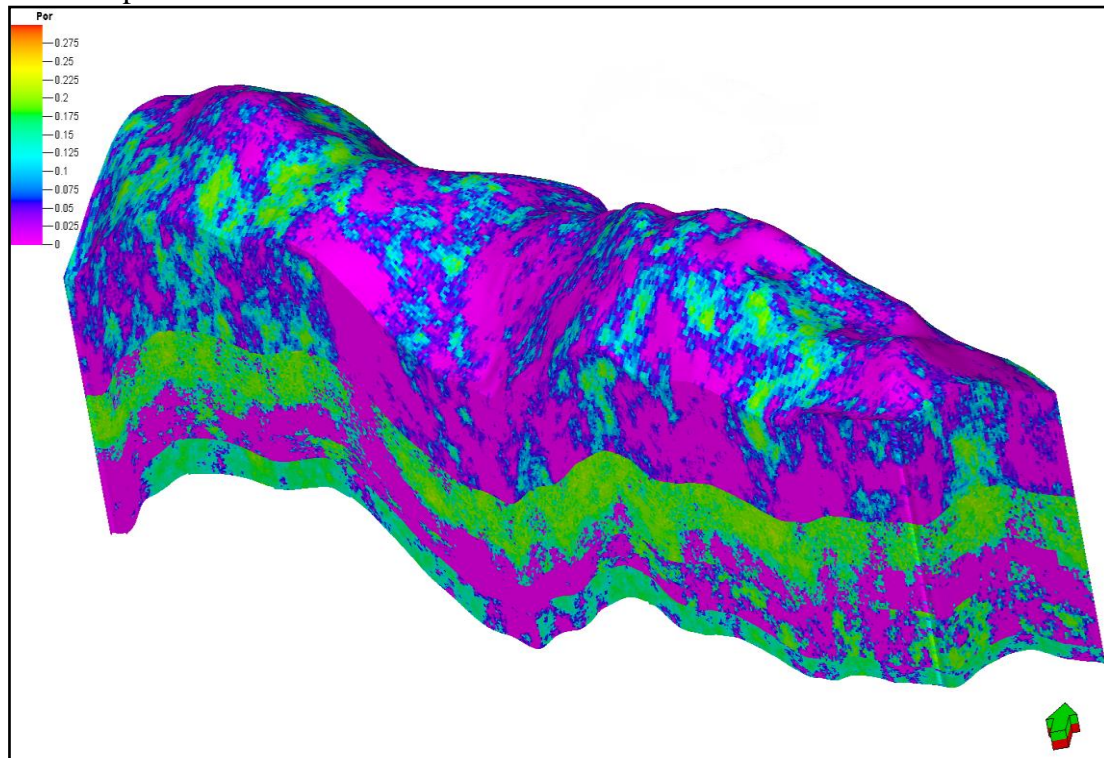
### 8. Porosity Modeling

Porosity is considered one of the important properties of hydrocarbon reservoirs, due to it represents the ability and capacity of reservoir to reserve fluids (e.g. oil, water). Mathematically, the porosity is defined as the ratio of all pores volume to the bulk volume of the rock [10]. The porosity property of the Mishrif reservoir has been determined based on the porosity logs (neutron & density) combined with the core analysis. The algorithms used to model the porosity property of the Mishrif Formation are shown in Table 1.

**Table 1-**The algorithms that were used in the porosity modelling

Zones	Algorithm
MA-MB1	Sequential Gaussian Simulation (SGS)
MB2	Sequential Gaussian Simulation (SGS) with Net/Gross Co-Kriging.
MC1	Sequential Gaussian Simulation (SGS) with the top of MC1 surface Co-Kriging.
MC2	Sequential Gaussian Simulation (SGS) with the top of MC2 surface Co-Kriging.

The porosity modelling of the Mishrif Formation showed a vertical and lateral variation in the porosity property (Figure10 and Figure 11). The model shows that the middle and lower parts of Mishrif Formation, which represent MB21 and MC2 units consequently, are characterized by a good porosity (15-20%) compared with the upper part of the formation (Figure11). The model illustrated that the porosity decreases toward the top of the Mishrif Formation (Figure11). This coincides with the facies model that showed an increase in the shale volume toward the top of formation.



**Figure 10-** 3D porosity model of Mishrif reservoir in Buzurgan oil field.

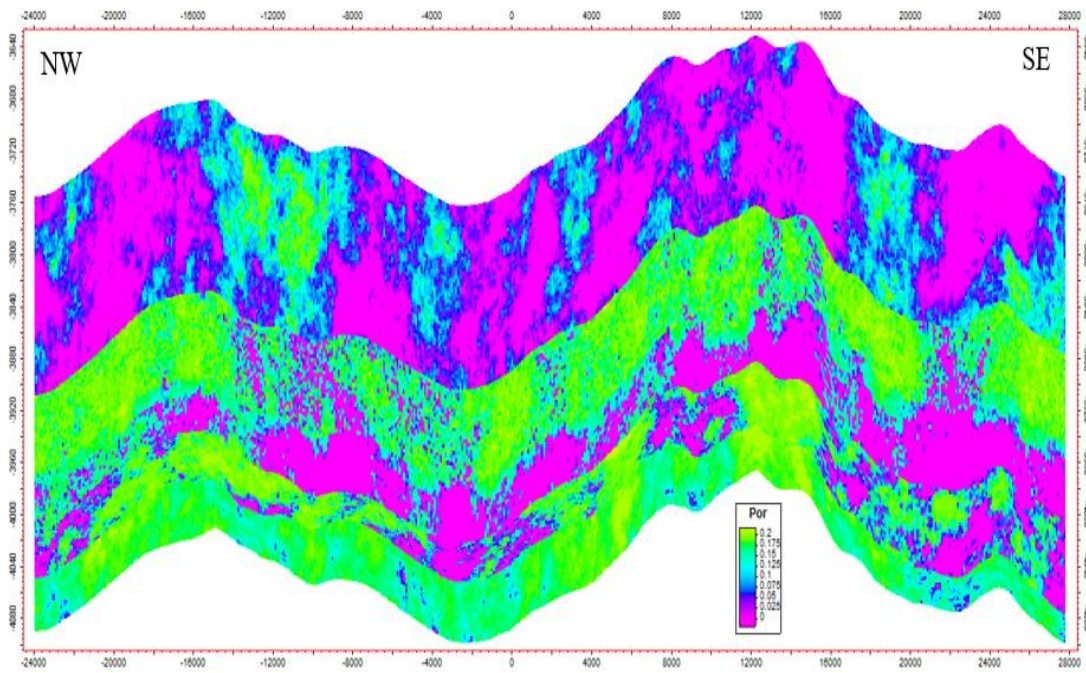


Figure 11- 2D cross section along the porosity model of Mishrif reservoir.

### 9. Water Saturation Modelling

Water saturation is defined as the ratio of the fluid volume within the pore spaces of the rock to the total volume of the pore spaces [11]. Estimation of water saturation is very significant because it leads to determining the hydrocarbon saturation. The water saturation model of the Mishrif reservoir was built based on the sequential Gaussian simulation algorithm and by using Petrel software. The 3D water saturation model showed that the upper and lower parts of the Mishrif Formation contain high to moderate values of water saturation (70 – 100%), while the middle part has a low value of water saturation (0 – 30%) (Figure 12). The NW-SE cross section of the water saturation model illustrated vertical and lateral variations in the water saturation of the Mishrif reservoir (Figure 13).

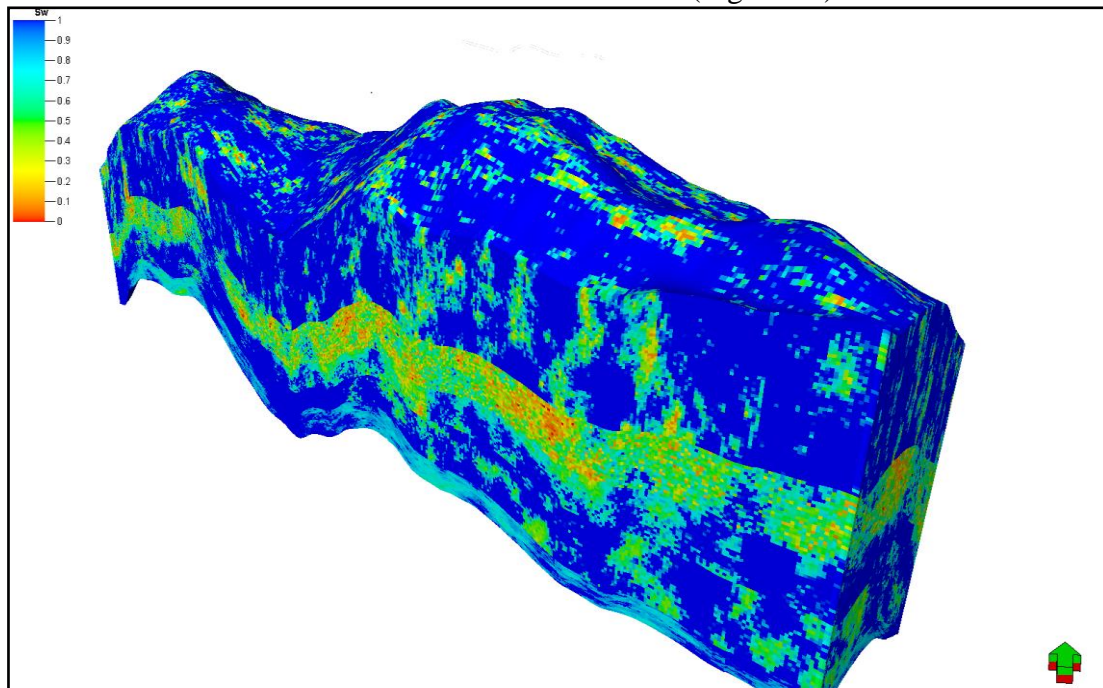
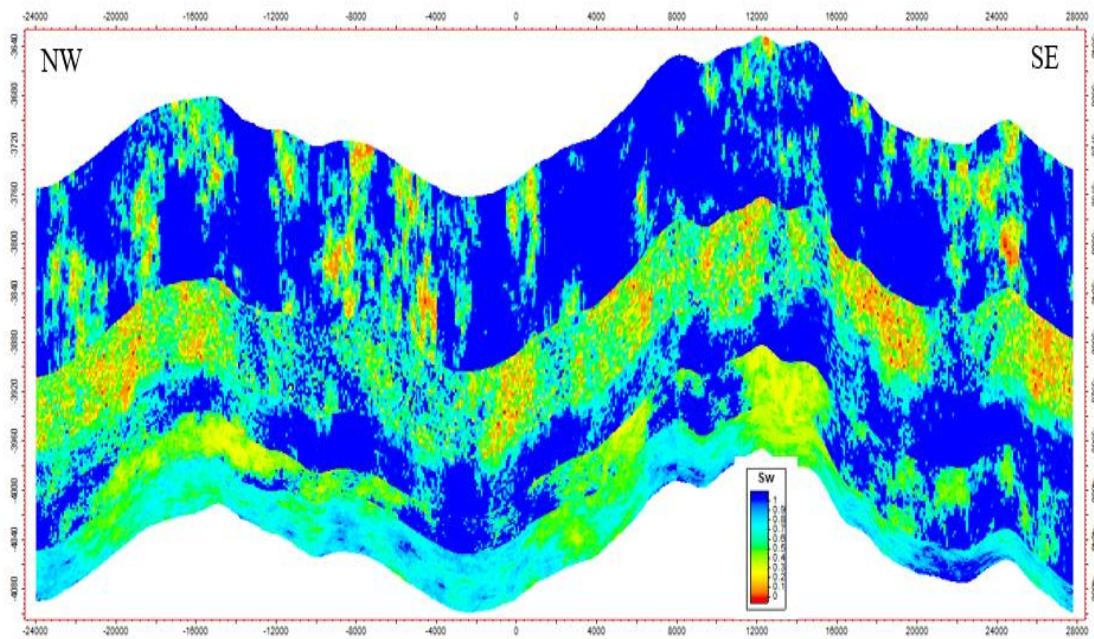


Figure 12- 3D water saturation model of Mishrif reservoir in Buzurgan oil field.





**Figure 13-** 2D cross section along with the water saturation model of Mishrif reservoir.

## 10. Conclusions

The reservoir model of the Buzurgan oil field has been set up based on the well data and structural contour map of the top of Mishrif Formation, and by using Petrel software. The structural model of the Buzurgan oil field illustrated that the field represents an asymmetrical anticline extending northwest-southeast with two domes separated by a depression. The facies model improved that the most dominant lithology of Mishrif reservoir is limestone and dolomite with interbedded shale layers. The petrophysical model of Mishrif reservoir was set up using the Sequential Gaussian algorithm, and it involved the porosity model and water saturation model. The porosity and water saturation models showed variations in the porosity and water saturation characteristics of the Mishrif reservoir vertically and laterally. The integration between the structural, porosity and water saturation models illustrated that the middle and lower parts of Mishrif reservoir have high porosity and low water saturation. This indicates that these parts represent MB21, MC1 and MC2 units of the reservoir are the main oil-producing units of Mishrif reservoir.

## Acknowledgement

The authors are grateful to the University of Mosul College of Petroleum and Mining Engineering for providing access to their facilities, which greatly helped to improve the quality of this research. In addition, the authors would like to acknowledge the Misan Oil Company for providing the data for this study.

## References

- [1] Cannon, S. “*Reservoir modelling: A practical guide*”. Wiley Blackwell, 329 p, 2018.
- [2] Al-Ameri, T.K., S.W. Al-Marsoumi and F.A. Al-Musawi, F.A. “Crude oil characterization, molecular affinity, and migration pathways of Halfaya oil field in Mesan Governorate, South Iraq”. *Arabian Journal of Geosciences*, vol. 8, pp. 7041-7058, 2015.
- [3] Buday, T. “*The Regional Geology of Iraq, Stratigraphy and Paleogeography*”. Dar Al Kutub Published house, Mosul, Iraq, 445 p, 1980.
- [4] Aldaraji, M. Q. and Almayahi, A. Z. “Seismic structure of Buzurgan oil field, southern Iraq”. *Iraqi Journal of Science*, vol. 60, no. 3, pp. 610-623, 2019.

- [5] Al-Ali, M.M., M.M. Mahdi and Alali, R.A. "Microfacies and depositional environment of Mishrif Formation, North Rumaila oil field, southern Iraq". *Iraqi Geological Journal*, vol. 52, no. 2, pp. 91-104, 2019.
- [6] Mahdi, T.A., Aqrawi, A.A.M., Horbury, A.D., and Sherwani, G.H. "Sedimentological characterization of the mid-Cretaceous Mishrif reservoir in southern Mesopotamian Basin, Iraq". *GeoArabia*, v.18, no. 1, pp. 139-174, 2013.
- [7] Sungul, G., and Saqqa, M. *Final well report Bu-26. Misan Oil Company and Weatherford Company*, 2011.
- [8] Reulet, J. "Sedimentological study of the Mishrif Reservoir". *Department of Exploration, ELF – Iraq*, 1970.
- [9] Maechal, P. and Arnas, L. "Interpretation on Buzurgan Structure with the Velocities of Buzurgan 1, 2 and 3". *ELF-E.R.A.P. –Iraq Branch Direction Exploration*, 1971.
- [10] Schon, J.H. "Physical properties of rocks". *Handbook of Petroleum Exploration and Production*, vol. 8, Elsevier, The Netherlands, 2011.
- [11] Brock, J. "Applied Open-Hole Log Analysis". *Volume 2, Gulf Publishing Company, Houston, Texas*, 1986.