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A High Resolution 3D Geomodel for Giant Carbonate Reservoir- A Field Case Study from an Iraqi Oil Field

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ABSTRACT

Constructing a fine 3D geomodel for complex giant reservoir is a crucial task for hydrocarbon volume assessment and guiding for optimal development. The case under study is Mishrif reservoir of Halfaya oil field, which is an Iraqi giant carbonate reservoir. Mishrif mainly consists of limestone rocks which belong to Late Cenomanian age. The average gross thickness of formation is about 400m. In this paper, a high-resolution 3D geological model has been built using Petrel software that can be utilized as input for dynamic simulation. The model is constructed based on geological, geophysical, pertophysical and engineering data from about 60 available wells to characterize the structural, stratigraphic, and properties distribution along the reservoir. Fourteen geological surfaces for all Mishrif units have been generated based on well tops data and top Mishrif structural map. The reservoir has been divided into 163 sublayers through the vertical direction and 160*383 grid cells in x-y direction with 9,988,640 total grid cells. A scale up process are performed for well log data, then, Sequential Gaussian Simulation algorithm are applied to fill 3D grid cells with properties values in areas away from wells. Pertophysical properties distribution for all reservoir zones are analyzed. The estimated initial oil in place of Mishrif through this model is close to that calculated in other previous studies.

Key words: Giant carbonate reservoirs, 3D geo-modeling, fine gridding model, Iraq oilfields.

موديل جيولوجي عالي الدقة ثلاثي الابعاد لمكمن كاربوني كبير- دراسة حالة حقلية من حقل نفطي عراقي

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الخلاصة

انشاء موديل جيولوجي دقيق ثلاثي الابعاد للمكامن الكبيرة المعقدة يعتبر مهمة ضرورية لتقييم حجوم الهايدروكاربونات وكذلك كدليل لانجاز امثل تطوير للمكمن. الحالة المدروسة في هذا المنشور هي مكمن المشرف في حقل الحلفاية النفطي، وهو مكمن عراقي كاربوناتي كبير. المشرف يتكون اساسا من صخور جيرية يعود عمرها الى العصر السينومايني المتاخر. معدل السمك الكلي للمشرف هو 400 م. في هذا المنشور، تم بناء موديل جيولوجي ثلاثي الابعاد عالي الدقة باستخدام برنامج بترل. وذلك

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لكي يستخدم كمدخل للنمذجة الحركية للمكمن. الموديل تم بناءه اعتمادا على البيانات الجيولوجية، الجيوفيزيائية، البتروفيزائية, والهندسية من حوالي 60 بئر متوفر وذلك لغرض تمثيل التركيب, الطباقية, ونوزيع الخواص على طول المكمن. اربعة عشر سطح جيولوجي لكل وحدات المشرف تم تكوينها اعتمادا على بينات قمم الابار وكذلك الخريطة التركيبية لقمة المشرف. المكمن قسم الى 163 طبقية فرعية على طول الاتجاه العمودي للمكمن وكذلك 160*383 خلية في الاتجاه الافقي خلال المحورين السيني والصادي وعدد الخلايا الكلي هو 9,988,640. عملية الاختزال اجريت لكل بيانات تسجيل الابار، ومن ثم استخدمت طريقة كاوس التتابعية الاحصائية لغرض ملىء الخلايا ثلاثية الابعاد بقيم الخواص في المساحات البعيدة عن الابار. تم تحليل توزيع الخواص البتروفيزيائية لكل الوحدات المكمنية. النفط الاصلي المحسوب لمكمن المشرف خلال هذا الموديل هو متقارب جدا مع ذلك المحسوب في الدراسات السابقة.

الكلمات الرئيسية: مكامن كاربونية كبيرة، موديل جيلوجي ثلاثي الابعاد، التقسيم الدقيق للموديل، حقول النفط العراقية.

1. INTRODUCTION

One of the essential steps before building a dynamic simulation model is undoubtedly the definition of a geological model or static model of the reservoir rock, (**Cosentino, 2001)**. Generally, the oil productivity of a reservoir is depending on its stratigraphic, structural, and petrophysical properties. Hence, a representative geological model is an essential condition for the subsequent dynamic modeling phase, (**Vinh Phan, 2002).**

The main goal of this paper is to build a fine three dimensional geological model based on field data available from about 60 wells passed through Mishrif formation in Halfaya oilfield. This 3D geo-model includes structural, stratigraphic and the petrophysical to characterize the variation of these properties along Mishrif formation and finally estimate the oil initially in place for both whole Mishrif formation and subunits.

1.1 Area of Study

Halfaya oil Field is one of the Iraq's seven major oilfields and was discovered more than 30 years ago. The field is located in Missan province in Iraq southeast, 35 Km southeast of Amara city, as shown in **Fig.1**. It is a gentle elongated anticlinal structure with its long axis extending in a NW – SE direction about the structure is approximately 32 km long by 8.8 km wide. The structure was defined by 2D seismic data shot during years 1976 and 1980. Up to June 2010, eight wells were drilled by Missan Oil Company. The deepest well (HF-2) reached a depth of 4,788 m, down to the Lower Cretaceous Sulaiy formation. Significant oil accumulations have been discovered in multiple reservoirs of Tertiary and Cretaceous formations. In addition, 3D seismic acquisition was executed through 2010 and 2011, covering a total area of 496 km2. Up to June 2017, a total of 197 new wells have been completed drilling.

2. MODEL CONSTRUCTION

A high resolution three dimensional geological model for Mishrif reservoir has been constructed within (**Petrel-2013**) software that will be utilized as input for dynamic simulations. This software is mainly used for three dimensional geo-modeling as an input for subsequent simulation models and deployed by Schlumberger company, (**Schlumberger, 2013)**.

For the purpose of this paper, a data base for about 60 wells of Mishrif formation in Halfaya oil field was created through software. All these data have been introduced to the software through the main data base. The work flow design is utilized for the study and wide range of functional tools in the software include: 3D visualization, well correlation, depth conversion, 3D mapping, and 3D grid design for geology simulation, well log up scaling, petrophysical modeling, data analysis, volume calculation.

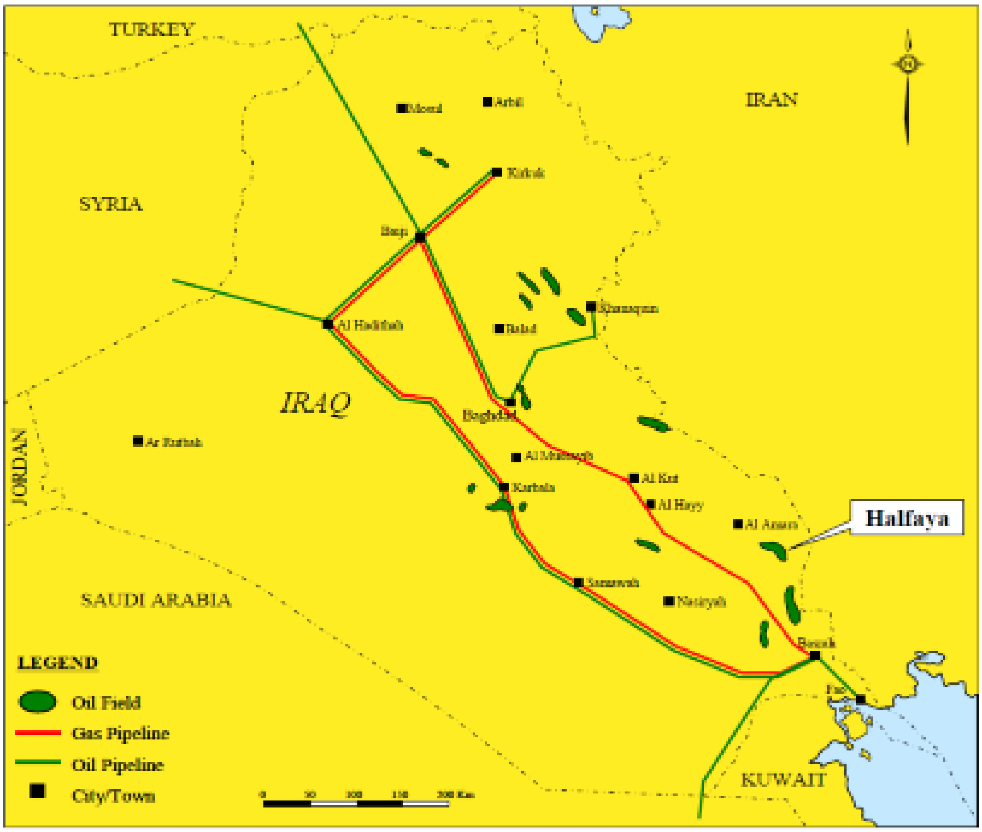

Figure 1. Halfaya oil field location.

2.1 Data Collection and Preparation

To begin the first stage of constructing Mishrif geological model, all required data should be gathered and prepared in many files, one file for each data object, then entered to software. These data files are included:

1 .Wellheads: involve the surface location for every well and the target measured depth.
2 .Well tops: points along the path of each w ell to mark a depth of each zone through formation.
3 .Well trajectories or well deviation survey: involve the well path data for all deviated, horizontals, and multilateral wells. The main data in these files include values of measured depth, inclination angle, azimuth and true vertical depth along hole path during drilling operations.
4 .Well logs and core data: include raw and interpreted data that are imported for whole Mishrif formation passing through the well path, Petrochina.

2.2 Structural Modeling

Structural model accuracy and consistency is crucial to the proper distribution of petrophysical properties into the geo-cellular model. Structural Model of Mishrif reservoir have been constructed by many steps which are illustrated in the following items.

2.2.1 Geological Surface Generation:

Fourteen geological top surfaces for all Mishrif units have been constructed before building a 3D grid model. These surfaces are generated based on the well tops and updated depth structural map of top Mishrif reservoir. This map was created depending on 3D seismic survey results that were achieved in 2010, **(Petrochina, 2017)**. **Fig.2** shows the geological surface of top Mishrif (Top MA1). Additional surfaces for other 13 units such as MA2, MB1-1, etc. were mapped depending on well tops data and top MA1 structural map were added to serve as guides in defining the stratigraphy of the Mishrif geologic model.

2.2.2 Grid Construction

Generating three-dimensional grid system is the initial step in building the 3D geological model. In present work**,** the three dimensional grid system of Mishrif formation consists of 383 grid cells through the x- axis, 160 grid cells through the y- axis, and 163 sublayers through the vertical direction (z- axis). The total number of grid cells is 9,988,640. The lateral grid size was fixed to be 100m through the x-axis and 100m through the y-axis. **Fig.3** displays a three-dimensional grid system of Mishrif geological model.

2.2.3 Mishrif Zonation

In goemodeling of Mishrif reservoir, 14 horizons and 13 zones have been built for all geological surfaces that have been generated in the first item. The fourteenth top surface (MC2), which was previously generated, is used as a reference surface only for the bottom of zone MC1-4. **Fig.4** shows all 13 zones of Mishrif formation.

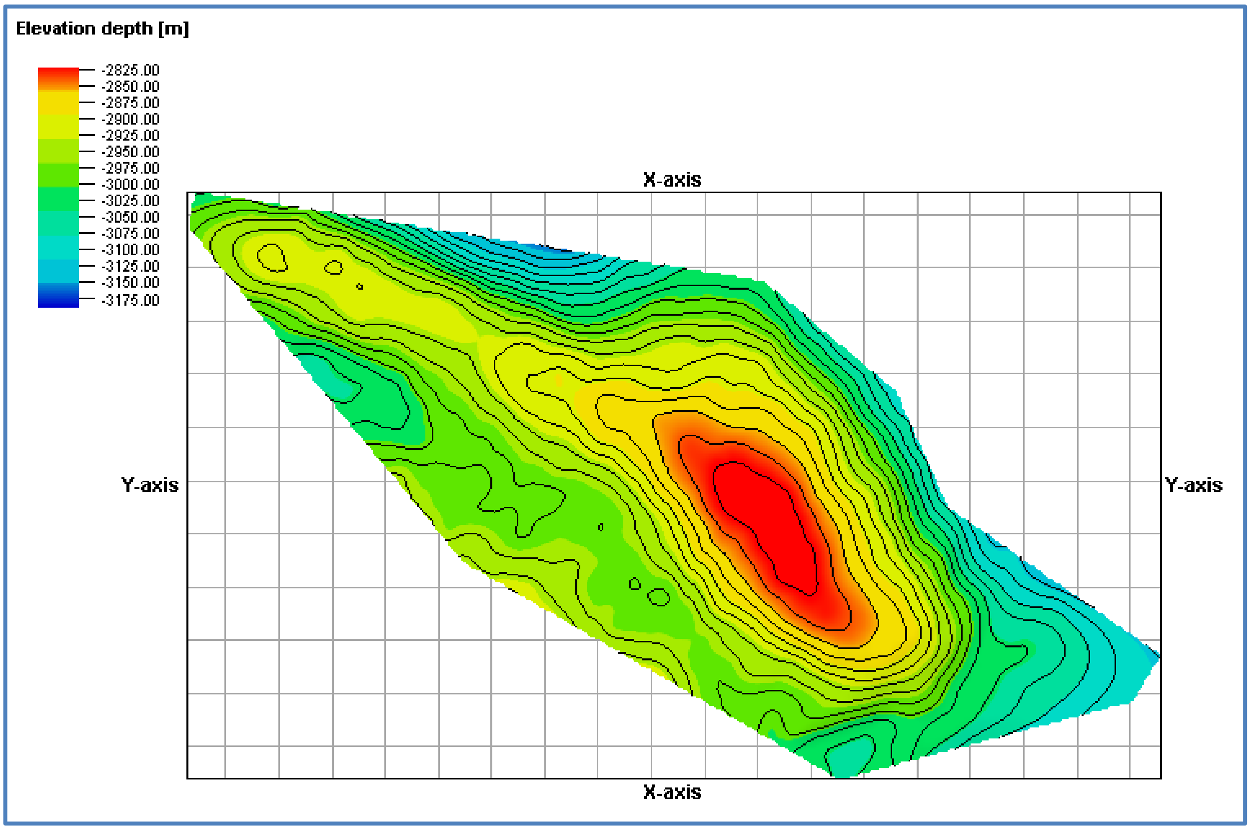

Figure 2. 2D Geologic surface of top Mishrif reservoir (Top MA).

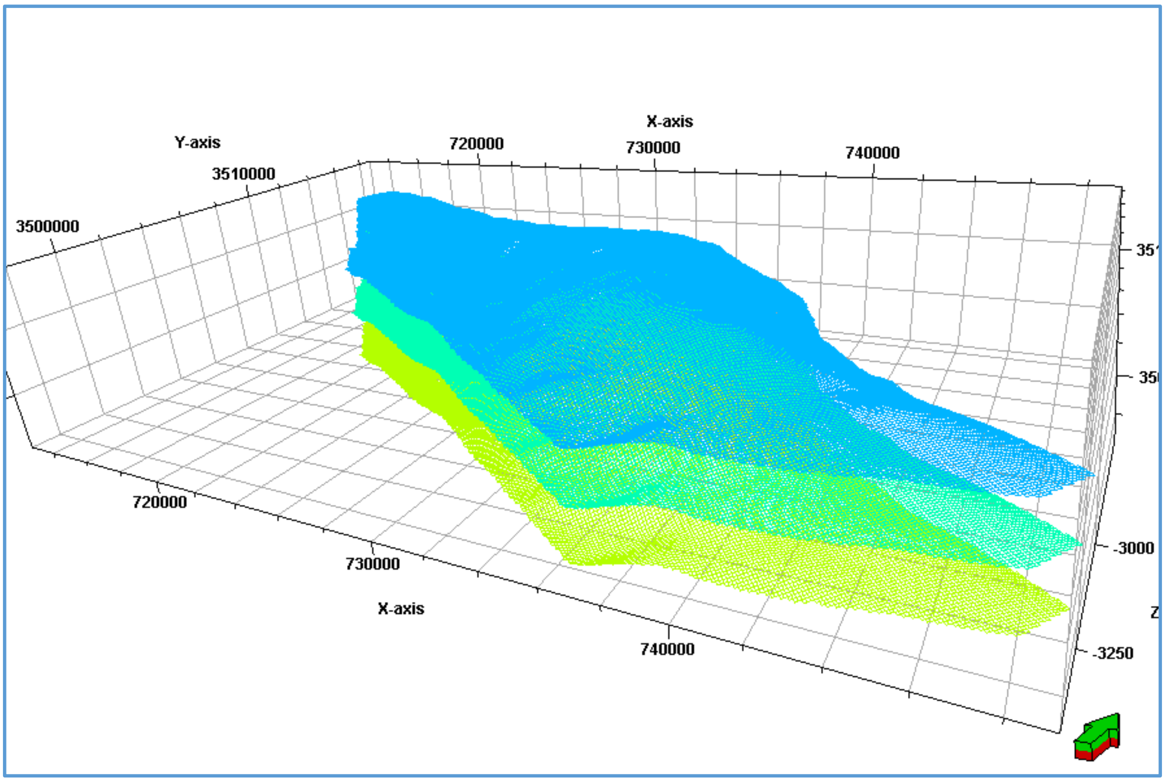

Figure 3. Grid system of Mishrif geological model.

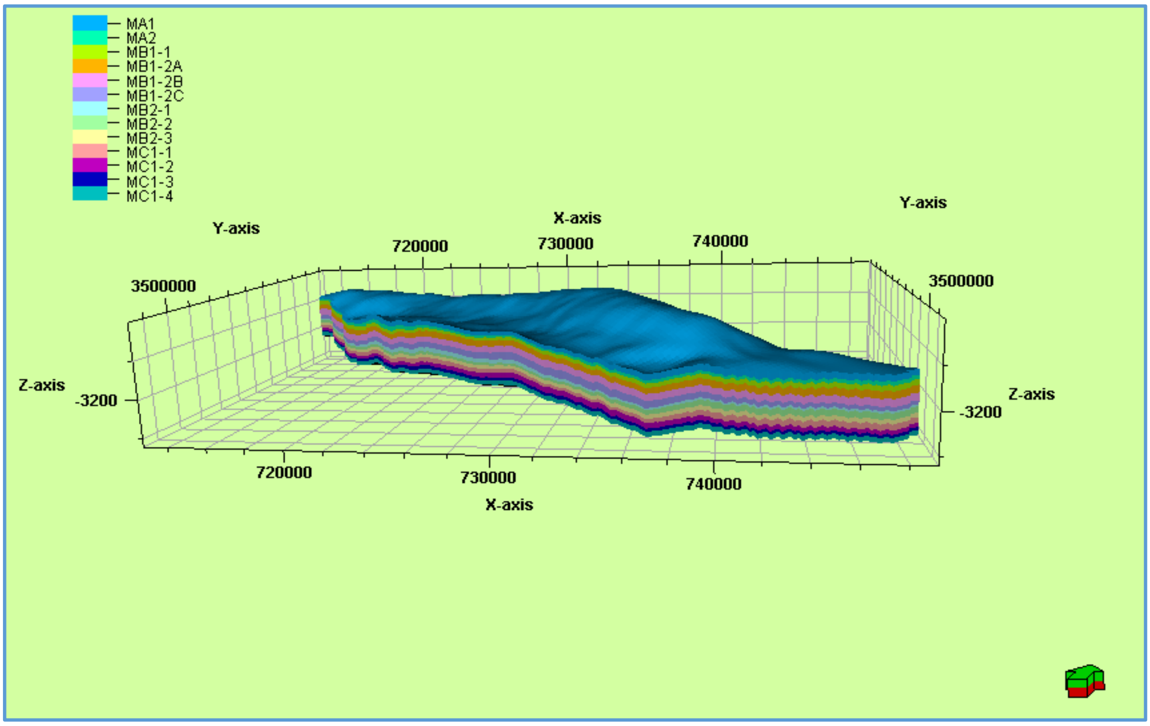

Figure 4. The zonation of Mishrif formation.

2.2.4 Layering

In layering process, each formation unit or zone will have subdivided into many fine layers. These fine layers act the upper and base of the grid cells through 3D grid system. This process is very crucial issue for representing the high vertical heterogeneity. Through current work, 163 proportional layers have been modeled in all Mishrif zones, and therefore, individual layer thickness will fluctuate based on the total thickness of each zone. Layer thickness (cell height) was about (1-2) m to reflect a proper vertical resolution of the model. Table 1 displays Mishrif formation zones and their layers.

Table 1. Zones and layering of Mishrif formation.

Zone Name	No. of Layers
MA1	6
MA2	9
MB1-1	5
MB1-2A	22
MB1-2B	22
MB1-2C	21
MB2-1	11
MB2-2	9
MB2-3	10
MC1-1	16
MC1-2	11
MC1-3	10
MC1-4	11
Total	**163**

2.3 Scale Up Well Logs

In the scale up process for well log data of each well, the arithmetic averaging algorithm was applied for the porosity, net to gross, and water saturation scaling up. On the other hand, the geometric averaging algorithm is used for permeability scaling up. This geometric averaging is highly sensitive to poor values of permeability. **Fig.6** represents the scale up well log for well N137 as an example.

2.4 3D Petrophysical Model

In this step, the reservoir rock properties and fluid saturations are estimated away from the wellbore and through areas where no data are available. Sequential Gaussian Simulation (SGS) algorithm is used as a statistical technique, allowing for finer scale heterogeneity and better control as well as prediction of porosity, water saturation, net to gross thickness, and permeability in regions far away from the wells positions. Moreover, in water saturation and permeability modeling, co-kriging with the 3D porosity model is used as a guide for these properties distribution guessing along the reservoir under study. **Fig.7** to **Fig.15** display the 3D model of reservoir rock properties and water saturation distribution for important reservoir zones in Mishrif.

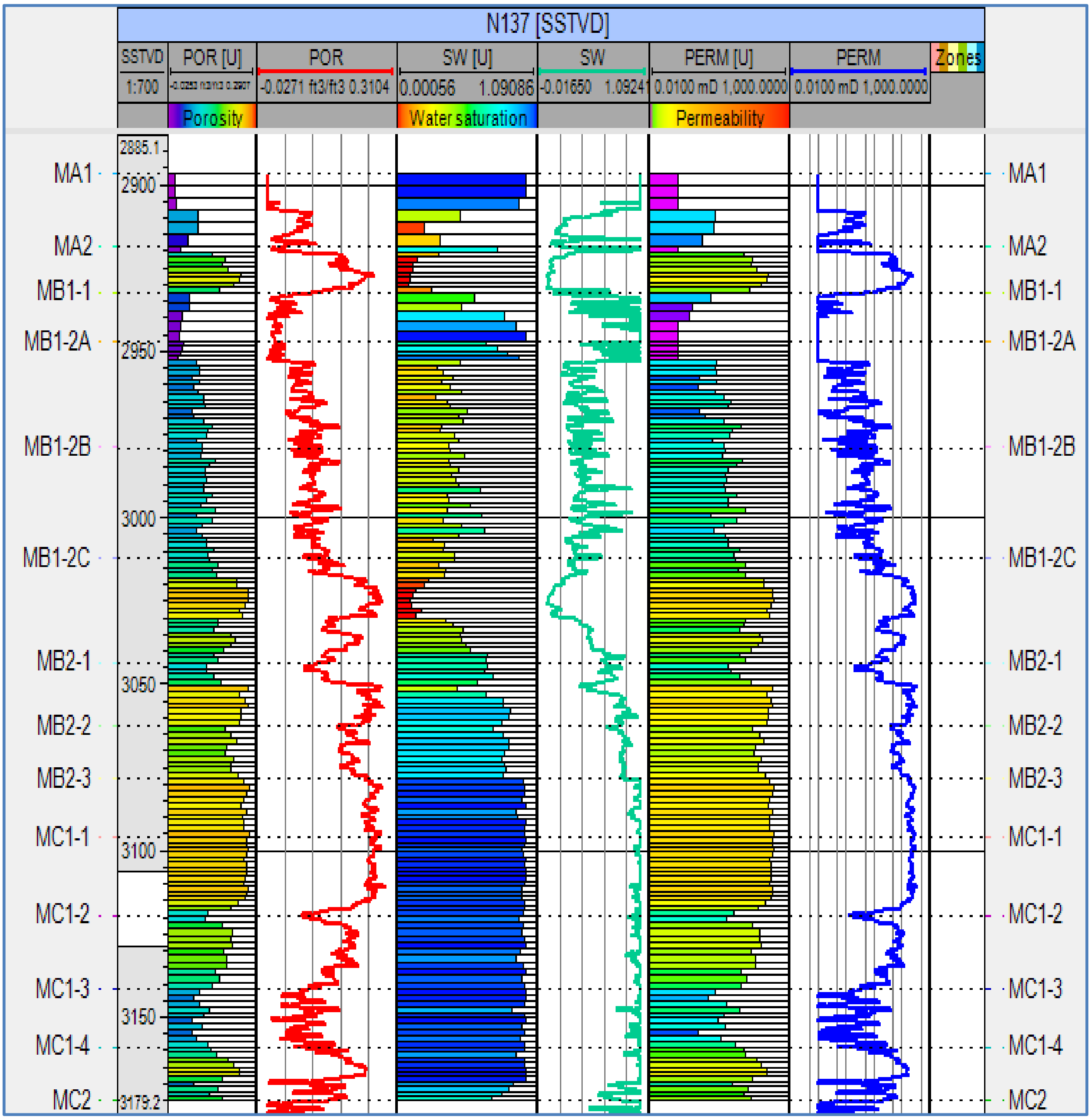

Figure 6. Petrophysical properties scale up for well N137.

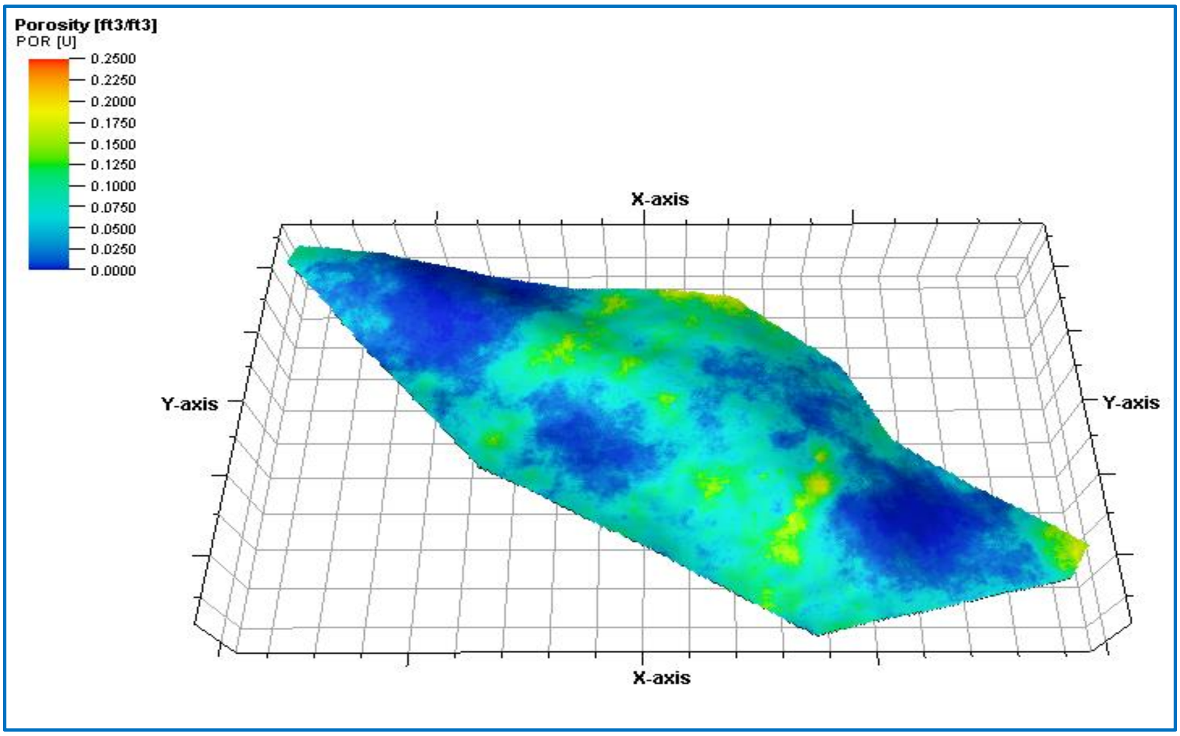

Figure 7. 3D Porosity model for zone MA2 in Mishrif reservoir.

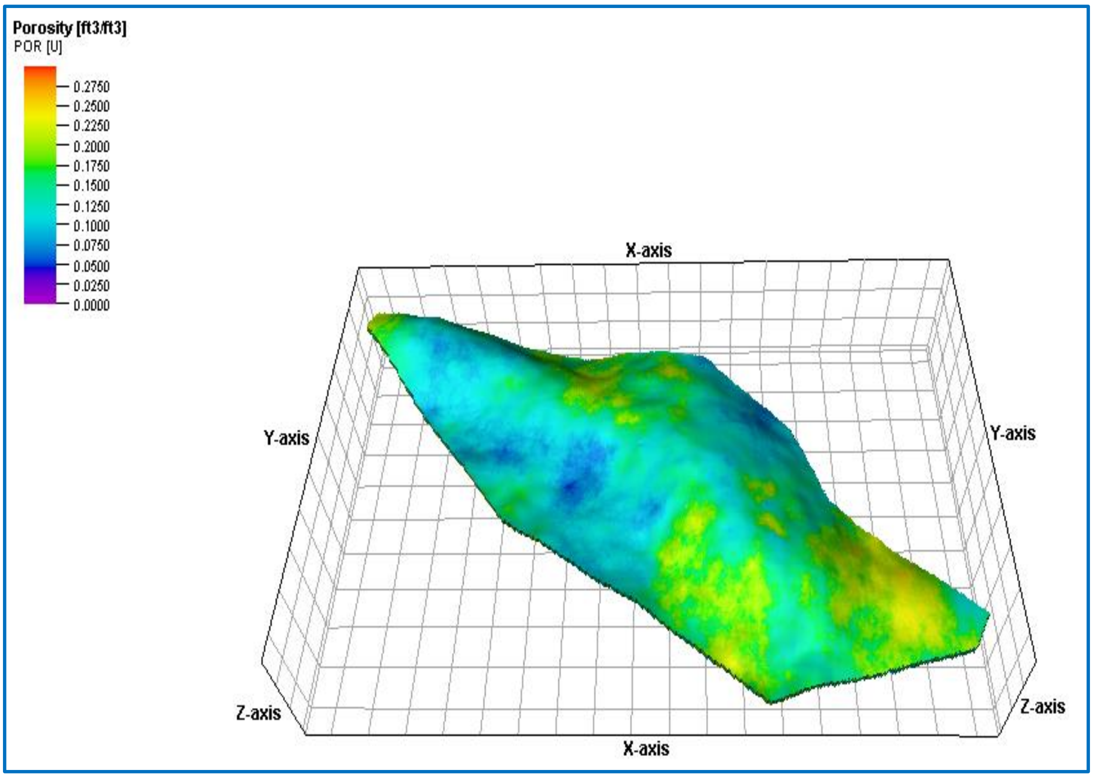

Figure 8. 3D Porosity model for zone MB1-2B in Mishrif reservoir.

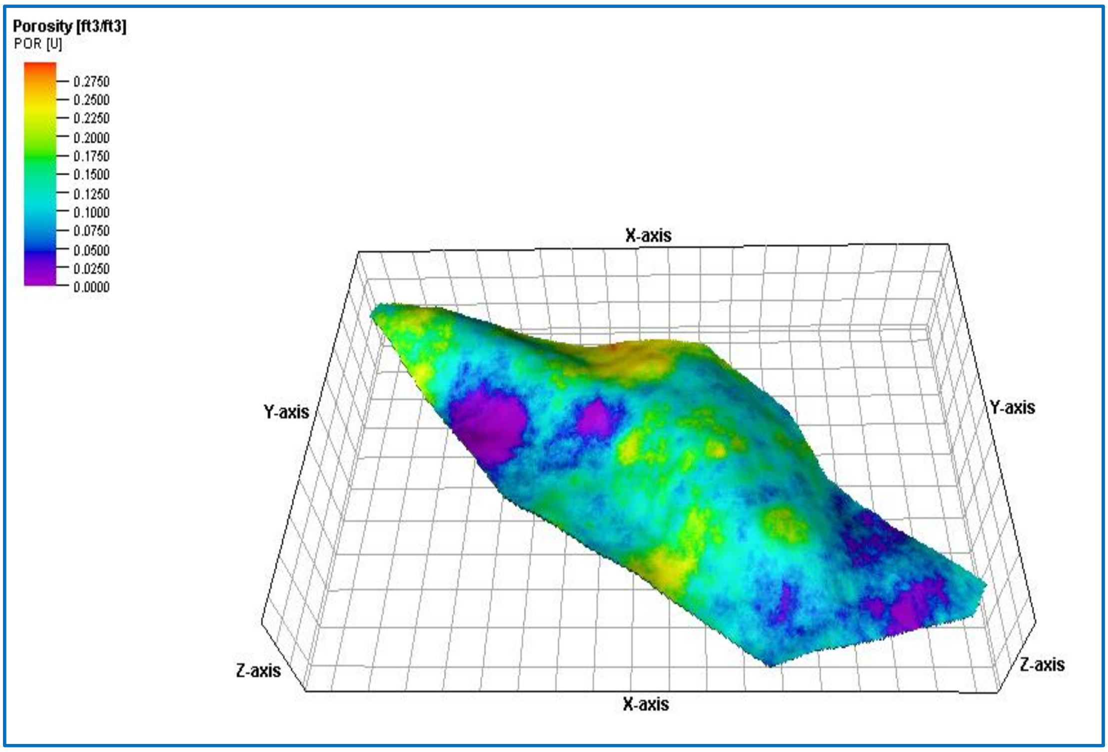

Figure 9. 3D Porosity model for zone MB2-1 in Mishrif reservoir.

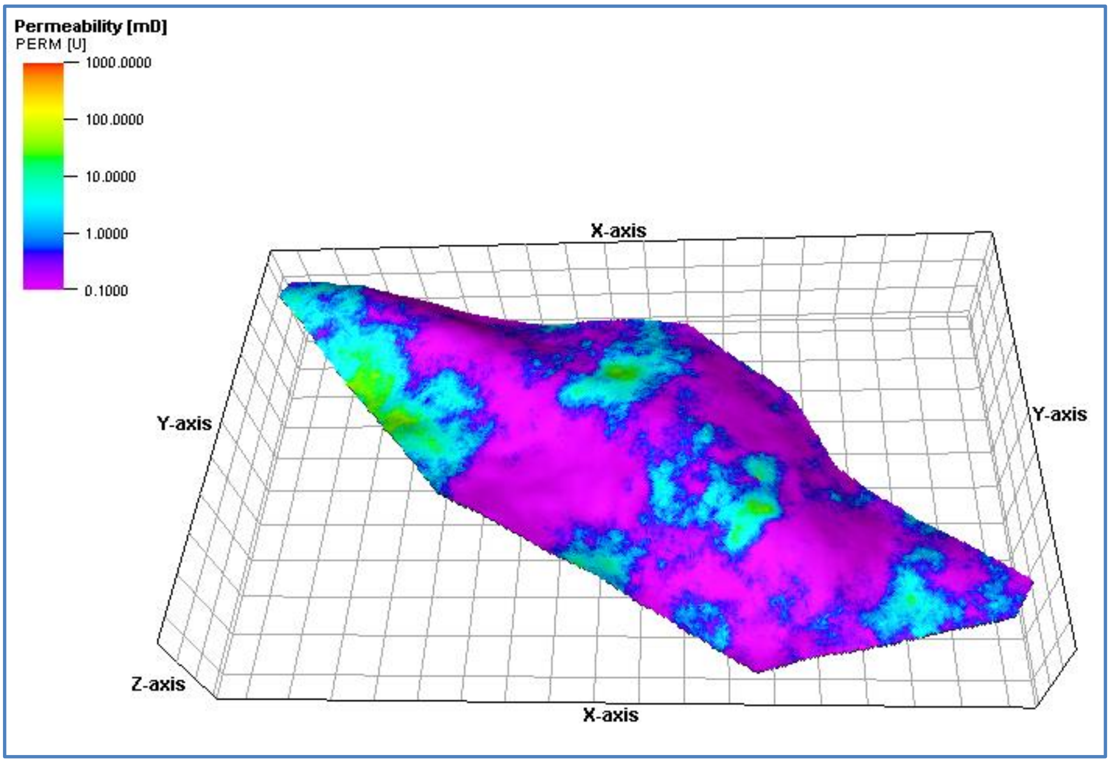

Figure 10. 3D Permeability model for zone MA2 in Mishrif reservoir.

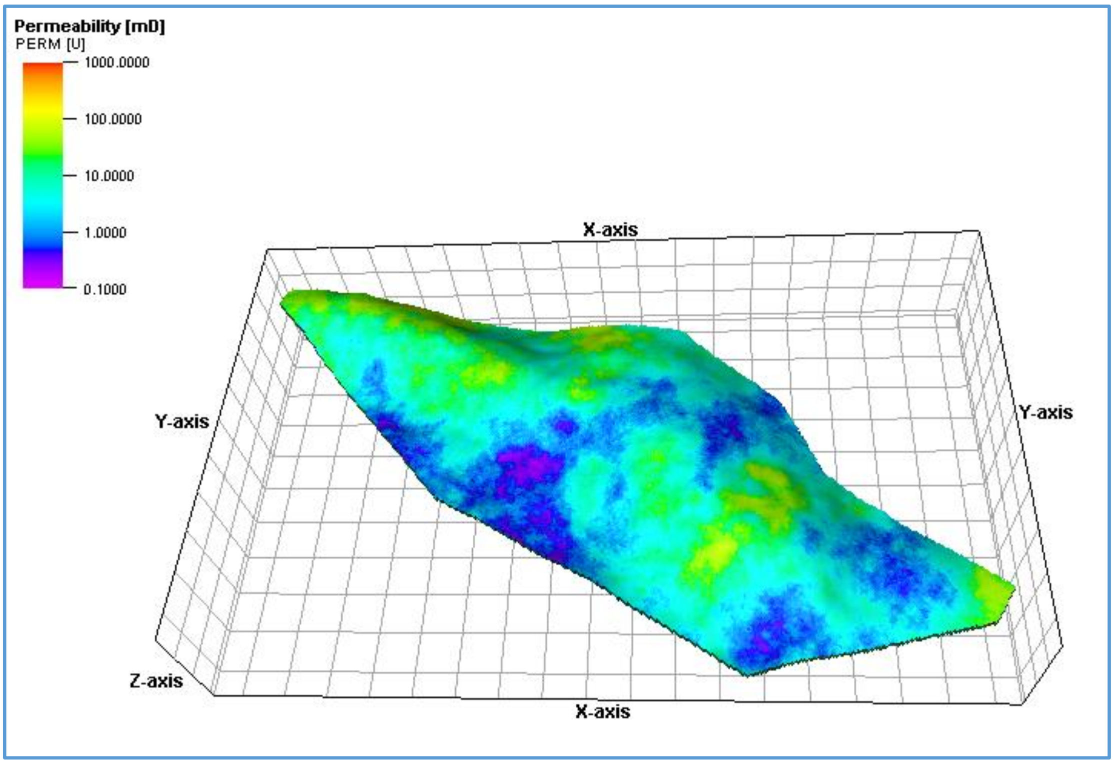

Figure 11. 3D Permeability model for zone MB1-2B in Mishrif reservoir.

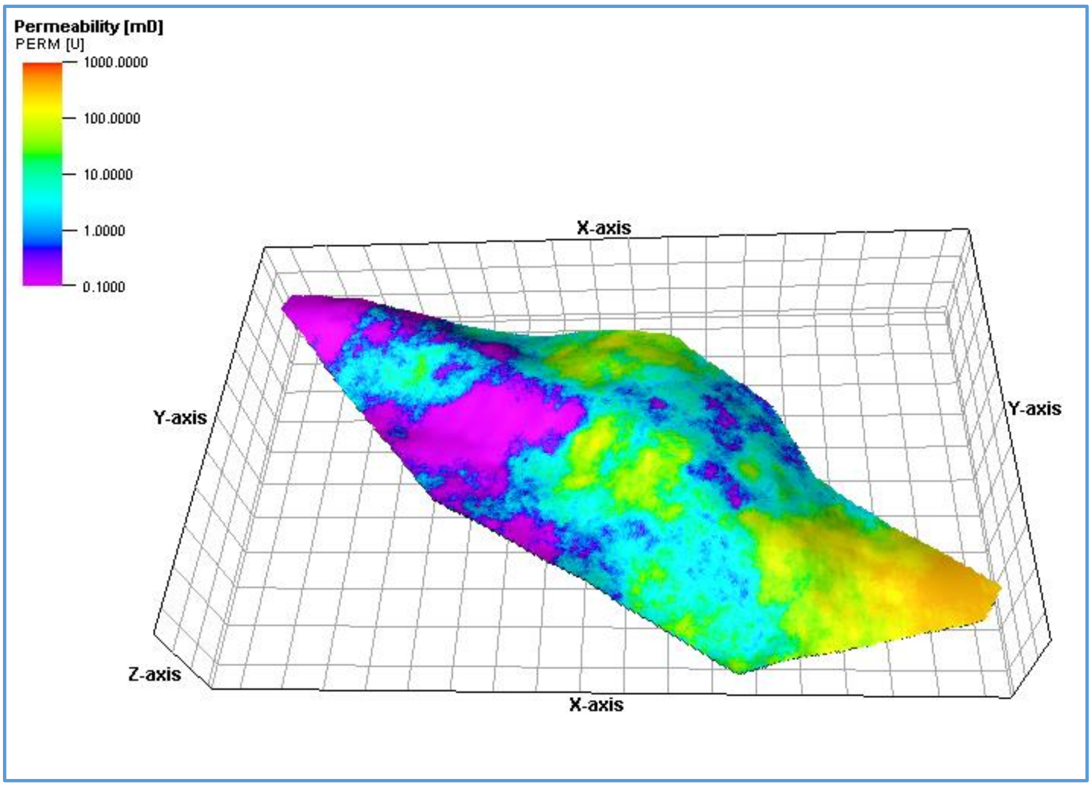

Figure 12. 3D Permeability model for zone MB2-1 in Mishrif reservoir.

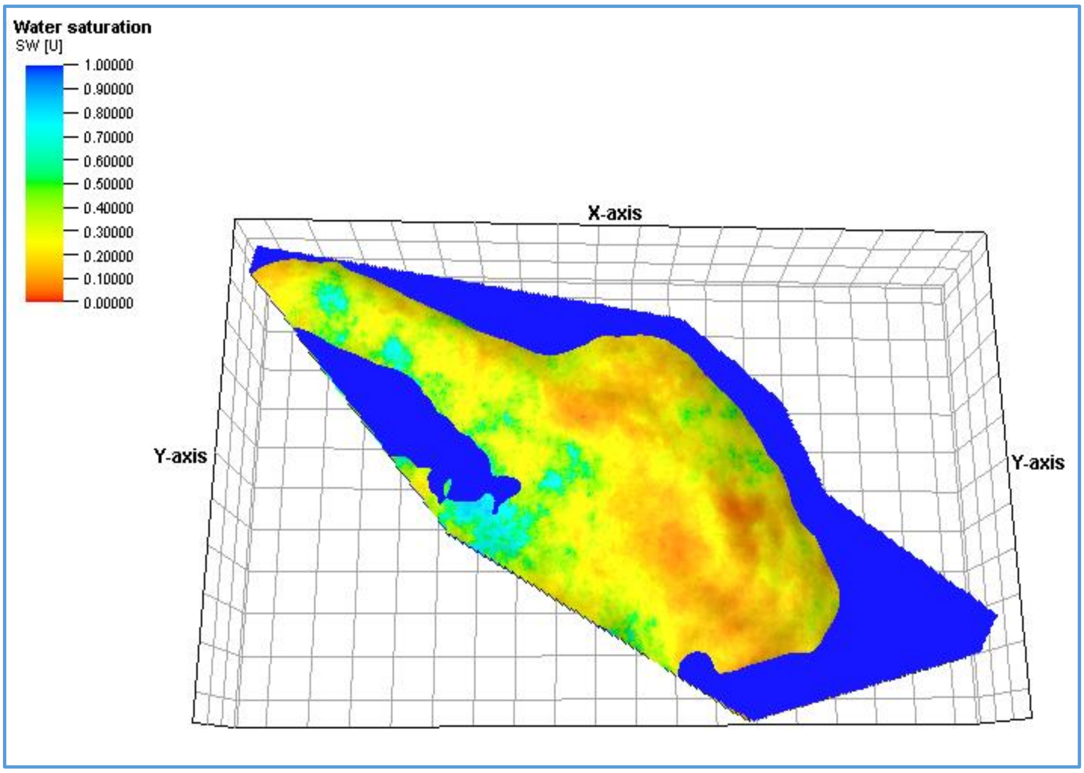

Figure 13. 3D Water saturation model for zone MA2 in Mishrif reservoir.

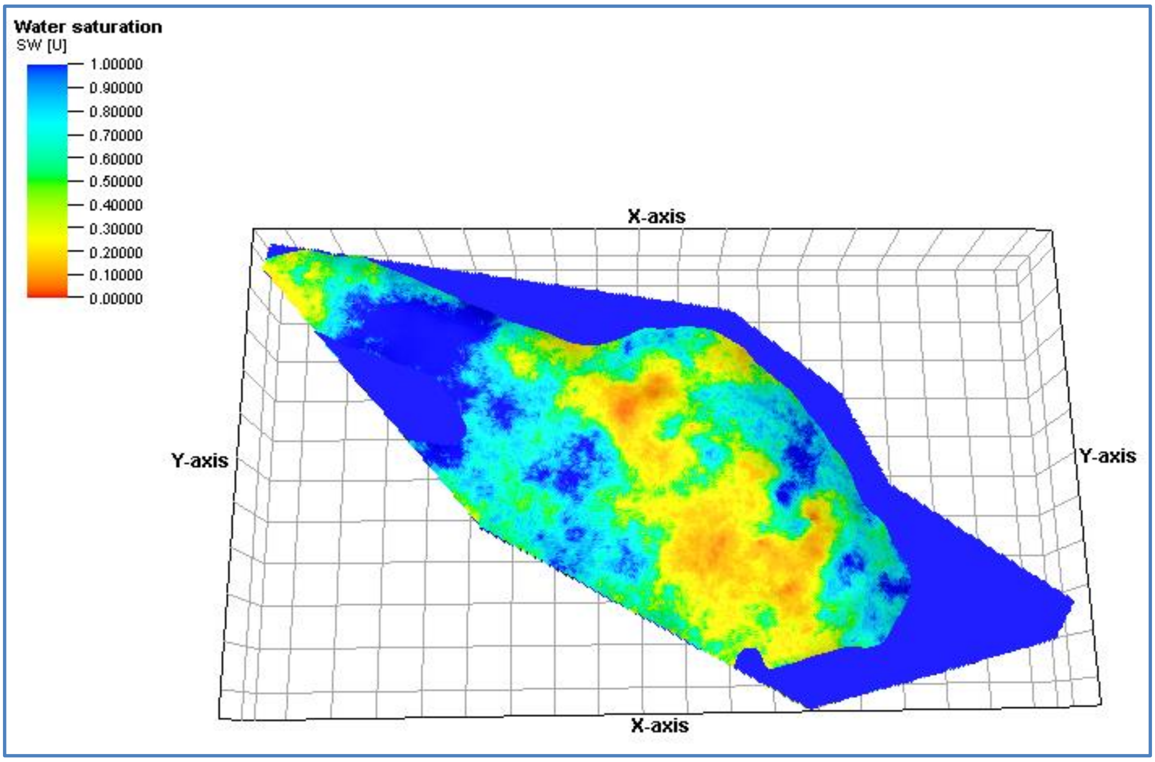

Figure 14. 3D Water saturation model for zone MB1-2B in Mishrif reservoir.

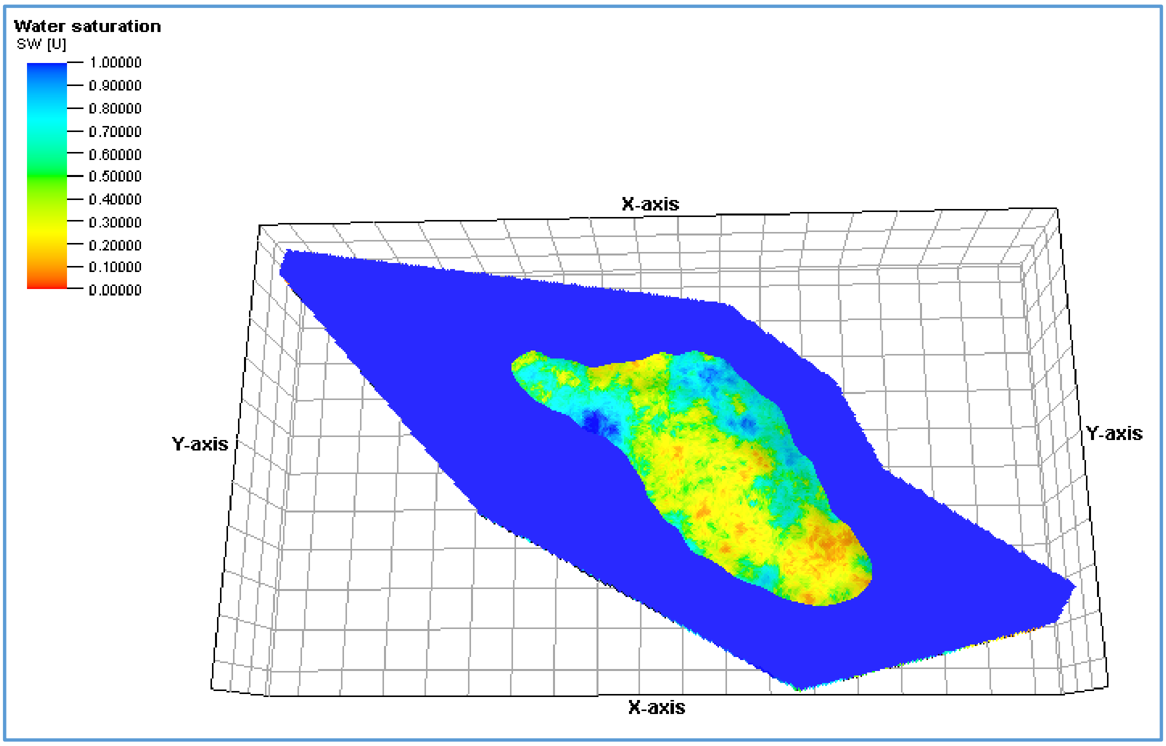

Figure 15. 3D Water saturation model for zone MB2-1 in Mishrif reservoir.

2.5 Oil Initially in Place (OIIP)

The static geo-cellular model for Mishrif reservoir has been utilized to estimate oil initially in place based on 3D petrophysical models, oil water contacts, and initial oil formation volume factor through using **"Petrel"** software.

3. RESULTS AND DISCUSSION

The main results and observations from the 3D pertophysical model and volume calculations can be introduced as followings:

- It has been observed that the porosity in MA2 increases in the east and south west direction from the crest towards the flanks. In the other Mishrif Formation units, the porosity values are significantly varied along each unit in the formation with more favorable porosity values detected in the units MB2-3 and MC1-1.
- It clear that the water saturation is dramatically changed from crest to flanks and from north west to south east in each unit in Mishrif formation. However, the minimum water saturation values can be observed in the south eastern part of the formation through most of Mishrif reservoir units.
- From the 3D NTG maps, increasing of NTG can be seen in the south east and decreasing towards north west, excepting in two units MA2 and MB1-2A. In addition, it improves in the crest more than flanks due to good properties (porosity and water saturation) in the middle and east southern portion of the formation.
- The results of pore volume, hydrocarbon pore volume, and initial oil in place for each reservoir unit in Mishrif are presented in table 2. According these results, the total initial oil in place of Mishrif reservoir is about 9,661 MMSTB, of which main unit MB1 accounts for about 72.8% while MA, MB2 and MC1 account for 7.7%, 14.3% and 5.2%, respectively.

- The total OIIP estimated by the current model for Mishrif reservoir and from other previous studies and models are presented in the table 3. From this table, the OIIP from the current model highly agrees with that estimate from the most recent previous study, **Pterochina, 2017**. However, there is a significant inconsistency between the OIIP result of the current model and that other two studies, **BHP, 1996,** and **PDP, 2010**. This high discrepancy can be mainly attributed to the oil water contact values for main Mishrif reservoir which was applied in the BHP study at 3040 mSS and in PDP study at 3055 mSS , while it was 3070 mSS in the current model.

Table 2. Pore volume and initial oil in place for Mishrif reservoir zones.

Unit	Total Pore Volume MMSTB	HC Pore Volume MMSTB	OIIP MMSTB
MA1	159	54	41
MA2	1324	922	704
MB1-1	599	316	242
MB1-2A	3936	2788	2128
MB1-2B	5578	3992	3047
MB1-2C	3233	2121	1619
MB2-1	1047	664	507
MB2-2	848	570	435
MB2-3	1019	578	441
MC1-1	993	546	417
MC1-2	198	103	78
MC1-3	6	1	1
MC1-4	1	1	0
Total	**18,940**	**12,656**	**9,661**

Table 3. Results of initial oil in place in current model and previous studies.

Study	IOIP MMSTB
Current Static Model	9,661
RFDP, **Petrochina, 2017**	9,512
MFDP, **Petrochina, 2015**	8,775
FDP, **Petrochina, 2013**	8,775
PDP, **Petrochina, 2010**	7,642
Reservoir study**, BHP, 1996**	7,610
Reservoir study**, AGIP, 1982**	9,736

4. CONCLUSIONS

1. It has been noticed that porosity values in the most of Mishrif formation increases in the crest and towards south east direction.
2. Permeability values are increasing downward especially in the south eastern part and in the crest better than flanks through most reservoir units of Mishrif. Furthermore, it is clear that many of thief zones, barriers, and baffles can be recognized in some regions of the reservoir especially in unit MB2-1.
3. In most of Mishrif reservoir units, the lowest water saturation values are observed in the south eastern portion and middle region of the reservoir.
4. The main unit MB1 constitutes about 73% of the overall OIIP of Mishrif reservoir, while main unit MC1 represent the lowest value of OIIP with about 5% only from the entire OIIP of the reservoir.
5. The OIIP of Mishrif reservoir by the current model highly matched with that estimate from the most of other models and studies.

5. REFRENCES

- AGIP CO., 1982, Halfaya Field Reservoir Study: Mishrif Formation, Vol. 4, December 1982, Italy.
- BHP Co., 1996, A Field Study and Preliminary Development Plan, Vol. 6, Reservoir Engineering, February 1996, Australia.
- Cosentino, L., 2001, Integrated Reservoir Study, Institute François Petroleum Publication. Paris, France.
- Petrochina Co., 2010, Preliminary Development Plan of Halfaya Contract Area, Beijing, China.
- Petrochina Co., 2013, Field Development Plan of Halfaya Contract Area, February 2013, Beijing, China.
- Petrochina Co., 2016, Modified Field Development Plan of Halfaya Contract Area, Beijing, China.
- Petrochina Co., 2017, Field Development Plan Revision No.1 of Halfaya Contract Area, August 2017, Beijing, China.
- Petrochina Co., Core analysis reports and Log interpretation results data & analysis reports for all available wells in Mishrif formation/ Halfaya oilfield.
- Schlumberger, 2013, Petrel geology and geological modeling.
- Vinh Phan, 2002. Modeling Technical for Generating Fluvial Reservoir Descriptions Conditioned to Static and Dynamic Data, PhD Dissertation, Stanford University, USA.