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3D Geological Modelling for Asmari Reservoir In Abu Ghirab Oil Field

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Abstract

Building a geological model is an essential and primary step for studying the reservoir's hydrocarbon content and future performance. A three-dimensional geological model of the Asmari reservoir in Abu- Ghirab oil field including structure, stratigraphy, and reservoir petrophysical properties, has been constructed in the present work.

As to underlying Formations, striking slip faults developed at the flank and interlayer normal. Abu Ghirab oilfields are located on the eastern anticlinal band, which has steadily plunged southward. 3D seismic interpretation results are utilized to build the fault model for 43 faults of the Asmari Formation in Abu Ghirab Oilfield. A geographic facies model with six different rock facies types are developed. This new modelling system should be capable of more clearly reflecting the connectivity of the oil body and the heterogeneity of the reservoir. To represent the vertical and horizontal heterogeneity and create a framework for the Asmari reservoir in the Abu Ghirab oil field, the Petrel software has been used to create a reservoir in a 3D model. This model was constructed using data from 55 wells located across the Asmari formation. The model demonstrates accurate estimations (porosity, saturation, and net to gross). These reservoir models directly impact the facies model's computation of each layer of the net pay thickness of the reservoir. The final goal of the present work is to determine the initial oil in place (IOIP), which is found to be $269*10^6$ sm^3.

Keywords: Geological Model; Reservoir Properties; Original Hydrocarbon in Place (OHIP).

موديل جيولوجي ثلاثي الابعاد والحساب الحجمي لتكوين الاسمري في حقل ابو غرب النفطي

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الخلاصة

يعد بناء نموذج جيولوجي خطوة أساسية وأساسية لدراسة الخزان فيما يتعلق بمحتواه الهيدروكربوني وأدائه المستقبلي. تم في هذا العمل إنشاء نموذج جيولوجي ثلاثي الأبعاد لخزان الأسمري في حقل نفط أبو غرب ، والذي يتضمن الهيكل ، والطبقات ، والخصائص البتروفيزيائية للخزان.

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إن تطوير نموذج للسحنة الجغرافية بستة أنواع مختلفة من السحنات الصخرية ليس مجرد تحفيز وانما من الضروري بناء موديل جديد. يجب أن يكون نظام النمذجة الجديد هذا قادرًا على عكس الترابط بين جسم النفط وعدم تجانس المكمن بخصائص أكثر وضوحًا. من أجل تمثيل عدم التجانس الرأسي والأفقي وإنشاء إطار لتشكيل تكوين الأسمري في حقل نفط أبو غرب ، تم استخدام برنامج بترل (برنامج نمذجة المكمن شلمبرجير) لإنشاء نموذج مكمن ثلاثي الأبعاد. النمذجة الجيولوجية ثلاثية الأبعاد (3D) ، تدمج جميع الخصائص الهيكلية والسحنات والخصائص البتروفيزيائية في نموذج مكمن ثابت ثلاثي الأبعاد لتوضيح تباين هذه الخصائص في تكوين الأسمري باستخدام برنامج بترل (2017.4) من إنتاج شركة شلمبرجير.
الغرض من النمذجة الجيولوجية هي: – إدارة المكمن من خلال تزويد الموديل بتفاصيل كافية لتمثيل عدم التجانس الرأسي والجانبي ، وحساب الاحتياطي وتخطيط الآبار ، وحساسيات المتغيرات الثابتة والديناميكية (على سبيل المثال ، ɸ، K، NTG ، إلخ) وفي التقييم الأخير حساب الهيدروكربون الأصلي المعمول به (OHIP) للقرار الاقتصادي.

Introduction

Many models of oil reservoirs can produce fast based on a geostatistical program, for instance, Petrel modelling tools, a widely used modelling tool in oil production. However, it is required a few parameters can be chosen to initialise the flow simulation as a requirement for time computation **[1].** In general, the selection of the model should be for the objects and events in a practical way. A better model is adequate when representing some properties relevant to the research. The 3D geological model of a field does make sense when it outcomes the values of the practical reservoir modelling and simulations. Several models lead to a better outcome based on the above definition and multi-applications. The geological model provides a spatial explanation of the rock locations and the residues on the land subsurface **[2].** Moreover, realistic geologic models are crucial for oil and gas productions to initialise the reservoir program simulation by predicting the rocks' behaviours under different hydrocarbon recovery scenarios [**3**].

The current study aims to create a 3D geological model of the Asmari reservoir from the data of 55 wells (45vertial wells and 10 horizontal wells) in Abu Ghirab oil field. The 3D geological model (structural and well correlations) has also been built. Furthermore, the facies distribution is also included in the model.

The Study Area

Abu Ghraib oil field is located in the Missan governorate, southeast Iraq, near the borders with Iran. It has an axial length of about 30 km and a width of about 5 km, with coordinates of 3575000-360000 Northing lines and 71000-73500 easting lines. This area has two domes (northern and southern) with a saddle zone [4], as shown in Figure 1. The Asmari Formation is considered a heterogeneity, fracture distribution, and implementation of water control at a later stage of the field development. It is recommended to adopt a cased hole perforation method for vertical and directional wells. The reservoir mainly consists of Cretaceous and Tertiary carbonate reservoirs [5]. The field is located in the Missan Province, southeast Iraq and adjacent to the border of Iran, within the transitional zone between Zagros Mountain and Arabian Plate, southern Mesopotamian basin. It is about 350 km southeast of Baghdad and approximately 175 km north of Basra, as shown in Figures 1 and 2. The area of Abu Ghirab is 106.8 km^2 and lies in a hilly region that elevates 70 m to 160 m above sea level.

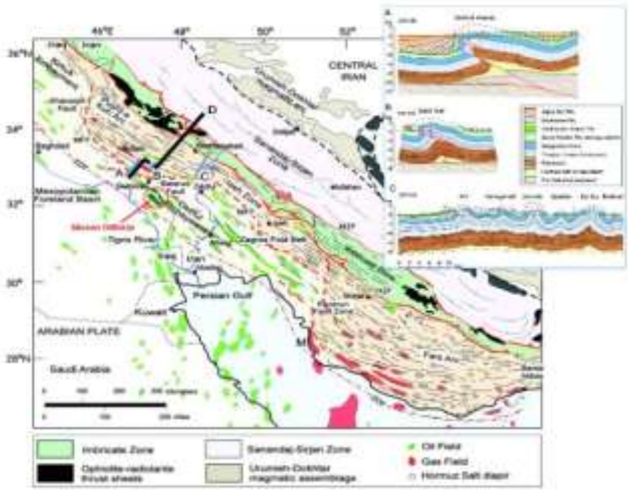


Figure 1-Missan Oilfields Structural Location

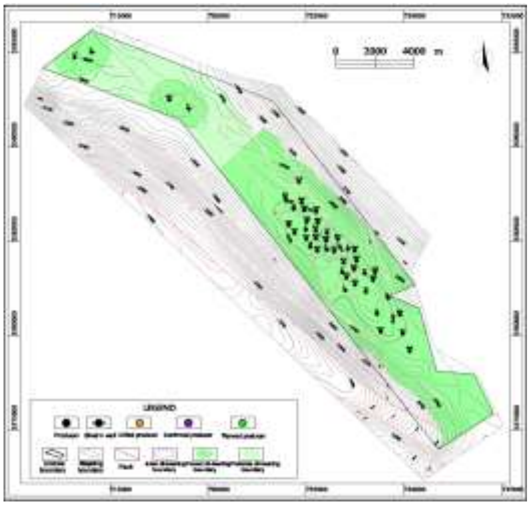


Figure 2- Top Structure map for member (A) of Asmari formation in Abu Ghirab oilfield

Methodology

To delineate the mentioned aims of this study, the data from the available logs such as gamma-ray, density, sonic, neutron and resistivity were used to calculate porosity, water saturation and shale volume. The results of these logs were loaded to the Petrel software 2017.4 to construct the structural maps and distribute the model's petrophysical properties, including water saturation, facies, permeability, porosity, and shale volume.

Well Correlation

The correlation sections of Abu Ghirab wells were initiated after the data entry into Petrel software (2017.4) [6]. The well correlation was used as a very basic approach to understand and visualise the thickness changes within the Asmari units and the petrophysical properties (porosity, permeability, and water saturation)[7].

The Asmari formation has three lithological sections with different logging characteristics. The resistivity curves show high, middle, and low changing trends. Inflection points appear concurrently in logging curves of gamma-ray, compensated sonic time, compensated neutron porosity, density, and resistivity, corresponding to the lithological changes (Figure 3). The member division and correlation for two vertical wells and one horizontal well in Abu Ghirab Oilfield are the available data for wells (AGCS-22, AGCS-27, and AGCS-29) aligned at the top Zone-A.

Member A is mainly dominated by dolomite, with a lower value of resistivity and density than the anhydrite cap rock located on top of this reservoir. The strata thickness is averagely about 69m. Member B contains limestone, sandstone, and some local dolomite, with lower resistivity, lower density, and higher compensated sonic time than member A. The strata thickness is averagely about 110 m. Member C is mainly sandstone and mudstones. Members A and B are significant oil-bearing, and water layers dominate member C, which partially bears oil as a similar result obtained by Buraq et al. [8].

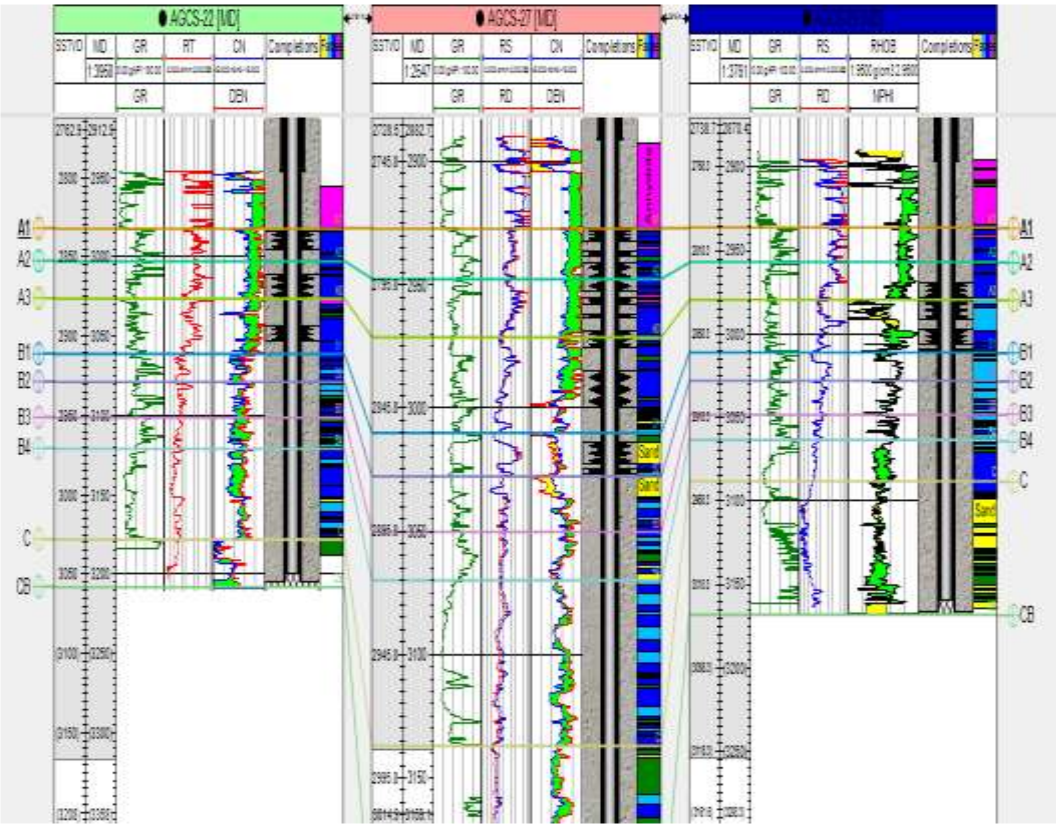


Figure 3- Well Correlations of Asmari Formation in Abu Ghirab Oilfield

Structural Contour Maps

Contour maps can be constructed by specific software from the surface and correlated borehole [3]. Structure contour maps for the top and bottom of each zone were created. Isopach maps for zone A-2 were created from the structure contour maps (Figure 4). Structural contour map for the top of the Asmari reservoir for zone B-3 was displayed in Figure 5.

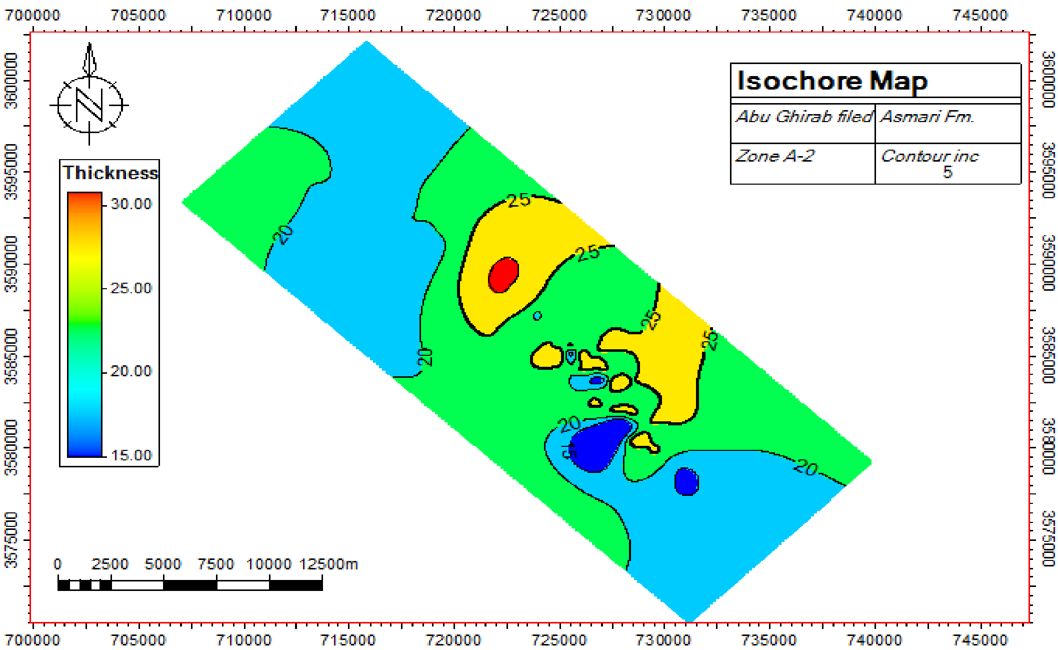


Figure 4-Isochore map of zone A-2

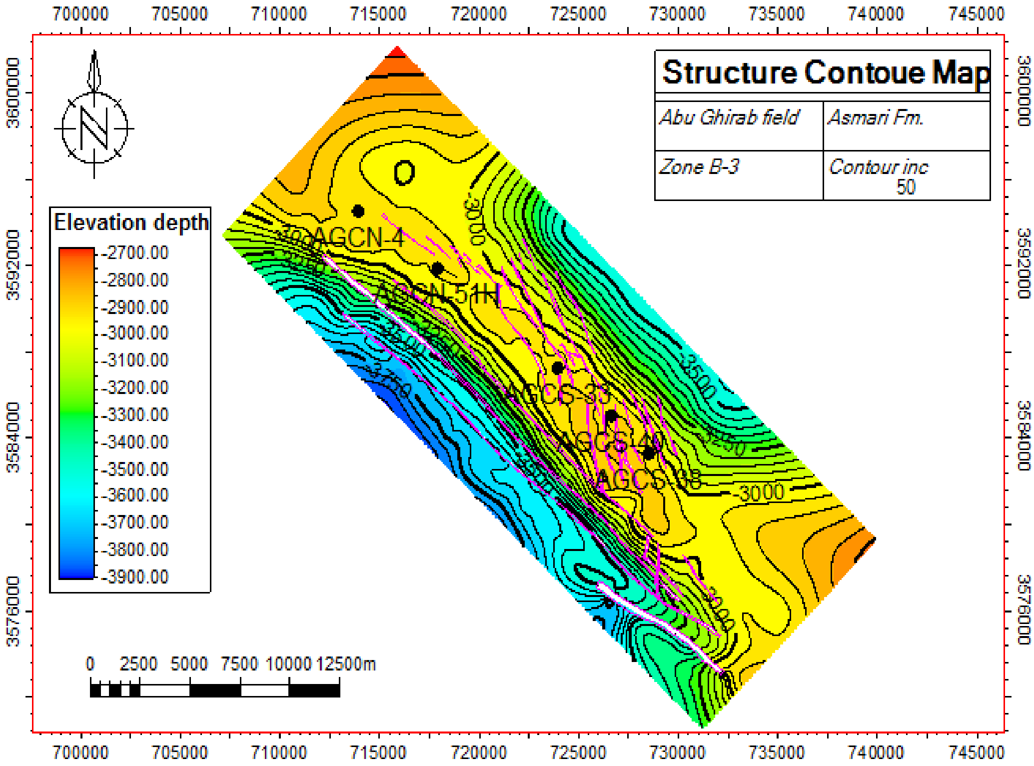


Figure 5-Structure contour map for top Zone B-3

To represent the vertical and lateral heterogeneity and create a framework for the reservoirs in Abu Ghirab oil field, the intelligent petrel (Schlumberger's reservoir modelling software) has been used to create the 3D simple reservoir model.

Modelling of the Reservoir

Modelling in petrel consists of the following steps:

1. Modeling of Fault

1.1 Modelling of Fault Definition

As to underlying formations, striking slip faults developed at the flank and interlayer [9]. Abu Ghraib Oil Fields are located on the eastern anticlinal edge that gradually slopped southward. In this field, 43 faults vary in their size. Three of these faults are large, and they have been considered a seal the reservoir from south to north. In this study, these faults must be modelled to describe the reservoir perfectly. After importing the digitized faults into Petrel software, the fault dip, depth, and the smoothness of faults have been adjusted to get a perfect representation. Figure 6 shows the structure of the fault in the simulator before grid construction [4].

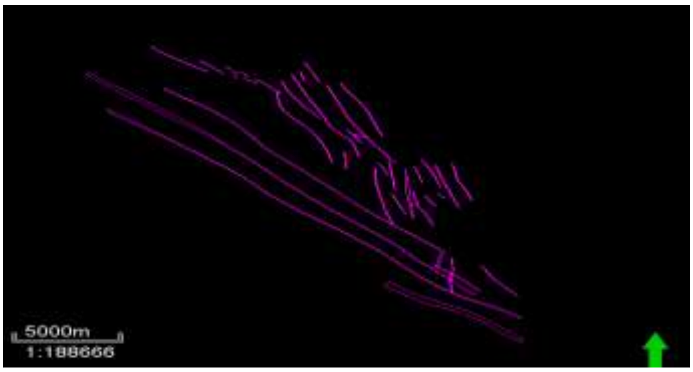


Figure 6-Fault polygons of the study area (2D view).

1.2 Defining the boundary

The Abu Ghirab oil field's boundary has also been obtained from the structure map [4] of the Asmari formation and then loaded in petrel to define the area of interest (Figure 7).

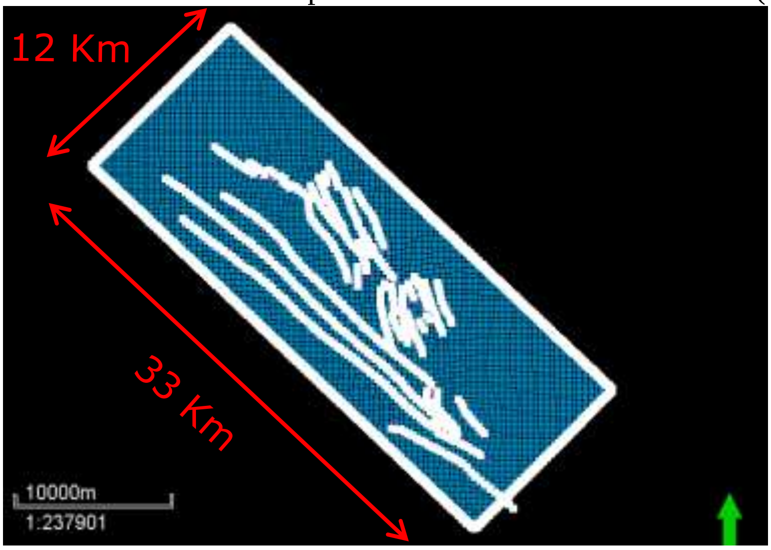


Figure7- Fault polygon in the study area with the boundary (2D view)

1.3 Concept of the Pillar Gridding

The concept of the Pillar gridding is special for the Petrel package, and it is defined as the process of generating the construction framework of the model. This framework is a mesh grid with a base, top, and middle construction grid. The grid is attached to the base, top, and middle spots of the pillars of the faults (Figures 8 and 9).

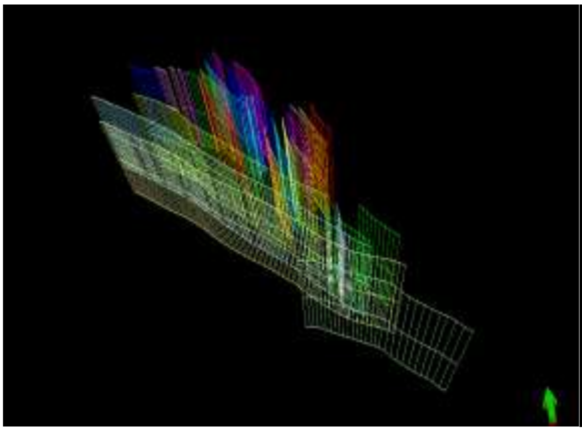


Figure 8-Fault key pillars inside the model (3D view).

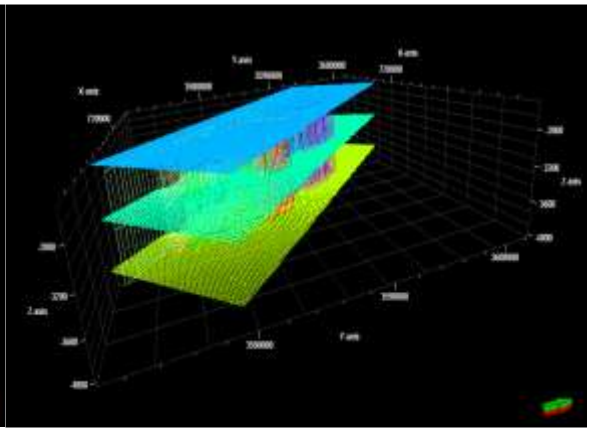


Figure 9-Top & Mid & Base skeleton framework with fault pillars (3D view)

1.3.1 Make Horizons: Once the skeleton framework has been created, the reservoir horizons of the Asmari formation and control points are inserted into the 3D grid in the model, honouring the grid increment and the faults defined in the previous steps to build the zones of the reservoir (Figure 10).

1.3.2-Make Zone: In this step, different zones of the reservoirs were created by adding horizons in the 3D grid as horizon A was subdivided into three zones (A1, A2, and A3), horizon B was subdivided into four zones (B1, B2, B3, and B4) and horizon C was not subdivided (Figure 11).

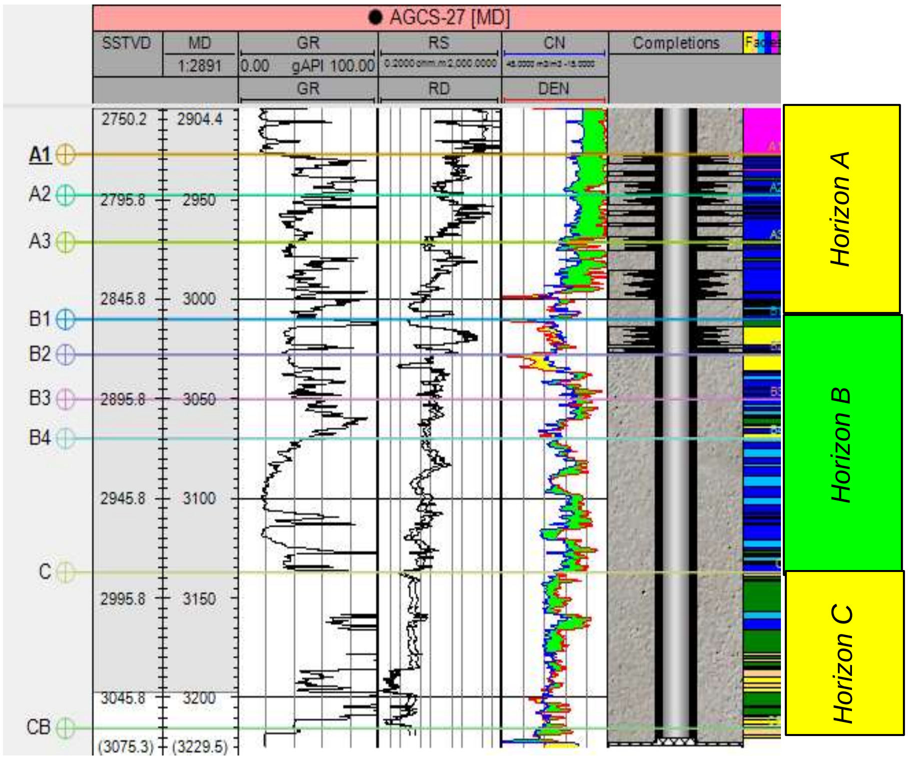


Figure 10- The three horizons of well AGCS-27

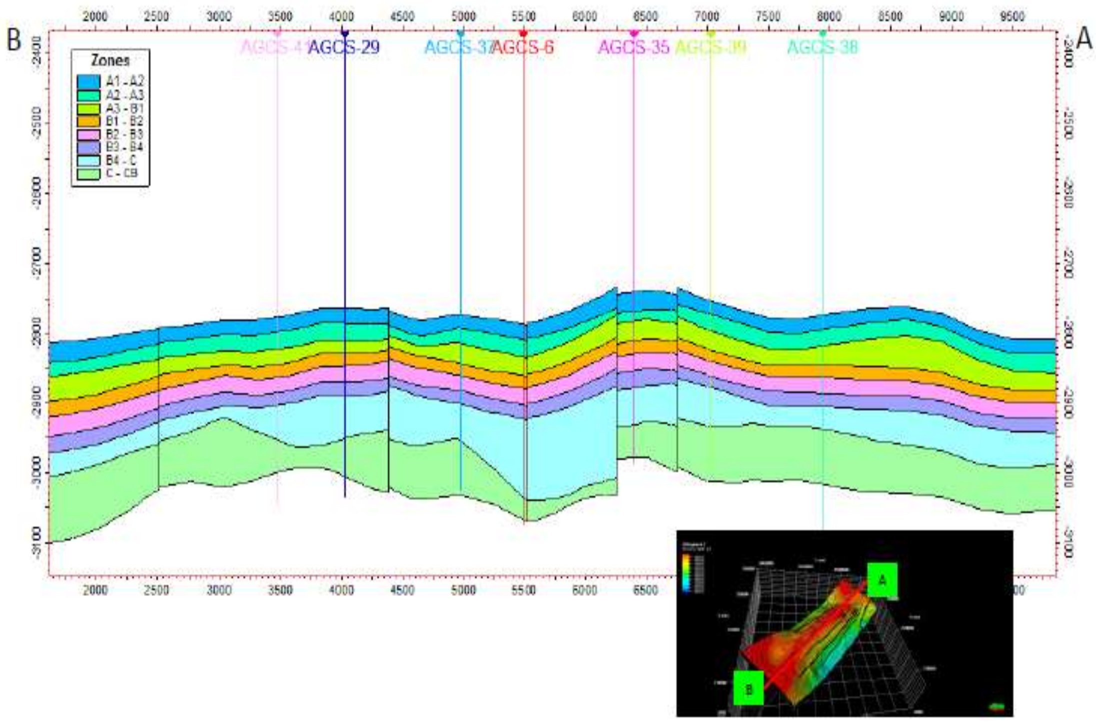


Figure 11- Cross-section passing through the Main area of the field show the subdivision of different zones

1.3.3 Layering: It is considered the final step in building the structure model. Layering is the creation of subdivisions in the central zones based on the particular specific properties of each layer's certain particular properties, specific particular properties. This process can only generate slightly better grid resolution. Zone A, B and C were divided as presented in Table 1.

Accordingly, it is necessary for property modelling (by providing more details) in the following steps to accurately calculate by the OOIP.

Table 1- Layering in subdivisions of zones

Horizon	zone	Number of layers
Horizon A	A1–A2	6
	A2–A3	8
	A3–B1	10
Horizon B	B1–B2	8
	B2–B3	7
	B3–B4	5
	B4–C	10
Horizon C	C–CB	3

1.3.4 Well logs scale-up: Petrel will first find the 3D grid cells the well penetrates [6]. Then, the log values for each grid cell will be averaged based on the specific algorithm to have one value. Discrete logs (facies log) will be scaled-up by assigning the most common value to the cell due to the scaling-up log (Figure 12). It only holds the values of the cells of the 3D grid of the wells that have penetrated. The values of the other grid cells will be assigned for the property modelling depending on the logs of the scaled-up well and the optional trend data. The well data is therefore always critical in the property model.

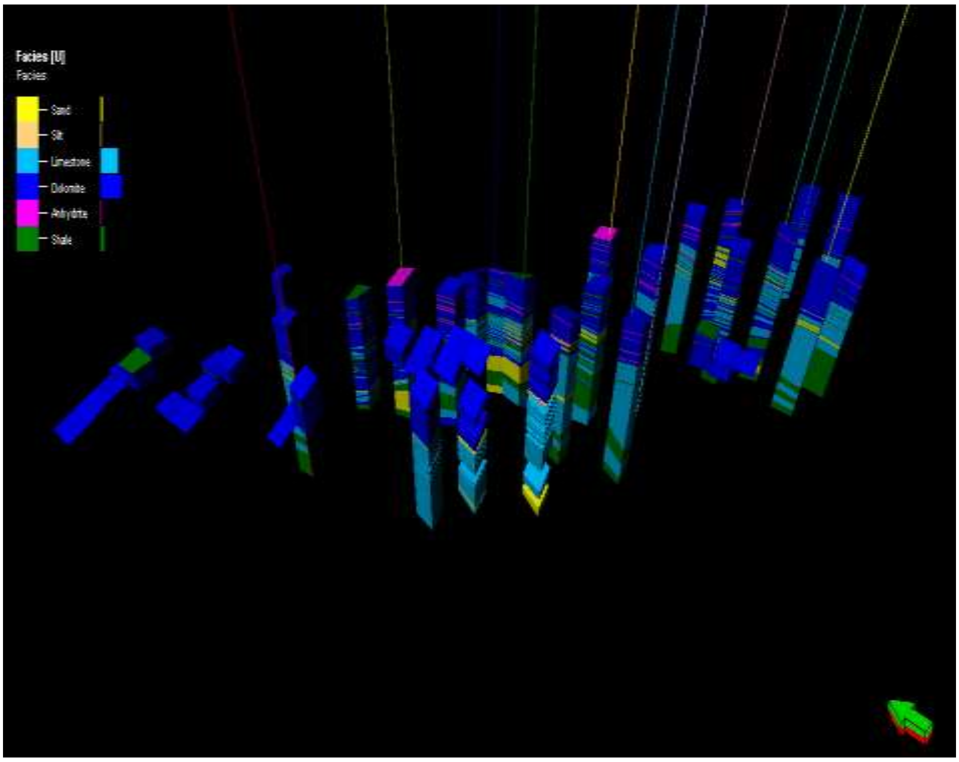


Figure 12- Well logs Scale-up (example from facies log).

2. Parametric modelling Applications:

The lithological analysis results with the core samples were used to be synthesized as an input for the simulation of the physical characteristics of the Asmari Formation. The basic parameters modelled are water saturation, porosity, facies, and permeability.

Property modelling is the distribution of the different rock properties between the wells such that it realistically preserves the reservoir heterogeneity matching the well data in the grid cells. The layer geometry was given to the grid during the layering process. The Petrel program propagates property values along with the grid layer while data points are interpolated. This process was therefore relayed on the existing grid geometry [10].

2.1 Facies Modeling

The facies modelling provides discrete facies to the grid model. The well-logs with discrete properties in the model grid and possibly defined trends within the reservoir were scaled-up by analysing data [11]. The pay zone facies are considered dolomite, limestone, sand, and silt while considering the facies shale and anhydrite are not a reservoir or non-pay. Facies modelling allows propagating the up-scaled facies throughout the 3D grid. The facies are generated using the well-log interpretation in the current model.

Sequential indicator simulations controlled the distribution of the up-scaled facies due to the absence of the sedimentological distribution for the facies or seismic property distribution. Figure 13 shows the 3D facies model of the Asmari Formation in Abu Ghirab Oilfield.

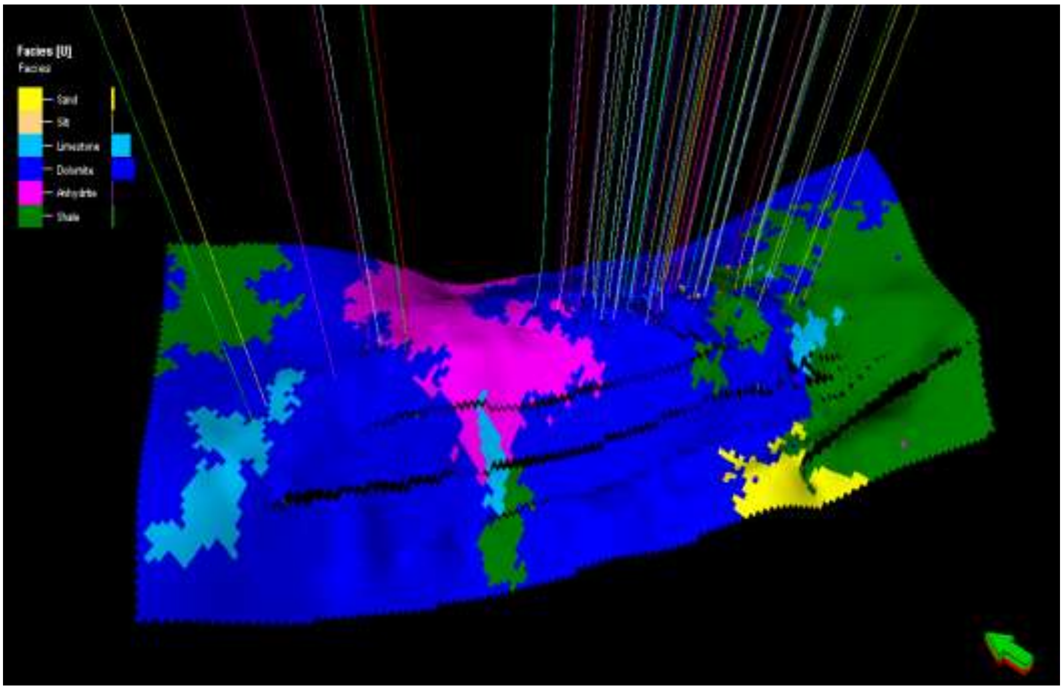


Figure 13-3D facies distribution model (An example from one layer)

Later, the petrophysical modelling process was conducted by distributing parameters for the property variation according to the facies type.

2.2 Petrophysical Model

The petrophysical model is the interpolation or continuous simulating data of permeability, porosity, and saturation. The Petrel software offered several algorithms for modelling the allocation of petrophysical properties in the model of the reservoir [12].

Porosity and water saturation were distributed using the CPI log data at a well scale (Figure 14). They were also distributed at the reservoir scale after upscaling using the Sequential Gaussian Simulation (SGS) algorithm in Petrel. The procedure was done by considering the porosity and water saturation range for each facies, obtained by using bias with the distribution of the facies in the 3D distribution.

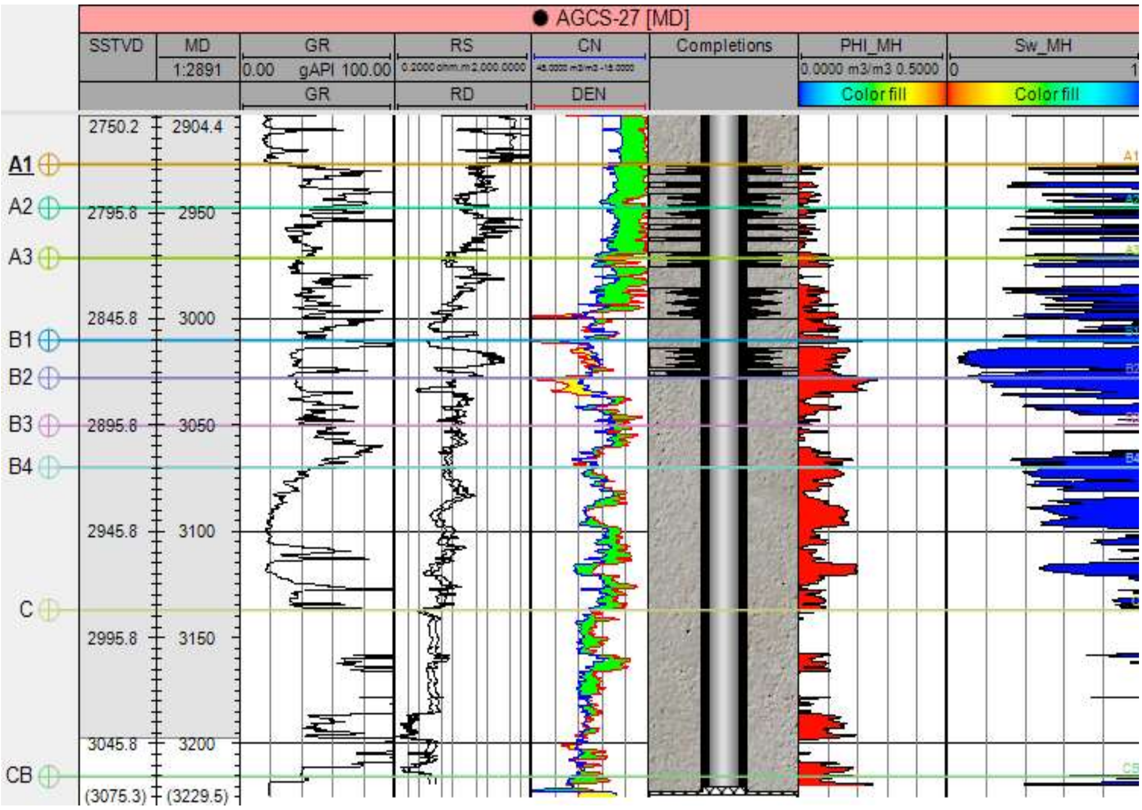


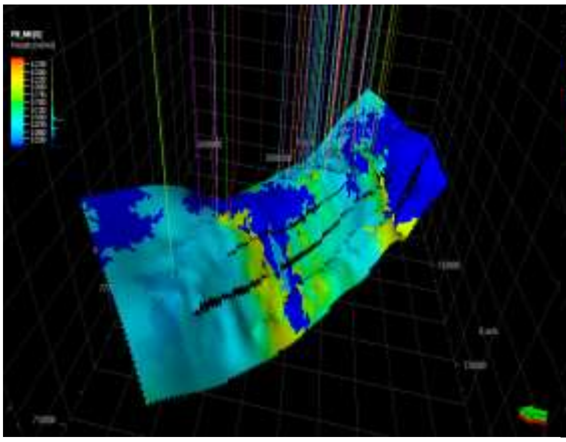
Figure 14-Loaded data from wireline logs and CPI

2.2.1 The Model of Porosity

The porosity model was achieved based on the results of porosity logs (density and neutron) corrected and interpreted by the model. A statistical sequential Gaussian simulation algorithm was used as fits the available data [7].

The essential step of the porosity mode is to scale up the porosity model from the cells of the entire model to distribute the porosity from the well-logs to the grid cells in a 3D model as realistically as possible to preserve the heterogeneity of the geological subsurface. Before the porosity could be modelled, the original porosity distribution was transformed into a stationary and normally distributed data set using the SGS algorithm in petrel. Removing trends before modelling allows the input data to be fixed [6].

The facies model was dependent on distributing the porosity and building the porosity model. Figures 15 and 16 show the distribution of porosity inside the facies model of the Asmari Formation. For layer A, the porosity mainly ranges from 1.3% to 21.3%, from ultra-low to medium porosity. Besides, zone A3 has better porosity than A1 and A2; the porosity mainly ranges from 1.1% to 30.3% for layer B. In comparison, zone B4 has the best properties due to the high porosity of sandstone. Dolomite and limestone in layer B are medium properties, which is low to high porosity, and dolomite is a little better than limestone. Dolomite in layer A has the worst properties, which is ultra-low to medium porosity. Layer A has a low porosity reservoir, while layer B is much better than layer A, which displayed a medium porosity. Zones B4 and B2 have the best physical property, while zone B1 and B3 do not have good porosity in layer B. Zones in layer A are not good. The porosities of zone A1 and A2 are a little less than in zone A3.



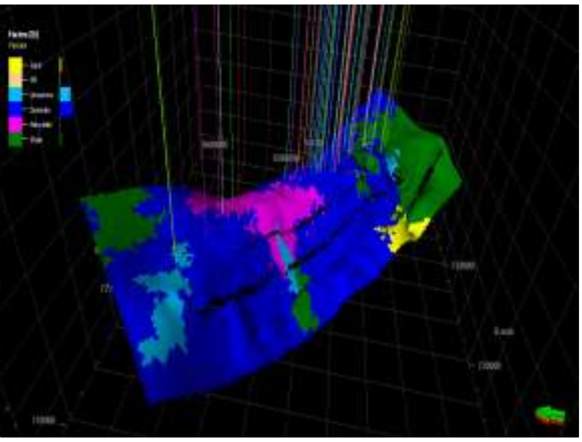


Figure 15-Distribution of facies in the 3D grid **Figure 16**- Distribution of porosity inside the facies

2.2.2 Water Saturation model

The water saturation model has been created using the same geostatistical method as the porosity model after scale-up. In addition, the facies model was also used as a base for the distribution of the water saturation values in the model. Figure 17 shows the distribution of water saturation inside the facies.

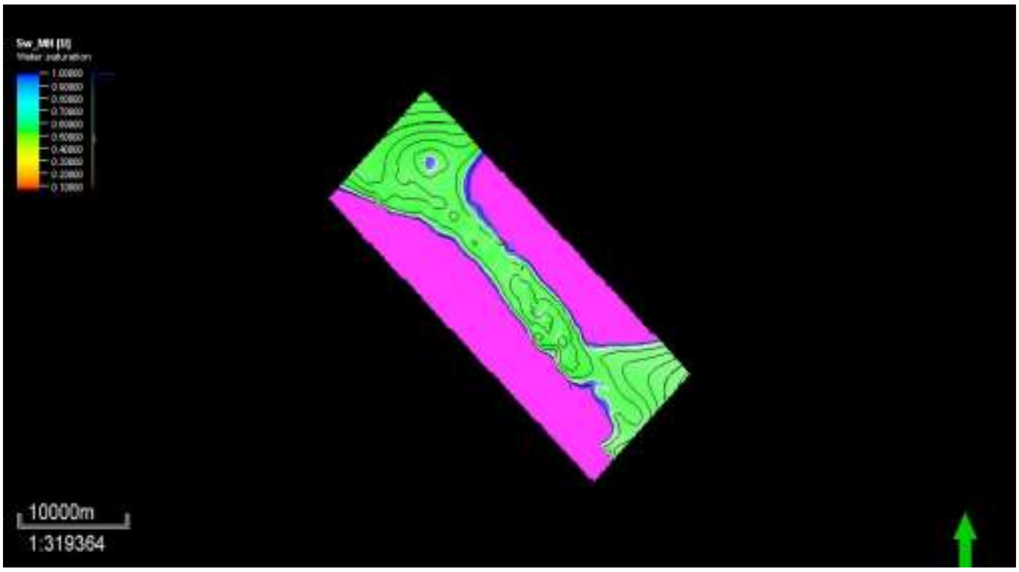


Figure 17- Distribution of water saturation inside the facies

2.2.3 Permeability Model

The oil and gas discoveries require a core sampling before the development stages. The outcome of the current study is not just related to the well log correct effect interpretation but also provides an outcome to the field model and orientations to future developments [13]. Nine samples were collected from layers A, B, and C at AGCN-2, AGCS-3, AGCN-4, AGCS-9, AGCS-10, AGCS-13, AGCS-14, AGCN-17, and AGCS-101 wells within the Asmari reservoir.

After conducting the basic routine core analysis to provide inputs for the permeability model, it was found that the permeability of the Asmari reservoir ranges from good to very good.

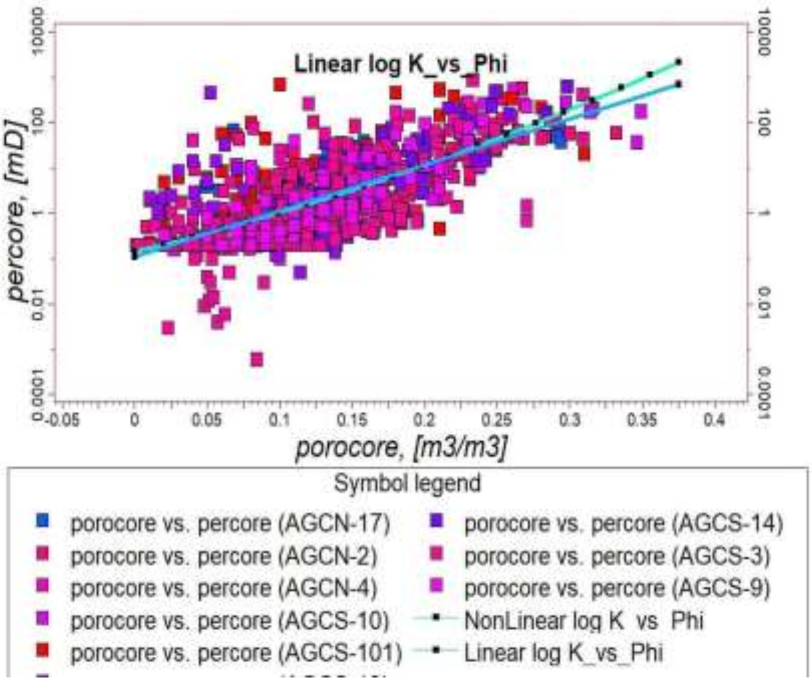


Figure 18-Core porosity and core permeability for nine wells in the Asmari reservoir

Figure 18 shows the horizontal permeability versus the core porosity created in six equations depending on facies ranges. These facies were presented in Figure 19 using statistical probability to compute the permeability of sand, silt, limestone, dolomite, anhydrite, and shale volume in the Asmari reservoir.

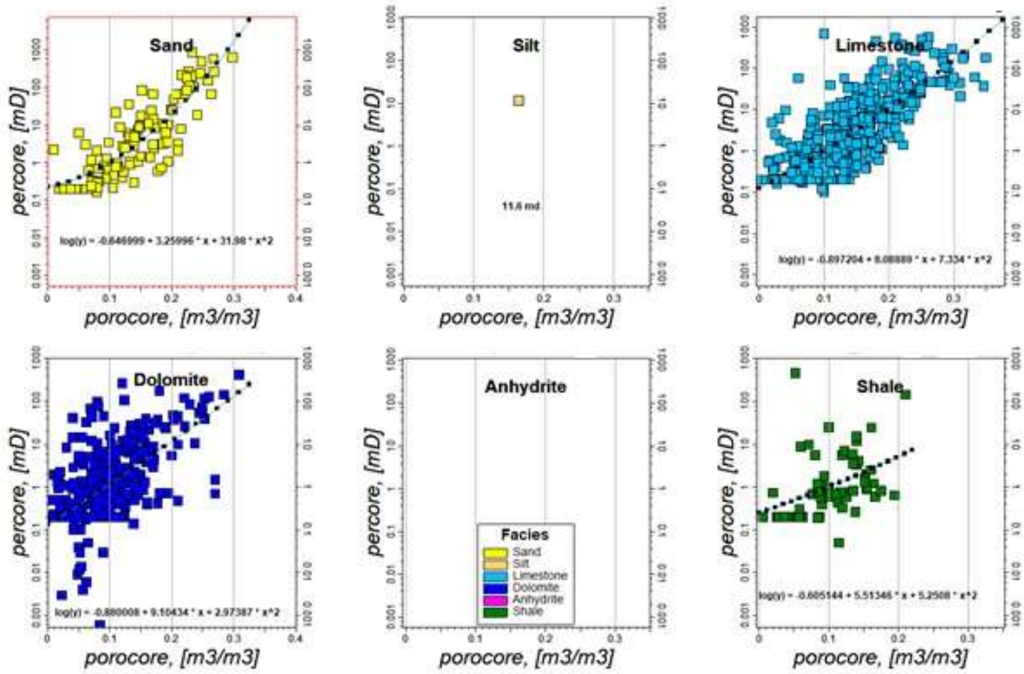


Figure 19-Distribution of facies on core porosity and core permeability of the Asmari reservoir

The permeability has been computed in each cell penetrated by wells after facies and porosity simulations using the permeability/porosity transforms defined per facies [14]. Then the permeability is distributed into the 3D grid of the model.

Table 2-The results of horizontal permeability in 9 wells

Rock type	Correlation	**Covariance**
Sand	log(K) = -0.646999 + 3.25996 * PHI + 31.98 * PHI^2	0.0575581
Silt	11.6	
Limestone	log(K) = -0.897204 + 8.08889 * PHI + 7.334 * PHI^2	0.0502586
Dolomite	log(K) = -0.880008 + 9.10434 * PHI + 2.97387 * PHI^2	0.0316807
Anhydrite	0	
Shale	log(K) = -0.605144 + 5.51346 * PHI + 5.2508 * PHI^2	0.0151179

The porosity and permeability equation’s covariance coefficients are 0.0151179 and 0.0575581, respectively. Therefore, the developed permeability relationship for a sand interval in a well is better applied than shale due to lateral heterogeneities (Table 2).
Figure 20 shows the Asmari reservoir permeability distribution modelling obtained from the Abu Ghirab oil field. The permeability of layer A mainly ranges from 0.1 mD to 454 mD. Zone B4 has the best properties due to the existence of sandstone as a high permeable media. Dolomite and limestone in layer B are characterized by ultra-low to high permeability. Dolomite is more permeable than limestone, but layer A has the worst properties (ultra-low to medium permeability). Zones A1 and A2 have better permeability than A3. For zone B, the permeability mainly ranges from 0.1 mD to 4823 mD. Zones B4 and B2 have the best physical property, while zone B1 and B3 are not good in layer B. Zones in layer A are not good too, and the permeability of zone A1 and A2 are better than zone A3.

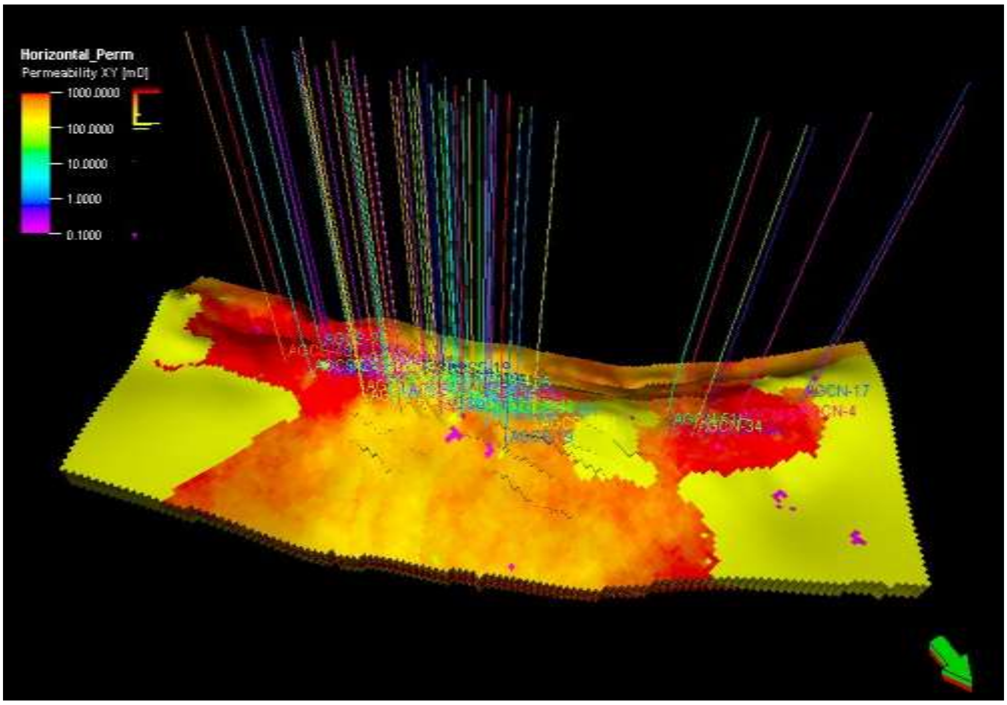


Figure 20-Permeability distribution modelling of Asmari reservoir

3- Oil-Water Contact: Any hydrocarbon contacts (oil/water, oil/gas, gas/water, etc.) used in the volume calculation process must be pre-defined in the make contact process to facilitate the use of contacts inside the 3D grid.

The volumetric method is adopted for OOIP calculation. The OOIP of different oil-bearing formations is calculated separately. When calculating the OOIP, the oil-water contact differences of different zones must be built, defined for zone A as (-2925.5 m) and zones B and C (-2972m), as shown in Figure 21.

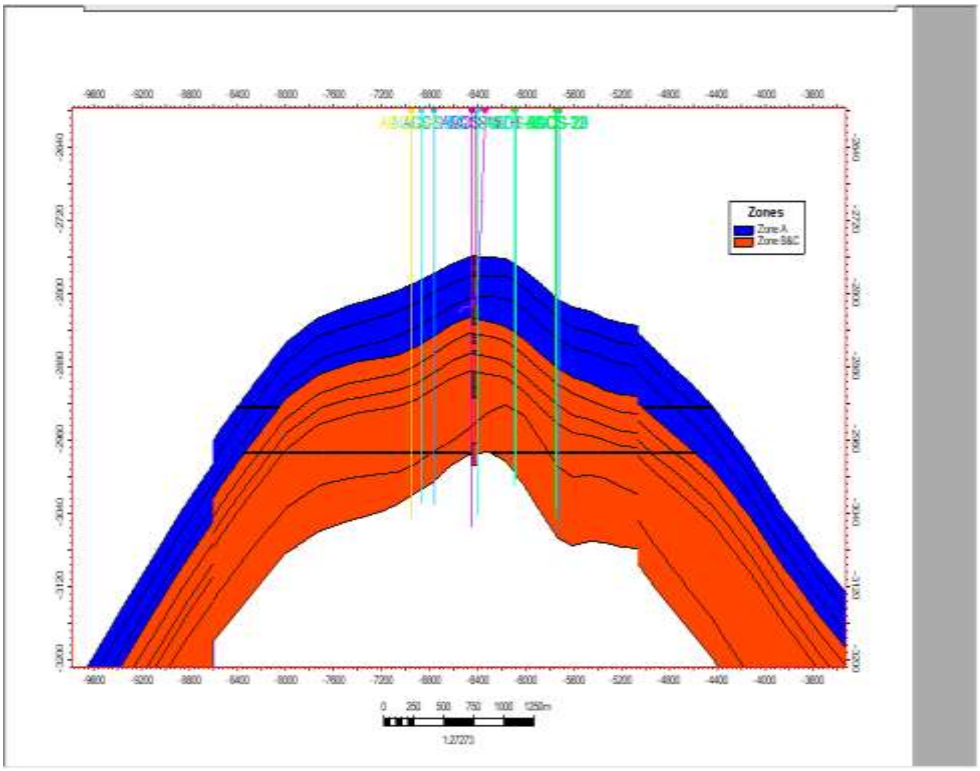


Figure 21-The cross-section of oil-water contacts of zone A, B and C

4-Volume calculation

Calculation of the original hydrocarbon in place (OHIP) of the Abu Ghirab oilfield reservoir is the last step in evaluating the reservoir to estimate the oil quantity. Original Hydrocarbons in Place are those quantities of hydrocarbon and related substances estimated at a particular time to be recoverable from known accumulation.

In the study area, based on well log correlation, the reservoir characterizes and minimizes the impact of shale in calculating the NTG map and Net Bulk Volume (NBV).

There are many methods to estimate the OHIP, but the volumetric way is the most commonly used approach to assessing the OHIP [15]. The volumetric calculation equation of the hydrocarbon in place as follows:

$$OHIP = G.B.V * N/G * \Phi * S_o * 1/B_o \quad m^3 \qquad [1]$$

Where,

OHIP: in place original hydrocarbon ($MMSm^3$)

G.B.V: the reservoir gross bulk volume (m^3) = 10^6 x A x h.

N/G: reservoir net thickness/ reservoir gross thickness.

Φ: effective porosity (fraction).

S_o: saturation of oil.

B_o: formation volume factor (res.m^3/stm^3).

Table 3 shows the OOIP calculation results for each geological member of this reservoir. The calculation is conducted by the grid, which fully considers the impact of pore space heterogeneity on the calculation of OOIP. Table 4 shows the value of the original oil in place for previous studies.

Table 3- Results of OIIP in the geological model

Zones	Bulk volume [10^6 m^3]	Pore volume [10^6 rm^3]	HCPV oil [10^6 m^3]	STOIIP [10^6 m^3]
A1 - A2	3609	69	33	25
A2 - A3	2760	58	31	24
A3 - B1	1337	54	26	20
B1 - B2	5257	247	98	76
B2 - B3	3694	164	58	44
B3 - B4	2170	101	29	22
B4 - C	5121	201	67	51
C	2186	50	9	7
				total =269

Table 4-Results of OIIP in geological model and previous studies

Study	**OIIP** [*10^6 m^3]
Current Static Model	269
OOIP by RERP in 2017 (10)	240.1623
OOIP by ERP in 2014 (9)	253.1240

Conclusions

1. The structural model has 43 faults created in high reliability. The model grid size is (200 m x 200 m x 57 m) which was fit the field size and sufficiently detailed to represent the heterogeneity parameters of the physical lithology. Abu Ghirab oilfield comprises two asymmetrical anticlinal domes, and its axis extends toward Northwest–Southeast ranges about (33km * 12km) with north and south domes structurally.
2. Asmari reservoir in Abu Ghirab Oilfield was investigated using Well trajectories, well logs, CPI, Core data, stratigraphic zonation, lithological facies from core and wireline logs, and reports. The reservoir is divided into nine layers (A1, A2, A3, B1, B2, B3, B4, C, and CB) separated by low porosity and high water saturation barrier beds.
3. The lithological parameters of the physical model (facies, porosity, permeability, and water saturation) were made using Petrel software (2017.4), which is generally interpreted for each well. In addition, it shows that layers (A and B) are critical reservoir units with good reservoir properties and oil-bearing zones than layer C, which is a water-bearing zone. The permeability variation was narrowed down after being divided into nine lithologies. Thus, it is helped to minimize errors in the parameter modelling.
4. The simulated model has six classes of facies based on the porosity-permeability properties that reflect the interconnectivity of the oil, which are important and determine the flow capacity. The average porosity of layer A is about 8.72%, and the average permeability is about 10.61 mD. In comparison, the average porosity of the B layer is about 16.78%, and the average permeability is about 268.5 mD. Layer A is characterized by low and low to medium porosity, while layer B, much better than Layer A, has medium porosity and medium to high permeability.

5. The oil initially in place stored in the model was 269 million $sm^{3,}$ including 69 million sm^3 from zone A and 193 million sm^3 from zone B and a small volume from zone C (7 million sm^3).

Abbreviations:

OHIP: Original Hydrocarbon In Place; CPI: Computer Processing Interpretation; SGS: Sequential Gaussian Simulation; SCAL: Special Core Analysis; LSM: Least Squares Method; NTG: Net To Gross; (NBV): Net Bulk Volume

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