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Building A 3D Geological model Using Petrel Software for Asmari Reservoir, South Eastern Iraq

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Abstract

Building a 3D geological model from field and subsurface data is a typical task in geological studies involving natural resource evaluation and hazard assessment. In this paper a 3D geological model for Asmari Reservoir in Fauqi oil field has been built using petrel software. Asmari Reservoir belongs to (Oligocene- Lower Miocene), it represents the second reservoir products after Mishrif Reservoir in Fauqi field. Five wells namely FQ6, FQ7, FQ15, FQ20, FQ21 have been selected lying in Missan governorate in order to build Structural and petrophysical (porosity and water saturation) models represented by a 3D static geological model in three directions .Structural model shows that Fauqi oil field represents un cylindrical anticlinal fold which contains number of culminations at northern and southern parts separated by depressions. After making zones for Asmari reservoir, which is divided into 4 zones (Jeribe/ Euphrates and Kirkuk group which includes Upper Kirkuk, Buzurgan member, Lower and Middle Kirkuk) , Layers are built for each zone of Asmari reservoir depending on petrophysical properties. Petrophysical models (porosity and water saturation) have been constructed for each zone of Asmari reservoir using random function simulation algorithm. According to data analyses and the results from modeling, the Upper Kirkuk zone which divided into five layers is a good reservoir unit regarding its good petrophysical properties (high porosity and low water saturation) with high presence of oil in economic quantities. Cross sections of porosity model and water saturation model were built to illustrate the vertical and horizontal distribution of petrophysical properties between wells of Fauqi oil field.

Keywords: Asmari Reservoir, Fauqi oil field, Petrophysical properties.

بناء موديل جيولوجي ثلاثي الابعاد بأستخدام برنامج البتريل لمكمن الاسمري جنوب شرق العراق

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قسم علم الارض، كلية العلوم، جامعة بغداد، بغداد، العراق.

المستخلص

بناء الموديل الجيولوجي الثلاثي الابعاد من المعلومات التحت السطحية والحقلية هي مهمة اساسية في الدراسات الجيولوجة المتضمنة تقييم الموارد الطبيعية وتحديد الاضرار. يتضمن هذا البحث بناء موديل جيولوجي ثلاثي الابعاد لمكمن الاسمري في حقل فكة النفطي بأستخدام برنامج بتريل الحاسوبي.مكمن الاسمري يقع تحت عمر الاوليغوسين – المايوسين الاسفل. يمثل هذا المكمن هو المكمن الثاني بعد تكوين المشرف في حقل فكة. تم اختيار خمسة ابار من حقل فكة المسماة FQ6, FQ7, FQ15, FQ20, FQ21 الواقعة في محافظة ميسان لبناء موديل تركيبي وبتروفيزيائي (المسامية والتشبع المائي) والمتمثلة بالموديل الاستاتيكي الجيولوجي الثلاثي الابعاد.يوضح الموديل التركيبي بأن حقل فكة عبارةعن طية محدبة غير اسطوانية تحتوي على عدد من الذروات

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او القمم عند الاجزاء الشمالية والجنوبية تفصل بينها المنخفضات. بعد بناء الانطقة في مكمن الاسمري والذي قسم الى اربع انطقة (الجيربي/ الفرات ، كركوك الاعلى ، عضو بزركان ، كركوك الاوسط والاسفل) ، تم بناء عدد من الطبقات ضمن كل نطاق بالاعتماد على الخواص البتروفيزيائية. تم بناء الموديل البتروفيزيائي الذي يشمل المسامية والتشبع المائي لكل نطاق من انطقة مكمن الاسمري باستخدام طريقة محاكاة الدوال العشوائية اللوغارتمية. بالاعتماد على تحاليل المعلومات ونتائج الموديلات، تبين ان نطاق كركوك الاعلى المقسم الى خمسة طبقات يتميز بمواصفات بتروفيزيائية جيدة من حيث المسامية المرتفعة والتشبع المائي المنخفض وهذا يعطي دليل لوجود كميات جيدة من النفط الخام في هذا النطاق. تم بناء مقاطع عرضية لموديل المسامية وموديل التشبع المائي لتوضيح التوزيع العمودي والافقي للخواص البتروفيزيائية بين ابار حقل فكة النفطي.

Introduction

A large number of reservoir models can be created relatively quickly with geostatistical tools, such as Petrel modeling software, one of most popular modeling software in oil industry, but often, a limited number must be selected for input to flow simulation because of computational time requirements **[1].** 3D model is the process of developing a mathematical representation of any three-dimensional surface of object (either inanimate of living) via specialized software. The product is called a 3D model **[2].** In general a model is representation of some object or event in the real world. A model is good if it adequately describes the property or some properties of the real world that is relevant to the study. For example, a 3D geological model of an area is good if it gives back the values of the real world in reservoir simulations and reservoir modeling. According to the definition above, for various purposes different models will provide the best results. A geological model is a spatial representation of the distribution of sediments and rocks in the subsurface. The model is traditional presented by 2D cross-section, but increasingly visualized as digital 3D models **[3].**

The aim of this paper is to build a 3D geological model for Five wells of Asmari reservoir in Fauqi oil field namely FQ6, FQ7, FQ15, FQ20, FQ21 which have been selected. The 3D geological model includes structural models (structural maps) and well correlations have been also constructed and the petrophysical properties (porosity and water saturation) have been distributed in the model as well.

Study Area

Fauqi oil field is located in southeast of Iraq in Missan governorate near Iranian border, it has an axial length about 23 km and its width is about 6 km with these coordinates (3565000-3554000) northing lines and (73700-74300) easting lines. Fauqi oil field represents concerted fields with Iran especially in the northern part of field, see figures -1 and (-2). Asmari formation in this field is divided to four sub formations in which they are; (A) Jeribe- Euphrates, which it composed mainly of dolomite with some limestone and anhydrite. (B) Upper Kirkuk, it is composed of mainly limestone, dolomite and some sandstone. (C) Buzurgan Member, it is mainly containing sandstone with some dolomite, limestone, and shale in the upper part. (D) Middle-Lower Kirkuk, it is in general composed of limestone, dolomite, and sandstone **[4].**

Figure 1- location map of Fauqi oil field [5].

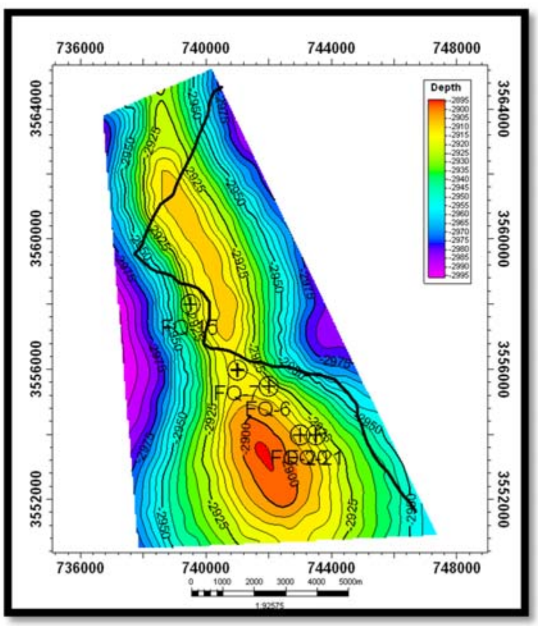

Figure 2- Structural map of top of Jeribe- Euphrates Fm. modified from [4].

Methodology

Petrel software 2009 has been used to build 3D model. Petrel is a PC- based workflow application for subsurface interpretation and modeling **[6].**Data preparation is the basis for geologic model. On this basis of software demand and research area characteristic, the data prepare for this 3D-geological model are well heads, well tops, well logs. The input data is imported from files – on file for each data object. These data include

1-Well head: include the position of each well in 3-dimentions, and the measured depth along the path.

2- Well tops: Markers representing significant points (well picks) along the well path, normally a change in stratigraphy.

3- Well logs: the data cover effective porosity and water saturation values along the well path.

Model Design Workflow

The main steps of building a static model of a petroleum reservoir using petrel software are:

Data import.
Input data editing and quality check (Q.C).
Well correlation.
Structural modeling, which includes:
Pillar gridding.
Make horizons.
Layering.
Property modeling, which includes:
Scale up well logs.
Petrophysical modeling

Well correlation

In this study, well correlation has been applied as a relatively easy method to give an idea and allow simple visualization of the changes in the thickness within Asmari units and the change of the petrophysical properties (i.e., changes in porosity and water saturation) of the various units of Asmari reservoir. After data were entered to Petrel software, correlation section of Fauqi wells were made. Figure -3 illustrates the vertical and horizontal variations in thickness of Asmari units as well as the variations in petrophysical properties.

Structural modeling:

Structural modeling is used for building geological model. It was subdivided into three processes as follows: fault modeling, pillar gridding, and vertical layering. All the three operations were performed one after the other to form one single data model **[7].**

A structure contour map is one of the most important tools for three-dimensional structural interpretation because it represents the full three-dimensional form of map horizon. The mapping techniques to be discussed are equally applicable in surface and subsurface interpretation.

3D Structural maps were built depending on the well tops for all Fauqi wells as well as the available structural map for top of Asmari reservoir from 2D seismic. 3D contour maps have been built to each zone of the Asmari reservoir. Figures -4 represents 3D structural modeling for the Amari units. This model shows that Asmari structure is composed of un cylindrical anticlinal fold which contains two domes at northern and southern parts separated by depressions.

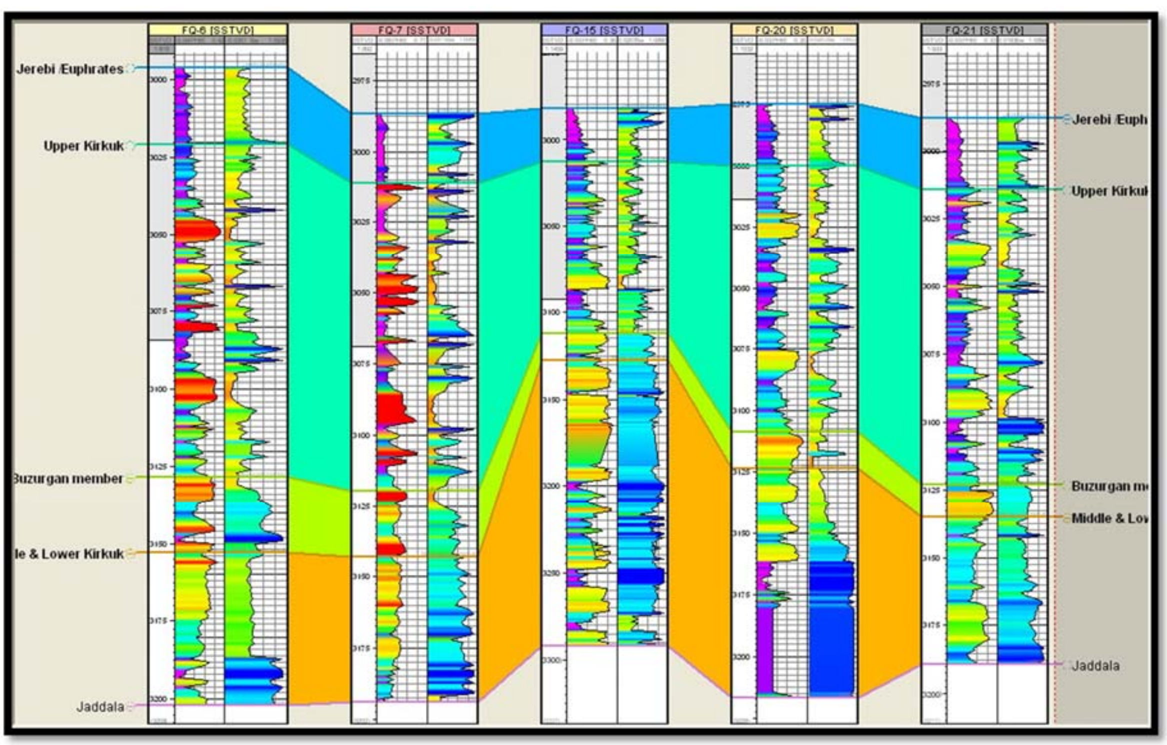

Figure 3- Correlation section of Asmari reservoir for Fauqi wells.

3D Grid Construction

A 3D grid construction is the first step to build the 3D model and is a network of horizontal and vertical lines used to describe a three dimensional geological model. In simple terms, a 3D grid divides a model up into boxes. Each box is called a grid cell and will have a single rock type, one value of porosity, one value of water saturation, etc. These are referred to as the cell properties. **[7].**

Pillar Gridding

Pillar gridding is the process of generating the grid, which represents the base of all modeling. The skeleton is a grid consisting of top, mid and base skeleton grids **[3].**

The grid which used in Asmari reservoir was represented by three dimensional grid systems of (100) grid along the X – axis and (100) grid along Y – axis. The size of grid was chosen depending on the area of the field and to specify the variation of the petrophysical properties. The result from pillar gridding is the main skeleton in top, mid and base skeletons as shown in figure **-**5. This figure shows a 3D grid or three skeletons of Asmari reservoir model in Fauqi oil field.

Make Horizons

The final step in structural modeling is to insert the stratigraphic horizons into the pillar grid, honoring the grid increment and the faults. Make horizons process step was used in defining the vertical layering of the 3D grid in Petrel. This present a true 3D approach in the generation of 2D surface, which was gridded in the same process, taking the relationships between the surfaces into account **[8].** Figure **-**6 represents horizons of the main units of Asmari reservoir.

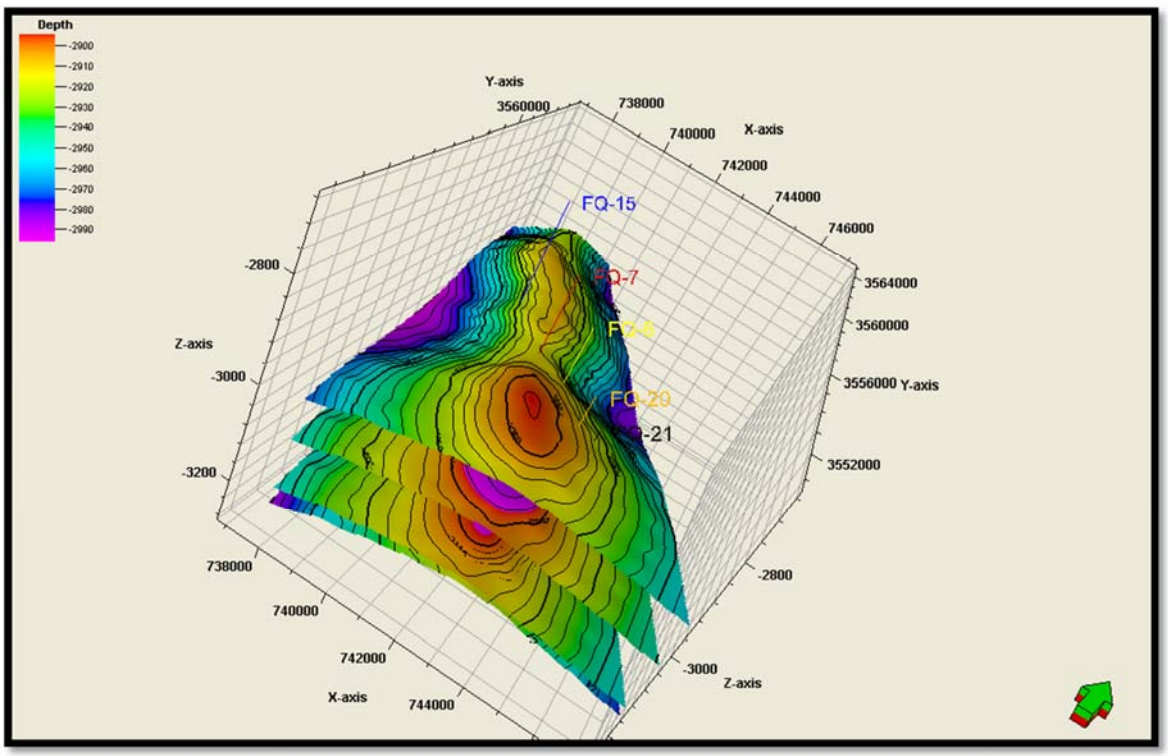

Figure 4- 3D structural modeling of Asmari reservoir in Fauqi oil field.

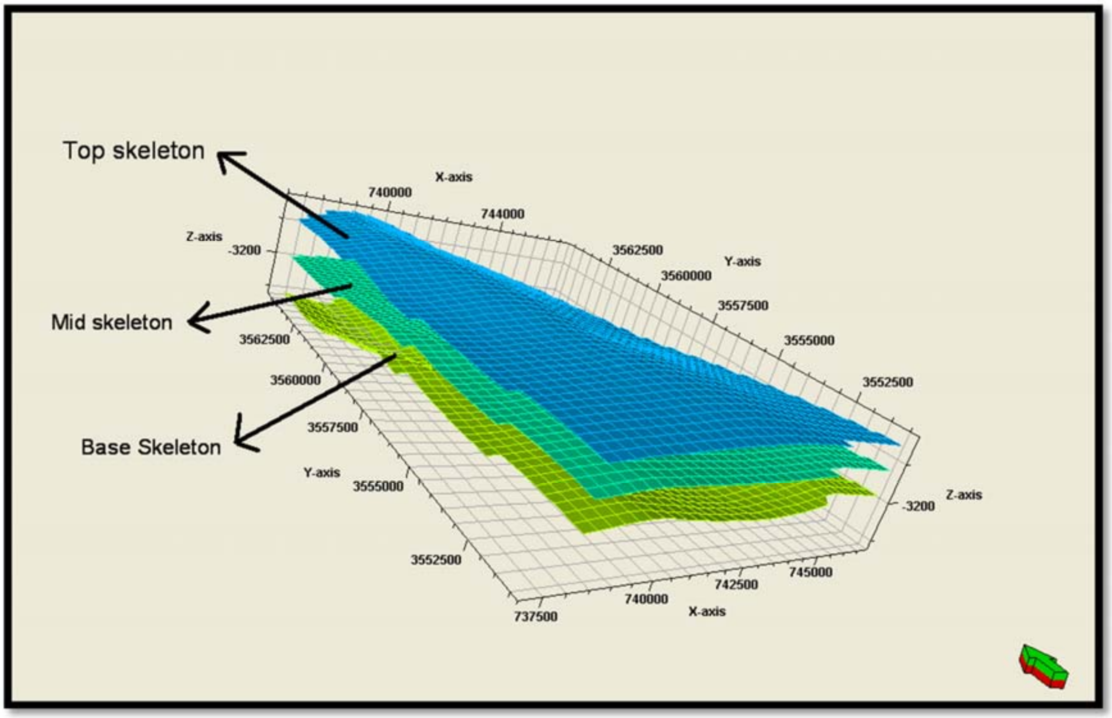

Figure 5- The skeletons of Asmari reservoir in Fauqi oil field.

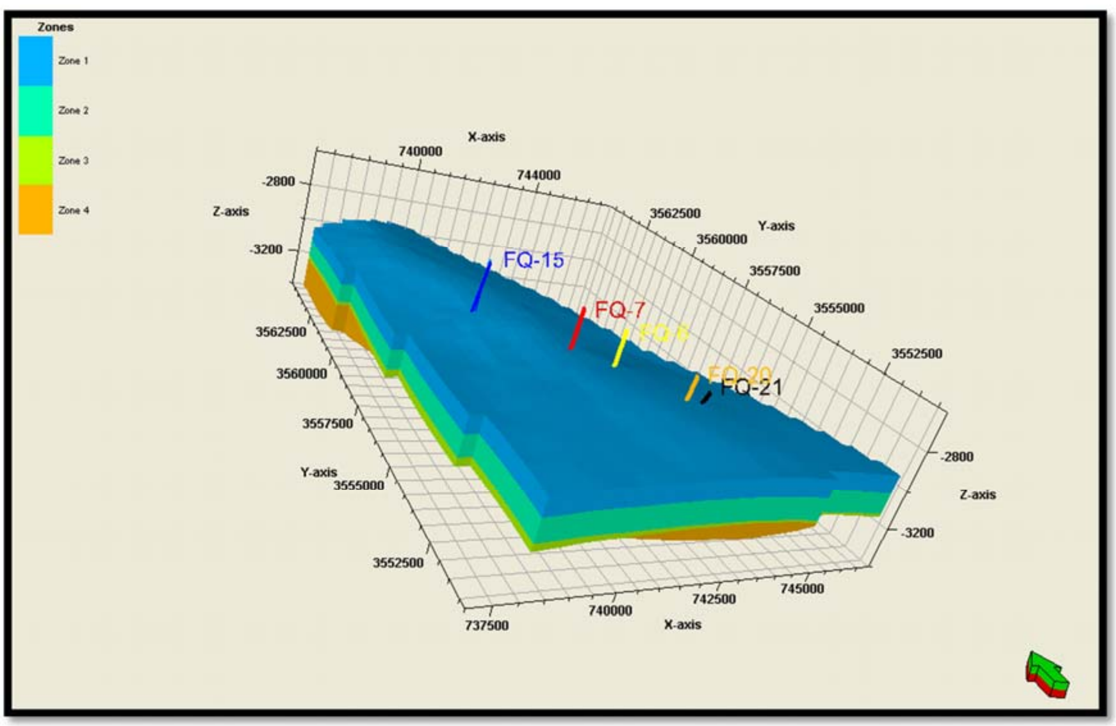

Figure 6- Main horizons of Asmari reservoir in Fauqi oil Field.

Layering

The final step in building the structural framework is to define the thickness and orientation of the layers between horizons of the 3D Grid. These layers in conjunction with the pillars define the cells of the 3D Grid that are assigned attributes during property modeling **[7].**

Modern geology requires accurate representation of layered volumes. Three-dimensional (3-D) geologic models are increasingly the best method to constrain geology at depth. Each Asmari unit in Fauqi oil field has been divided into many layers depending on petrophysical properties. The Jeribe/ Euphrates zone consists of two layers in the uppermost of the formation. Upper Kirkuk zone has a greater number of layers. This unit has 5 layers, but Buzurgan member has the least layers in the formation. It has one layer, while Lower and Middle Kirkuk zone was divided into two layers. (Figure-7).

Scale up Well logs

The Scale up well logs process averages the values to the cells in the 3D grid that are penetrated by the wells. Each cell gets one value per up scaled log. These cells are later used as a starting point for property modeling (Schlumberger, 2010). When modeling petrophysical properties, a 3D grid cell structure is used to represent the volume of the zone. The cell thickness will normally be larger than the sample density for well logs. As a result the well logs must be scaled up to the resolution of the 3D grid before any modeling based on well logs can be done. This process is also called blocking of well logs **[9].**

There are many statistical methods used to scale up such as (arithmetic, harmonic, and geometric method). The porosity and water saturation values in the current model have been scaled up using the (arithmetic average). Figure -8 shows the scale up of porosity and water saturation for FQ-6 well that is used in the Asmari Formation model.

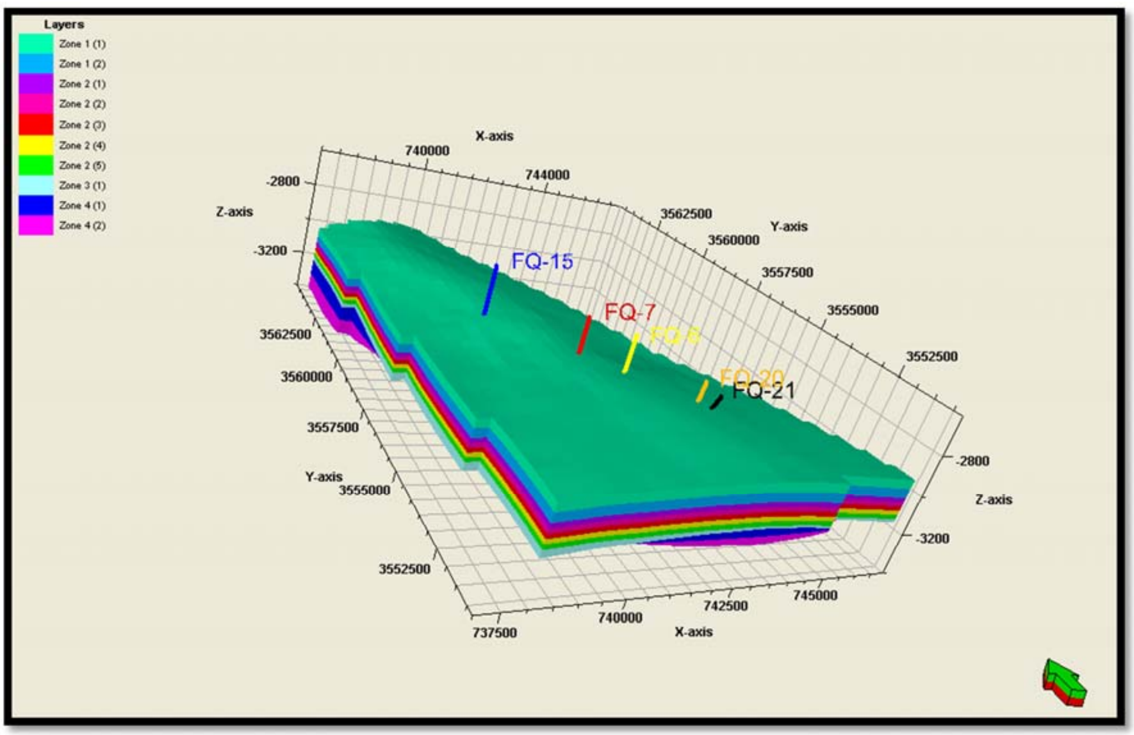

Figure 7- The layering in the Asmari Formation.

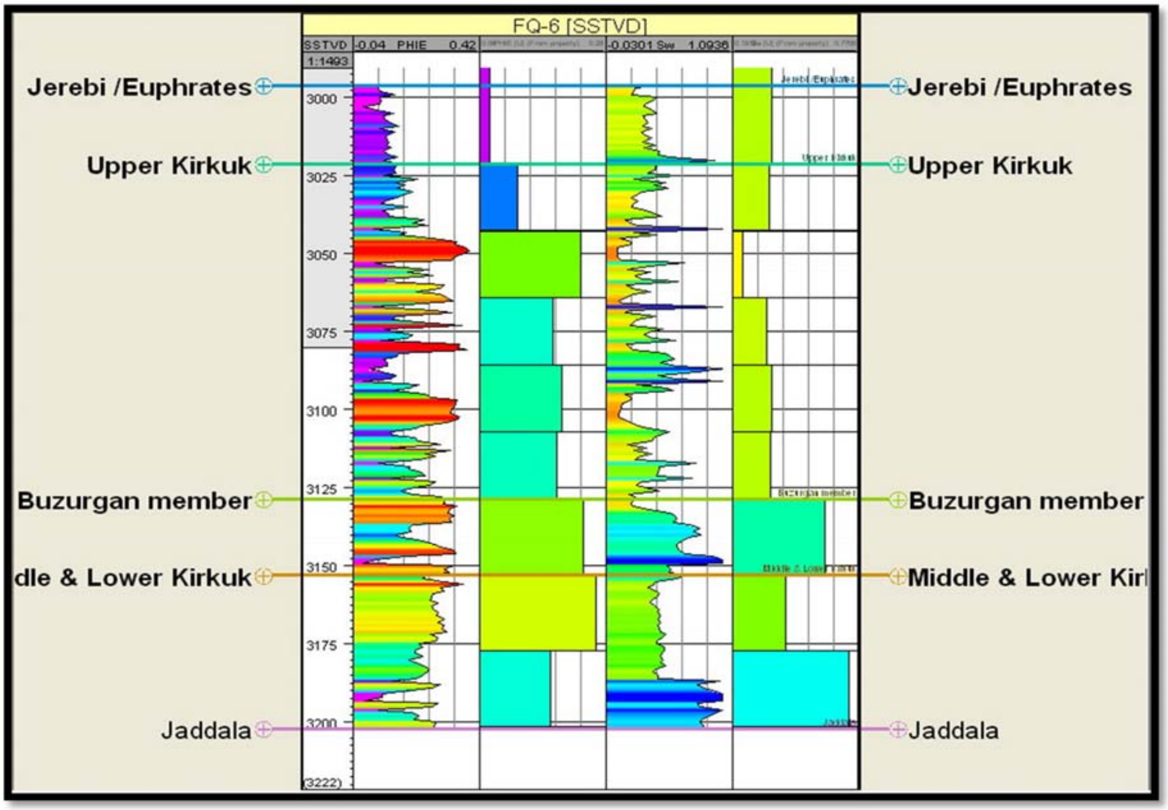

Figure 8- Scale up of porosity and water saturation for FQ-6.

Petrophysical modeling process

Petrophysical property modeling is the process of assigning petrophysical property values (porosity and water saturation) to each cell of the 3D grid. Petrel offers several algorithms for modeling the distribution of petrophysical properties in a reservoir model. Petrophysics model was built using geostatistical methods. Porosity and water saturation models were built depending on the results of porosity and water saturation values which have been corrected and interpreted in the IP software. Sequential Gaussian Simulation algorithm was used as a statistical method which fits with the amount of the available data.

Results and Discussions

From porosity and water saturation models for each zone of Asmari reservoir the following conclusions can be shown:

- The porosity model of the unit Jeribe- Euphrates as shown in figure (9) is characterized by low porosity values in all wells under study but some parts of this unit may show porosity increases to reach 15%. The porosity values in this zone range from (0-15%). From figure (10) of Water saturation model for zone Jeribe- Euphrates shows moderate water saturation values that range from (40-65%), so this zone is represented as having no reservoir unit in the wells under study.
- The porosity model of upper Kirkuk zone (fig.11) is characterized by high porosity especially in the upper parts of this unit in all well under study. The porosity values in this zone range from (11-30%). Figure (12) of water saturation model in upper Kirkuk zone shows low water saturation in the most parts of this zone. The water saturation values range from (15-40%).The upper kirkuk unit is characterized by high petrophysical properties and good reservoir unit and it contains oil quantities in all wells under study.
- The petrophysical properties in Buzurgan member change from high in wells FQ-6,FQ-7, and FQ-20 to low in wells FQ-21 and FQ-15.The figure (13) of porosity model for Buzurgan member shows variation in porosity values from high in wells FQ-6,FQ-7, and FQ-20 but decreases in wells FQ-21 and FQ-15. Porosity values range from (20-25%).Although the Buzurgan member characterized by high porosity in some wells under study but water saturation reaches to high values especially in well FQ-15

which is characterized by worse petrophysical properties as shown in figure (14) of water saturation model in Buzurgan member.

- In general, the middle and lower Kirkuk zone is characterized by variation in reservoir properties, whereas porosity and water saturation models in figures (15) and (16) show decreasing in porosity and water saturation in wells FQ-20,and FQ-21 and increasing to high porosity and water saturation with direction of wells FQ-6,FQ-7, and FQ-15.

Figures -17 and (-18) show the final porosity and water saturation models for Asmari reservoir in Fauqi oil field which were built from porosity and water saturation values using Sequential Gaussian Simulation algorithm as a statistical method after scale up of porosity and water saturation.

Finally, the cross sections in N-S direction for porosity and water saturation models were built in order to illustrate the vertical distribution of porosity and water saturation in each well under study. Figures (-19, and -20). These figures show the best location characterized as good reservoir properties in the FQ-6 and FQ-7 wells especially at upper parts of upper Kirkuk zone and decreases toward FQ-20 and FQ-21 wells and become bad reservoir properties in well FQ-15.

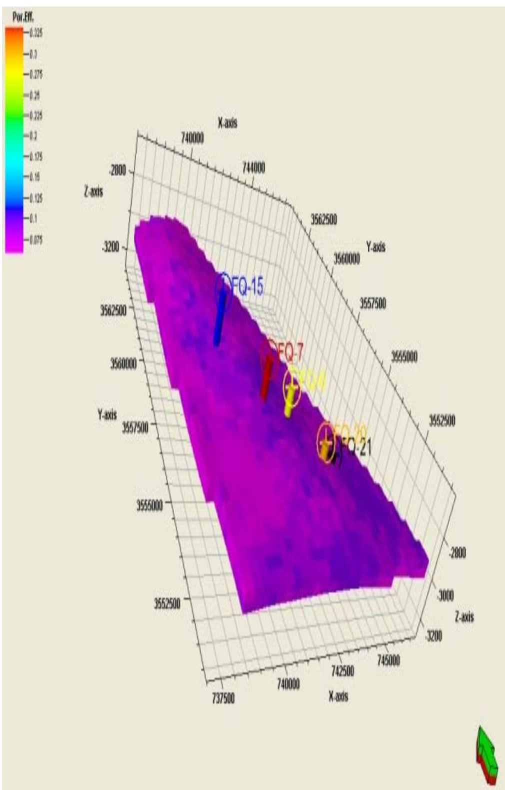

Figure 9- PHIE model for Jeribe- Euphrates

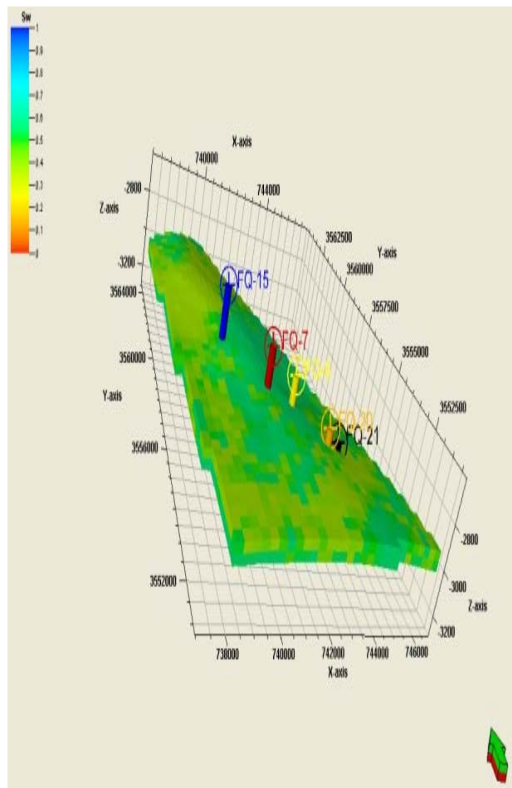

Figure 10- SW model for Jeribe- Euphrates

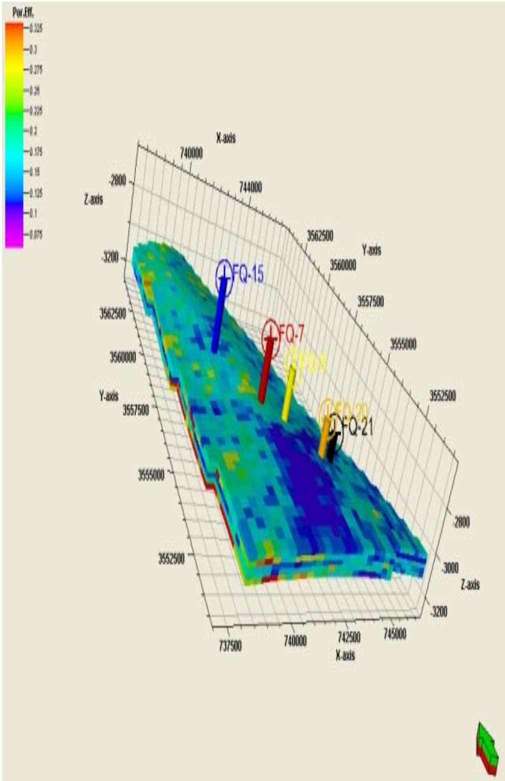

Figure 11- PHIE model for Upper Kirkuk.

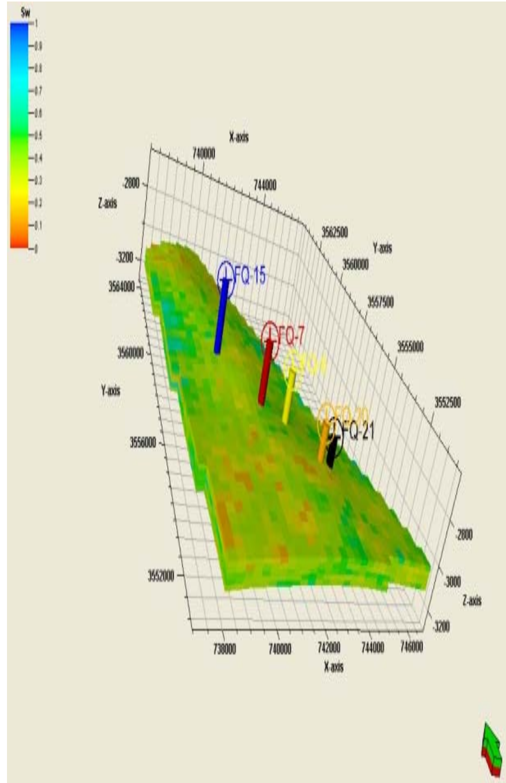

Figure 12- SW model for Upper Kirkuk.

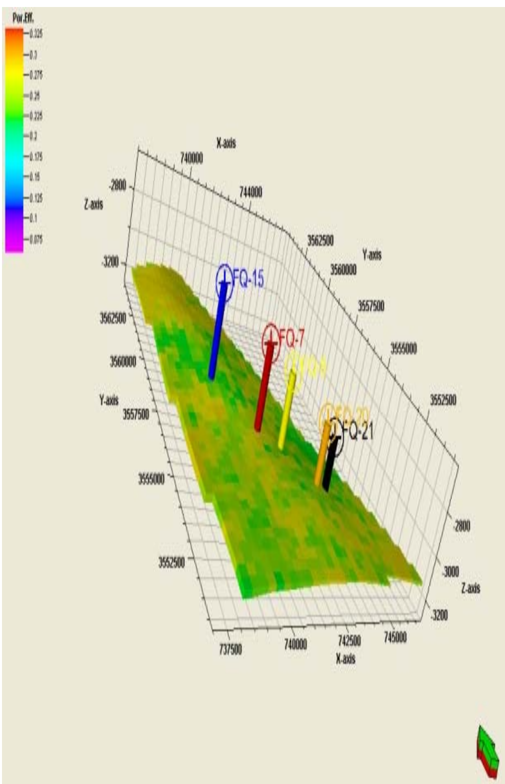

Figure 13- PHIE model for Buzurgan member.

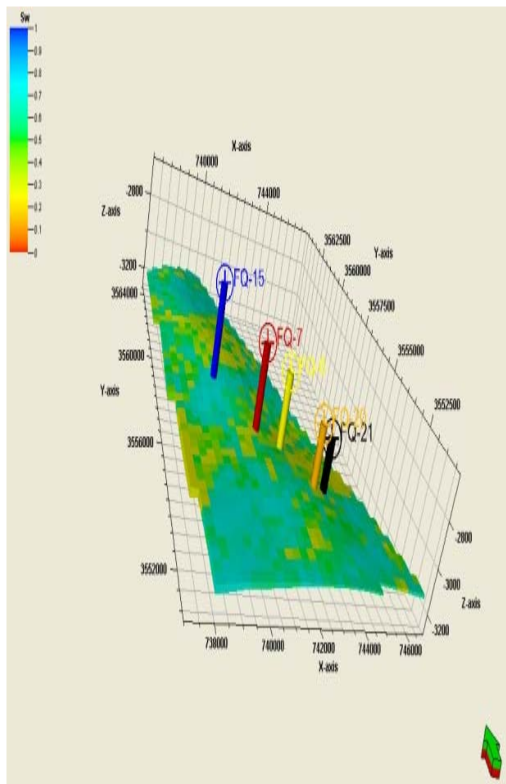

Figure 14- SW model for Buzurgan member.

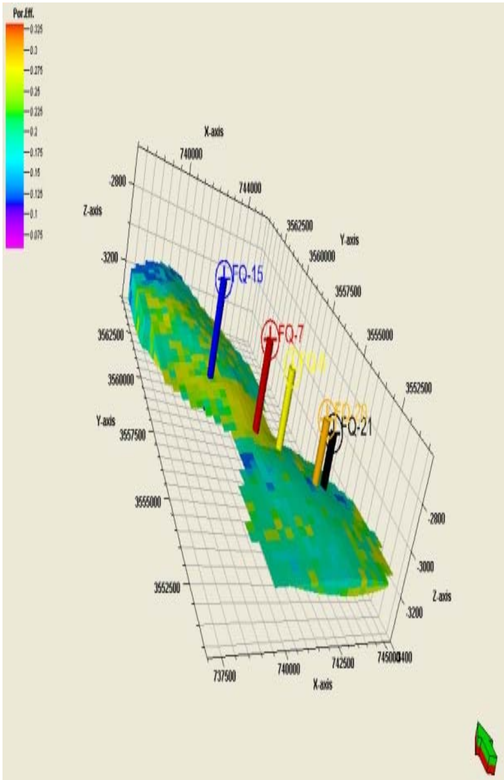

Figure 15- PHIE model for middle and lower Kirkuk.

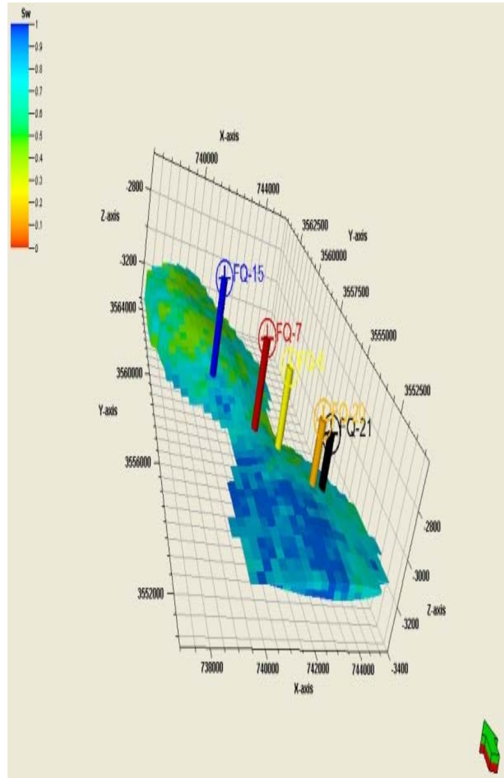

Figure 16- SW model for middle and lower Kirkuk.

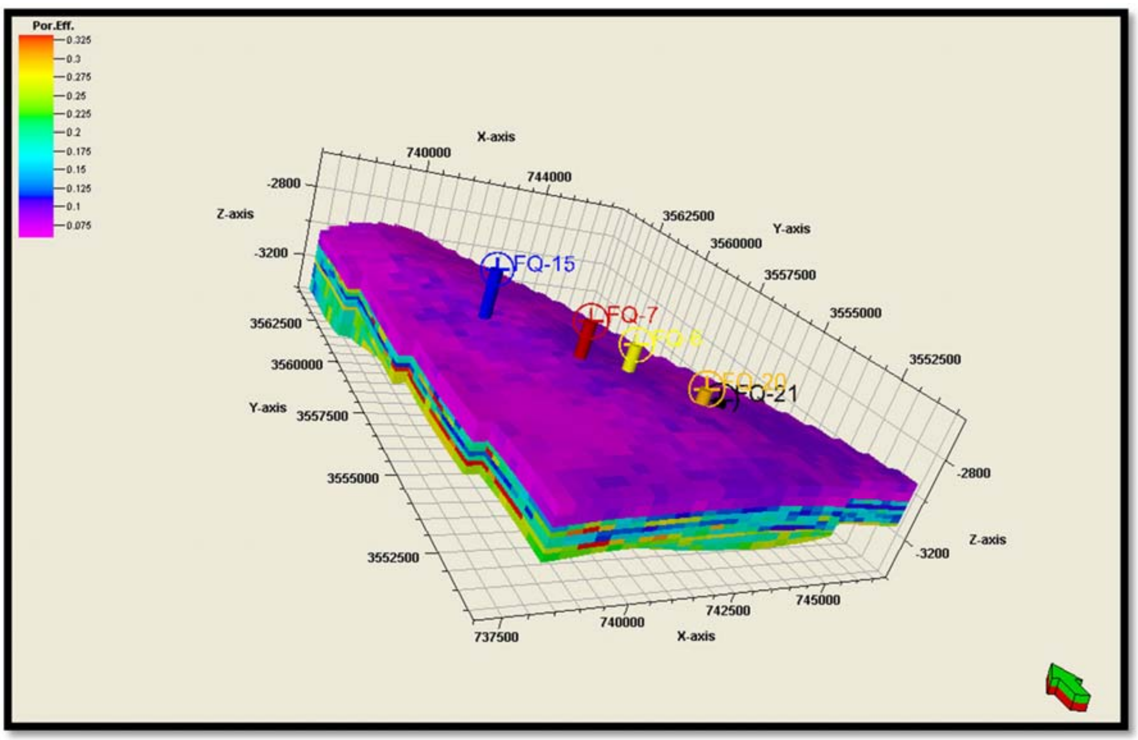

Figure 17- Final porosity model for Asmari reservoir in Fauqi oil field.

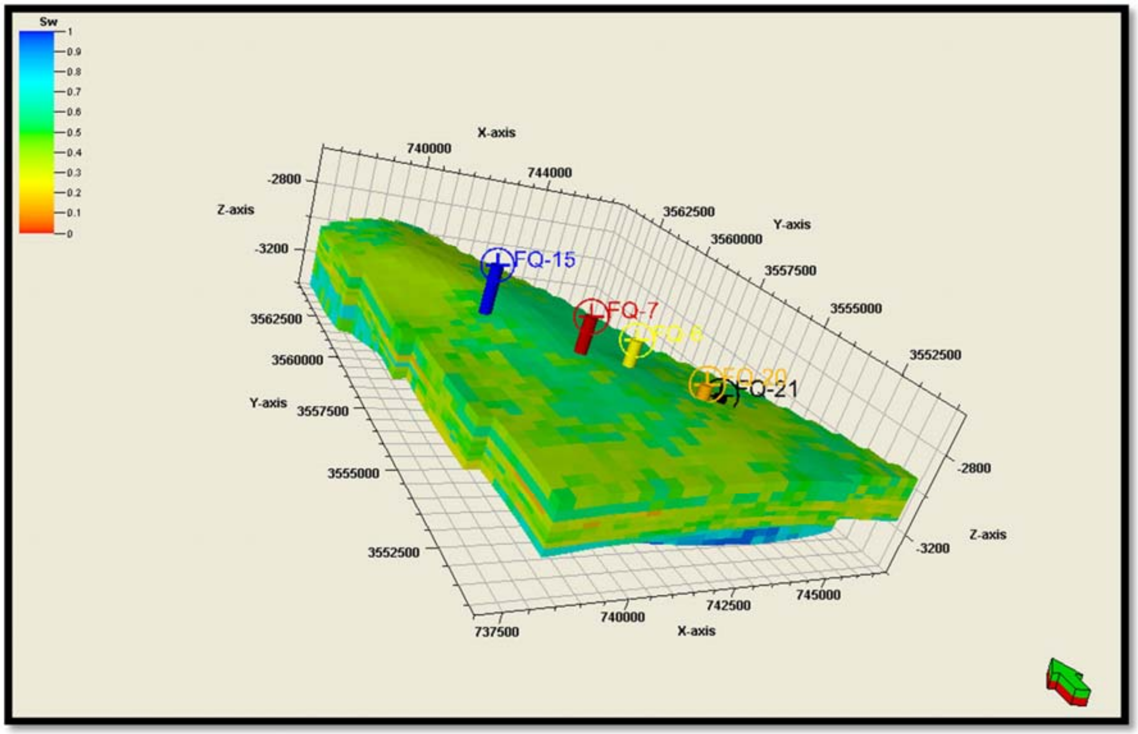

Figure 18- Final water saturation model for Asmari reservoir in Fauqi oil field.

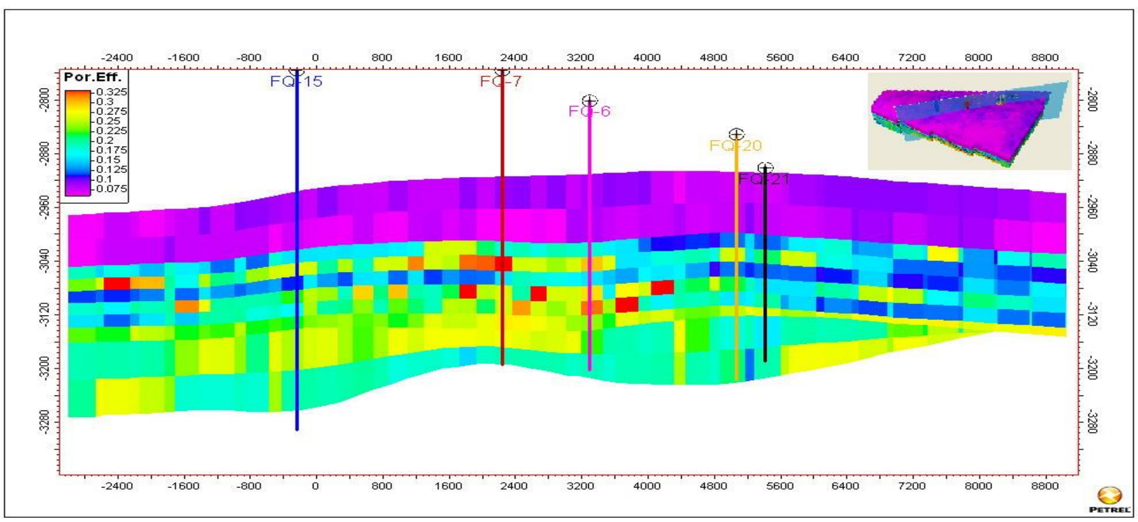

Figure 19- Cross section in N-S direction shows distribution of the porosity of Asmari reservoir.

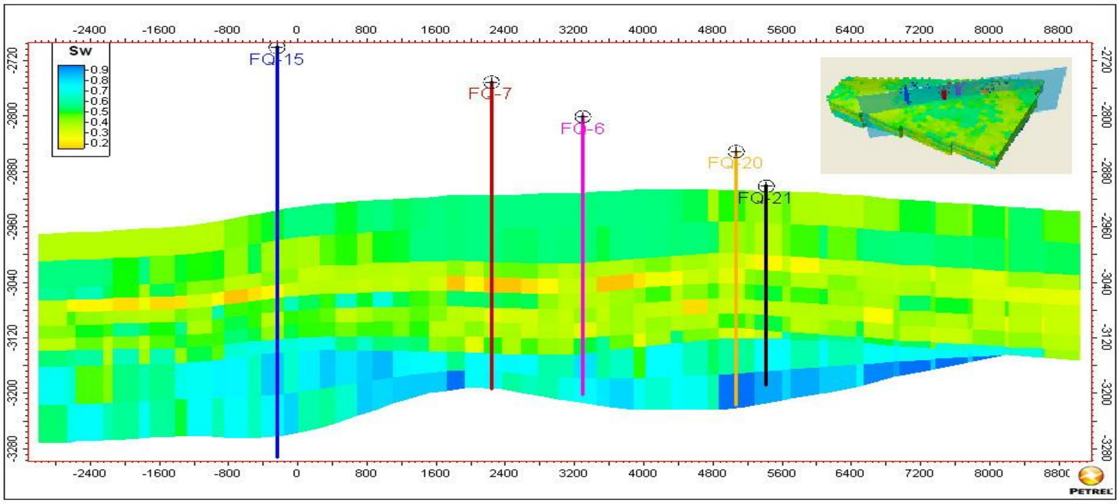

Figure 20- Cross section in N-S direction shows distribution of the water saturation of Asmari reservoir.

Conclusions

1- Structural model has been made using petrel software for Asmari reservoir. This model shows that Fauqi oil field represents un cylindrical anticlinal fold which contains two domes at northern and southern parts separated by depressions.

2- Horizons were made for Asmari reservoir and they are divided into 4 zones (Jeribe/ Euphrates zone, Upper Kirkuk zone , Buzurgan member , and Lower and Middle Kirkuk zone). Layers were built for each zone depending on petrophysical properties. Jeribe/ Euphrates zone and Lower and Middle Kirkuk zone were divided into two layers, Upper Kirkuk zone was divided into five layers while Buzurgan member divided into one layer.

3- Petrophysical model (porosity and water saturation) for Asmari reservoir in Fauqi oil field was built from porosity and water saturation values using Sequential Gaussian Simulation algorithm as a statistical method after scale up of porosity and water saturation. This model shows that the high porosity and low water saturation are placed in upper Kirkuk zone which represents the principle oil bearing unit in Asmari reservoir while Buzurgan member is characterized by moderate petrophysical properties but Jeribe/ Euphrates zone and Lower and Middle Kirkuk is not reservoir unit in Fauqi oil field.

4- From cross sections for porosity and water saturation models which are built in N-S direction show that the best location characterized by good reservoir properties is in the wells FQ-6 and FQ-7 and gradually these properties decrease toward wells FQ-20 and FQ-21.

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