Constructing 3D Geological Model for Tertiary Reservoir in Khabaz Oil Field by using Petrel software.

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Abstract:

A 3D Geological model for tertiary reservoir in khabaz oil field had been constructed by using petrel software. Seven wells have been selected in this study in order to design Petrophysical properties (porosity, water saturation, and permeability). Structural model can be clarified tertiary reservoir in term of geological structures is a symmetrical small anticline fold with four faults. Tertiary reservoir consist of six units are (Jeribe, UnitA, UnitA', UnitB, UnitBE, and UnitE). According to Petrophysical properties, layering had been constructed for each tertiary units. Petrophysical model has been designed using the sequential Gaussian simulation algorithm as a geostatistical method. The results illustrates that Unit B and Unit BE have the best petrophysical properties and the big amount of oil.

Keywords: Tertiary reservoir, 3D geological model, Khabaz oil field, Petrophysical properties.

بناء موديل الجيولوجي ثلاثي الابعاد للمكمن الثلاثي في حقل خباز النفطي، شمال العراق بواسطة برنامج بترال الحاسوبي

الخلاصة:

تضمن هذا البحث بناء موديل جيولوجي ثلاثي الابعاد للمكمن الثلاثي في حقل خباز النفطي الذي تم بناؤه بواسطه برنامج بترال الحاسوبي. تم اختيار سبعة ابار لهذة الدراسة لانشاء موديل التركيبي والبتروفيريائي (مسامية، تشبع المائي، النفاذية). يوضح الموديل التركيبي بأن المكمن الثلاثي في مصطلح الجيولوجي هو طية محدبة صغيرة متماثلة الشكل مع اربعة فوالق واضحة في التكوين. المكمن الثلاثي يتكون من ستة وحدات مكمنية

هي (جريبي ، وحدة A، وحدةA'، وحدة B، وحدةBE ووحدةE). بالاعتماد على موديل البتروفيزيائي تم بناء عدد من طبقات ضمن كل وحدات المكمن الثلاثي. الموديل بتروفيزيائي تم تصميمه بواسطة احد طرق الجيواحصائية وهي الدوال المحاكاة اللوغارتمية. بعد تحليل ومناقشة نتائج الموديل الذي تم بناؤه تبين ان وحدة B ، ووحدةBE تمتلك افضل الخواص البتروفيزيائية وهذا يعطي دليل لوجود كميات كبيرة من نفط الخام في هذة الوحدات.

الكلمات الرئيسية: المكمن الثلاثي، موديل جيولوجي ثلاثي الابعاد، حقل خباز النفطي، والخواص البتروفيزيائية.

Introduction:

In most of operations field, 3D geological model means to get best description for reservoir properties and quantities subsurface through information related to reservoir characteristics. Through description reservoir properties needed to understanding and covering most of geological features pertain to porosity, permeability, water saturation, types of rocks and barrels (faults and folds) and then knowledge some limitations of subsurface data in order to calculate distribution these features [1].

In general, the geological model includes four mainly stages: structure modeling, stratigraphic modeling, Petrophysical modeling and lithological modelling. The applications and technique are more complicated. Quantifying and improving hydrocarbon bearing zones needed to more accuracy at import data obtained and high resolution for geological model for reservoir Constructing 3D Petrophysical model for tertiary reservoir in khabaz field. Usually, the basic data can be used in 3D geological model in terms of sources, type of data, scales and more stages to clarify conduct of geologic modeling [2].

Area of study:

khabaz oil field is represent one of more importantly north Iraqi oil fields having many pay zones contain great amount of oil and gas, which is located North West (NW) of Kirkuk city and (12 km) far away from center of Kirkuk city. It's encircled by three oil fields Bai Hassan from North West and Baba dome exist in Kirkuk field from north east and Jumbour field from South east. Structurally represents a single symmetrical and anticline dome at subsurface consist of about (18 km) length and about (4 km) width. Approximately (42 wells) were penetrated Khabaz oil field, although these wells were targeted to tertiary reservoir more than half of wells were penetrated (cretaceous age), and a smaller number of wells were reached Shu'aiba formation. Actually, seven wells (Kz-1, Kz-2, Kz-3, Kz-4, Kz-9, Kz-14, Kz-15) used for this study in Khabaz oil field as shown in Figure (1). Generally, the section direction from North West to south east and denoted by A (NW) – B (SE). First well for Khabaz oil field (Kz-1) was drilled in 1976 [3].

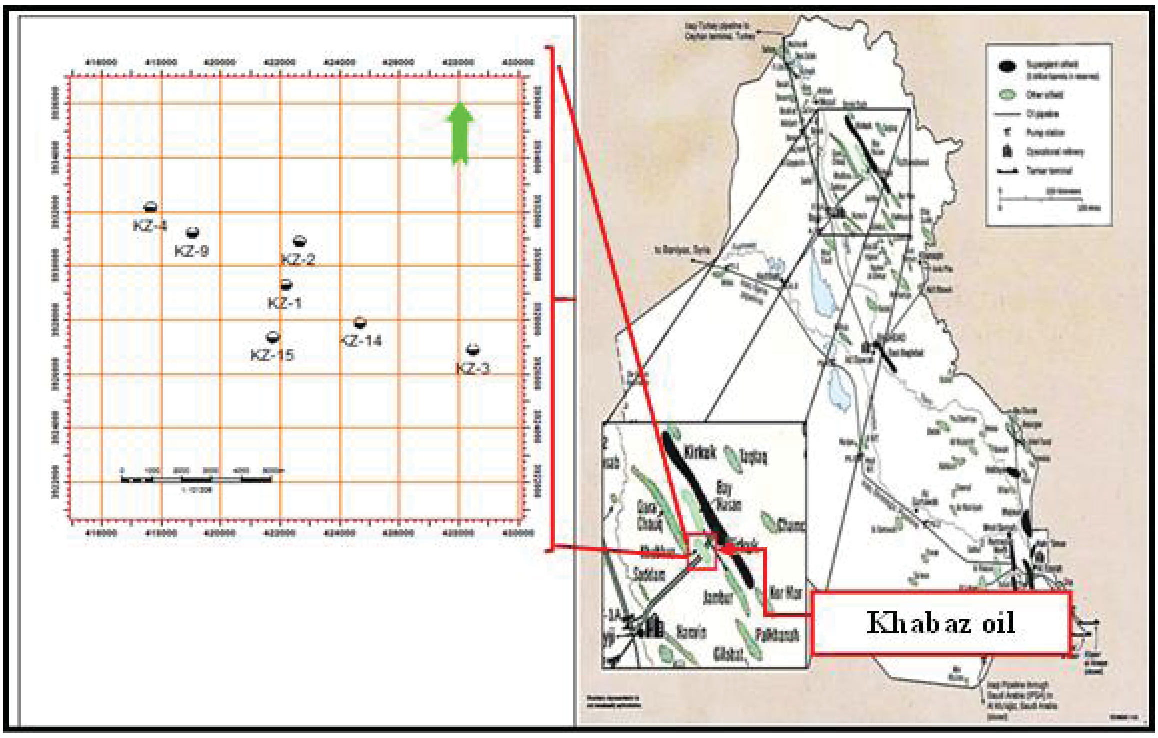

Fig. (1) Location map of khabaz oil field.

Methodology:

Petrel 2007 software has been employed for constructing 3D geological model for tertiary reservoir. There are many steps beginning as necessary data for constructing this type of model .These data are:

1- Well heads: - consist of position of each wells of khabaz field especially northern, eastern and Kelly bushing (RTKB)

2- Well tops: - clarified all reservoir zones or formations in Khabaz field and measured depth for each wells.

3- Well logs: - Includes reservoir properties (PHI, K, Sw, and facies) and CPI value which is obtained from IP (Interactive petrophycics V. 3.5), then imported to petrel.

Finally, a number of works have been done by volumetric method. Other reservoir data related to Khabaz field are provided from reports such as (final well reports (FWR), final geological reports (FGR), and core data analysis reports). The methodology is illustrated in the flow work diagram in Figure (2).

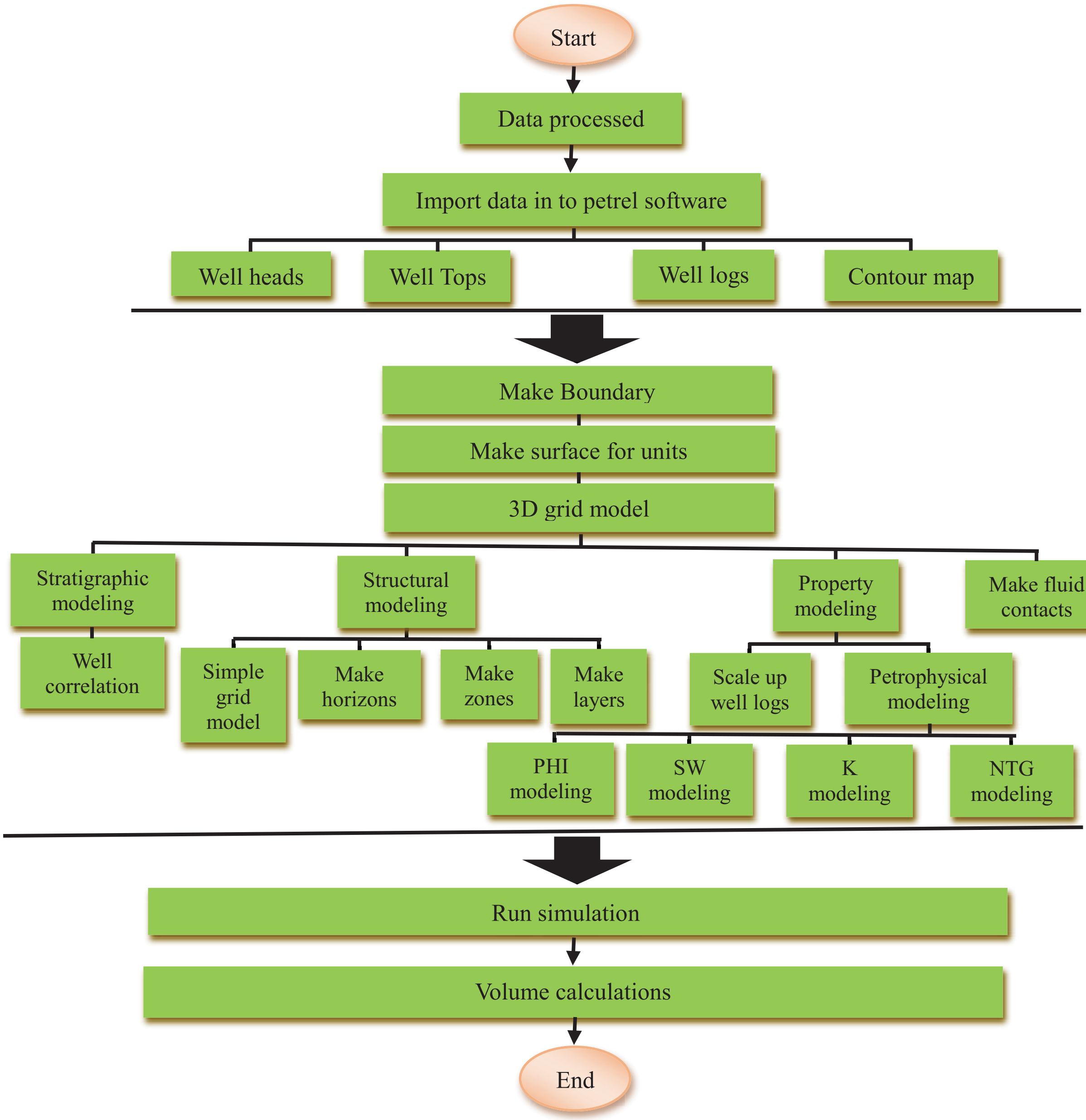

Fig. (2) The 3D geological model by Petrel software in work flow diagram.

Import Data:

There are various types of available data which introduced as input data. This data consists of well logs, cores and fluid analysis, which is prepared in folder or for each data folder are organized and imported files by petrel software for constructing 3D-geological modelling in khabaz field. Different types of data are briefly explained as the following:

1. Well Heads

Represent one of necessary data for geo-modelling and well head that is obtained for seven wells in khabaz field to show position of wells, Total Measured Depth (TMD) along path for all wells, name of wells and their symbol.

2. Well Tops

Well tops are considering noticeable points along well path with several geological units. Normally well tops are essential for structure model in order to construct contour map for all units for tertiary reservoir.

3. Structure Contour Map

Contour map can be generated from the surface and correlated borehole. Structural map for geologic units in tertiary reservoirs are constructed depending on well tops as well as top of Jeribe formation was obtained from 2D-seismic data.

4. Well Logs Data and Core Data

Well log attached to all wells of khabaz oil field to provide Petrophysical properties for reservoir rocks such as porosity, permeability, water saturation, and thickness of formation. Core data includes core porosity and core permeability. A various type of input data for the petrel software is explained below.

Well Correlation:

Basically regards good correlation of well log data. Most of important step in the 3D geological model in petrel software. Well correlation can be used to classify and arrange well logs data as 2D simple visualization. Generally, to make comparison between new wells which bring up to well section and wells which already correlated. Well correlation has been performed in this study to show changes in thickness and changes in reservoir properties for various geological units of Tertiary reservoir [4].

There are two cross sections in Figures 3and 4 explained thickness of tertiary units and changes of Petrophysical properties along reservoir units of tertiary reservoir. Figure (3) represents vertical section includes (Kz-4, Kz-14, and Kz-3) and Figure (4) represents horizontal section consist of (Kz-15, Kz-1, and Kz-2). As it can be seen from Figures (3 and 4) each wells involved by gamma ray (GR), porosity, water saturation (Sw), permeability and net to gross. Well tops have been selected and Jeribe represent as top for each units of tertiary. Through correlation between wells presented unit (B) represent high thickness in well (Kz-3) as compared with other units and have good Petrophysical properties. So considered interest zone at tertiary reservoir. Thickness of units (A, A', BE, E) is increase at south east more than units at North West along vertical section.

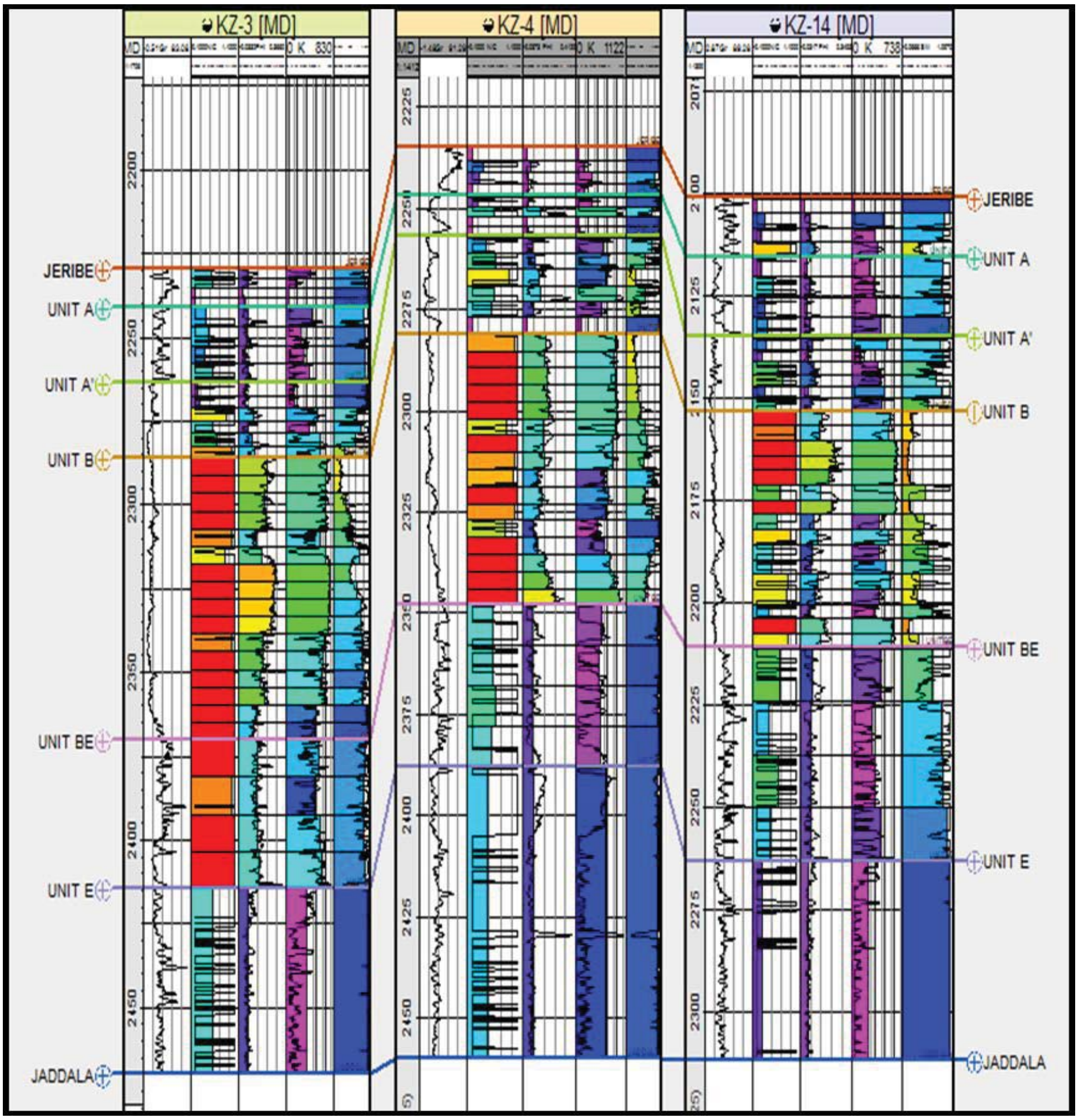

Fig. (3) Vertical section for (Kz-3), (Kz-4), and (Kz-14).

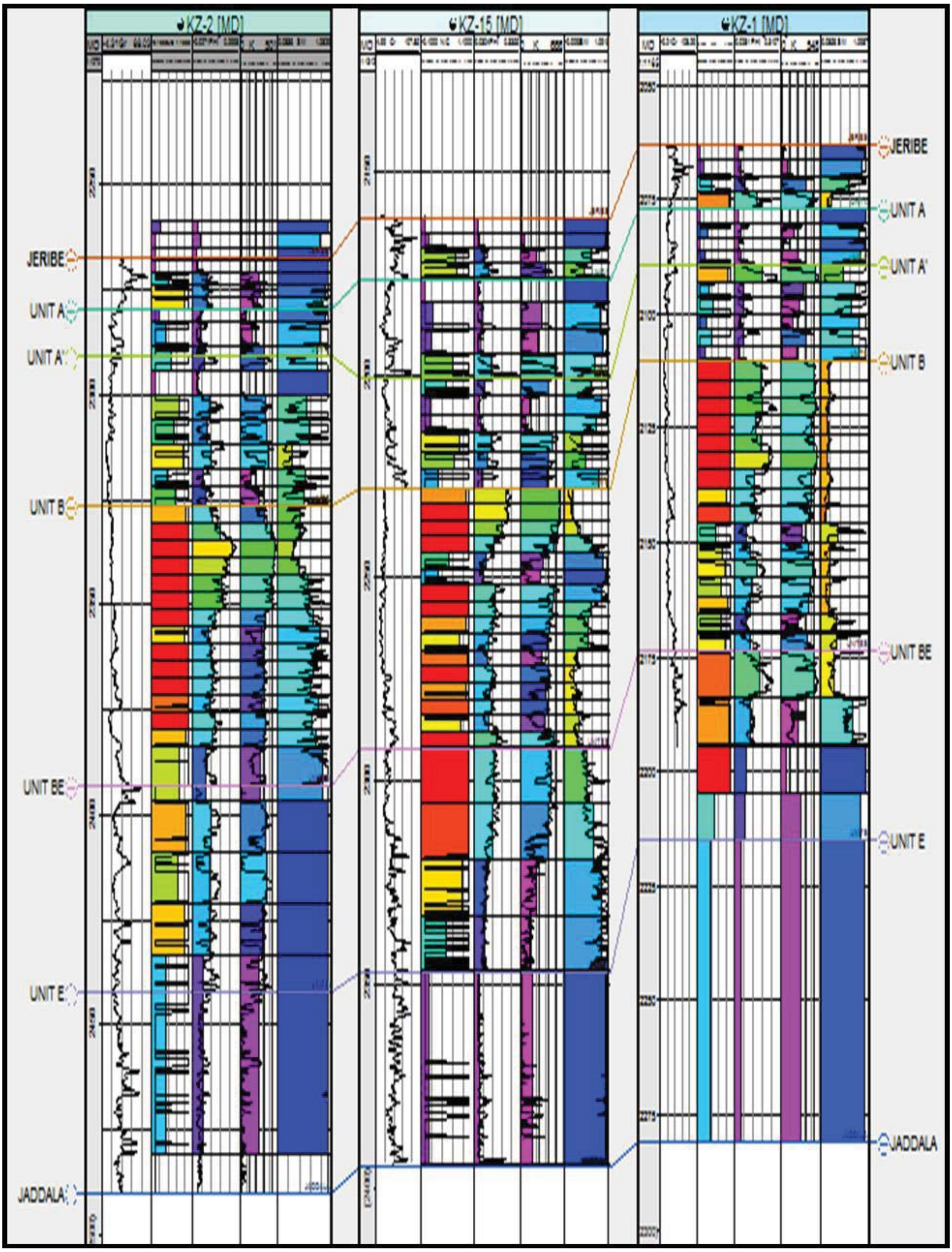

Fig. (4) Horizontal section for (Kz-1), (Kz-2), and (Kz-15).

Structural Model:

Structural modeling can be used to introduce and clarify special geologic properties inside the geo-model, which is normally consisted of fault model, and geologic constructions.

Obtaining best structure model for reservoir has considered more complex for petroleum engineer due to unorganized input data and more geometrical obstructions [5].

Structural modeling was subdivided in to three operations: fault model, pillar gridding and layering zones. All these steps were applied are after other from single value of data to structure 3D grids [6].

Six structures contour maps for (Jeribe, unit A, unit A', unit B, unit BE, and unit E) have been constructed includes tertiary reservoir in khabaz oil field which represented as 3D structures contour map in Figure (5).

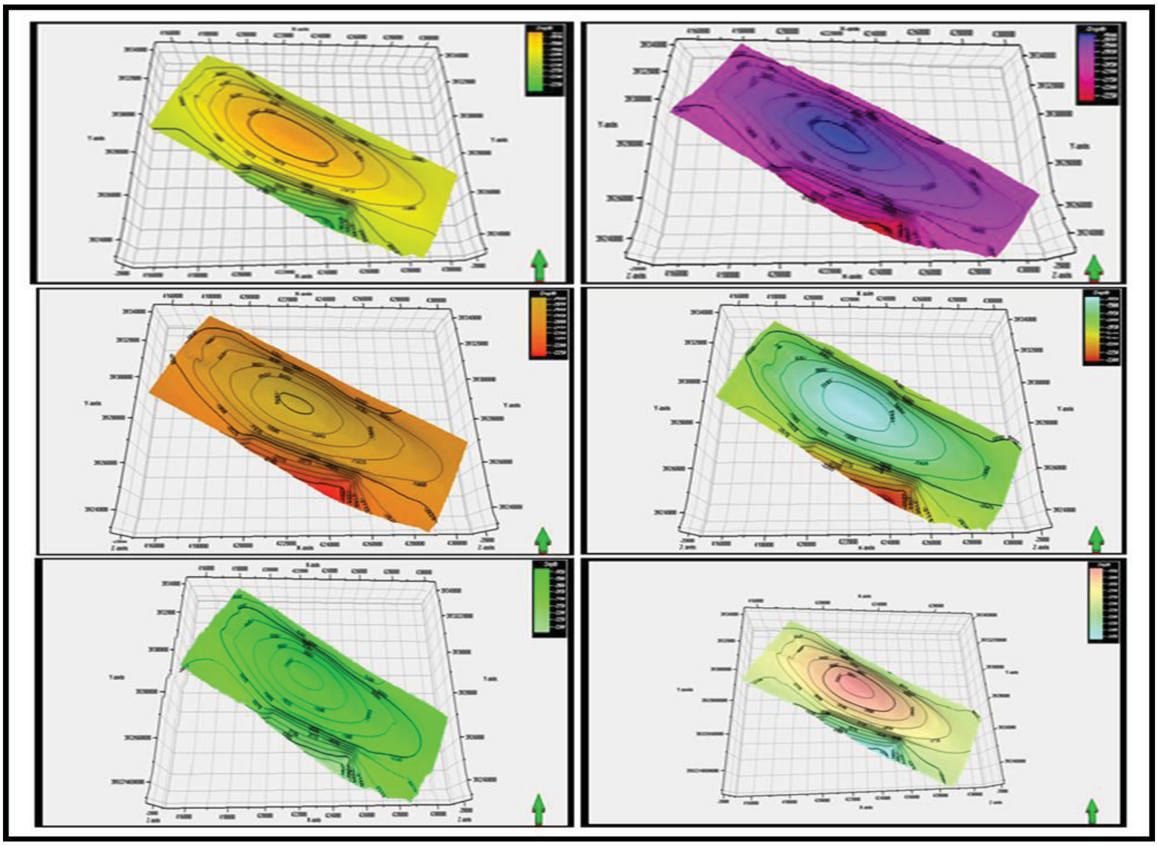

Fig. (5) 3D structures contour maps for tertiary reservoir units in khabaz oil field.

Fault Model:

Fault modelling is representing most essential process in structural model. Faults made includes vertical, inverse, and curved fault. The system of faults contains truncated fault (Y fault), series fault, conjugate fault, crossing fault, stair case fault, etc. The fault plane is a plane between top of surface and base surface and base surface of intersection lines. These lines are display as three dimensions in order to generate 3D fault in the structure model [7].

There are four faults which made geometrically and structurally in khabaz oil field represent with layers as three dimensional in Figure (6).

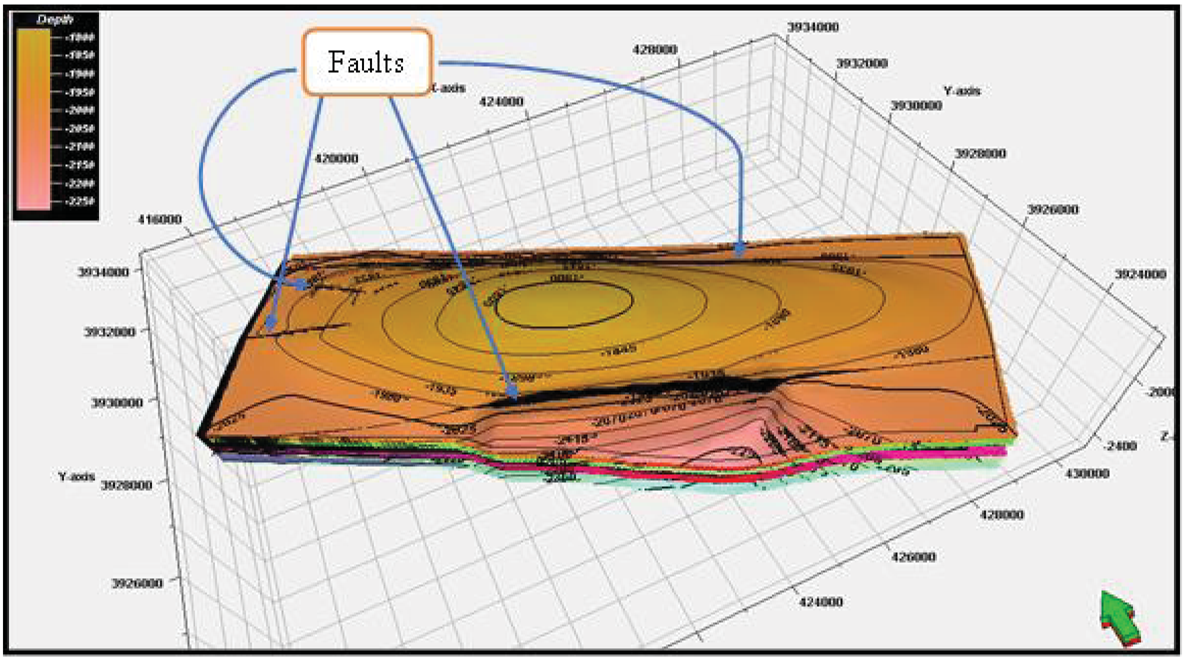

Fig. (6) 3D structure fault model for tertiary reservoir.

Pillar Gridding:

Pillar gridding is the operation which applied to generate skeleton framework are known as surface for (x, y, and z) locations to create a 3D structure. The skeleton is represent grid divided to top, mid, and base skeleton grids. These skeletons were connected to the points clarified faults.

At the first stage to construct 3D model is 3D grid building. Where 3D grid consist of space to boxes. Each box of grids is introduced as grid cell. Reservoir properties was performed at each grid cell such as, porosity, permeability, type of rocks, net to gross, etc., also named cell properties. Most of 3D gridding construction used in structural model consist of many of cubic cells lined up with horizons and stratify along faults [8].

3D grid model has been constructed for tertiary reservoir by using (100×100 m) on x, y axis pillar gridding increasing in order to construct structure for 3D grid. Figure (7) displays 3D pillar gridding skeleton for tertiary reservoir.

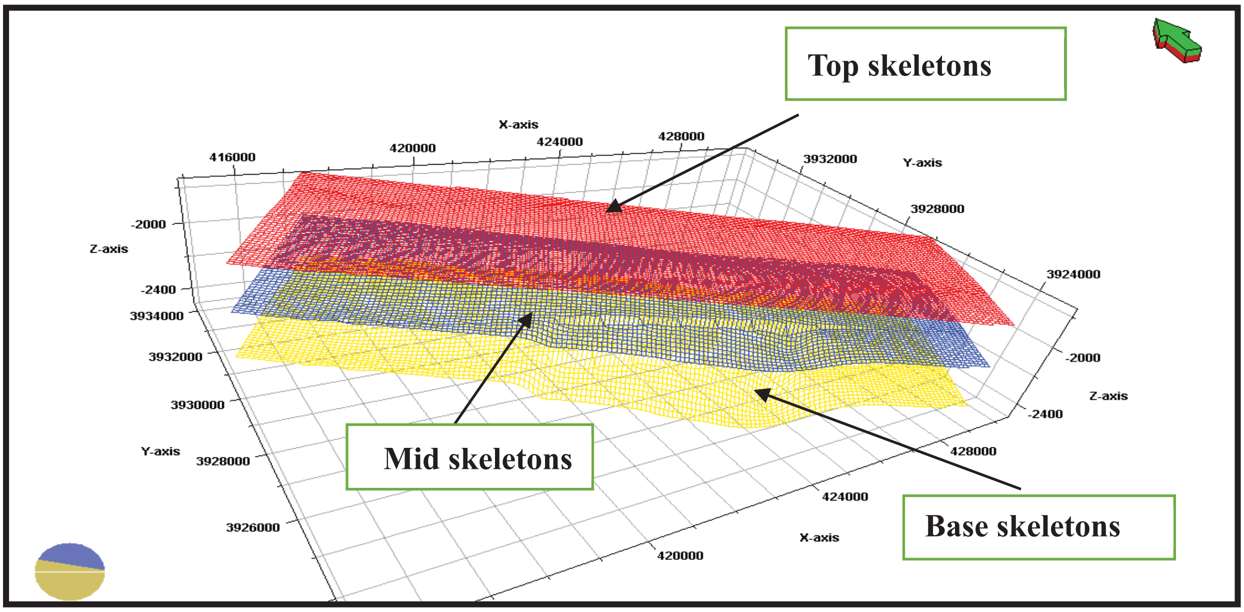

Fig. (7) The skeletons for tertiary reservoir.

Make Horizons:

Horizon is representing a border which discrete two beds or surface of top zones. Make horizon is a process used to introduce layers at vertical direction in 3D grid. True 3D statistical approach displayed surface of layer as 2D with keeping well tops of structure and picks of wells. After defining horizon which produces in 3D pillar gridding, all intersection points between horizons and pillar called nodes [9].

Layering:

The 3D grid cell has several vertical layers as main horizon in to the pillar gridding. Reservoir properties were defined for each units, permeability, porosity, etc. These properties are considered essential for fluid flow calculation and IOIP estimation. Make horizon and layering operation represent final two steps can be used to introduce the decision of vertical direction in 3D grid depending on number or thickness of cell layers. The top and base of geological units can be identified in grid cell and well top which required to be represented in section of well [10].

Table (1) Number of layers and average thickness for each zones of tertiary reservoir.

Zones	No. of layers	Average thickness (m)
Jeribe	4	14.85
Unit A	6	15.35
Unit A'	8	21.75
Unit B	25	68.87
Unit BE	15	44.78
Unit E	4	56.28

Tertiary units in khabaz oil field have been divided to many layers depending on reservoir properties and how much hydrocarbon content in the units. Best geological unit divided more than once as compared other units due to have good Petrophysical properties as tabulated in Table (1).

The Scale up of Well Log:

Scale up of well log is a process average values of well log in grid cell by using statistical approaches. Each cell 3D grid is penetrated by number of wells. Each cell has unity value for each Petrophysical properties. Where results of final 3D grid are only specified value grid cells through its penetration. The well log can be used in Petrophysical modeling after this operation is scaled up. When reservoir properties are modeled by dividing area which modeled to 3D grid. Grid cells are normally much bigger than density of samples taken from logs. Before any modeling operation depends on well log should be scaled up for well log to provide definition 3D grids that is called blocking of well logs [11].

There are a lot of statistical techniques used to scale up well log such as harmonic, arithmetic average and geometric methods. Average Petrophysical such as porosity, and water saturation value is scaled up by arithmetic average, while permeability is scaled by geometric method. Figure 8 shows (∅, Sw, and K) used for scaling up Kz-3.

Quality Control:

Quality control is considered a sensitive and necessary process after up scaling process for well logs in order to visualize tertiary units. This process depends on layering which specifies thickness of layers. If thickness of layers is very small may be too much data will be lost. Therefore, it is necessary to make some adjustments for thickness of layers. Histogram clarify properties are up scaling with original log data [12]. Figures (9, 10, and 11) show histogram for porosity, water saturation and permeability.

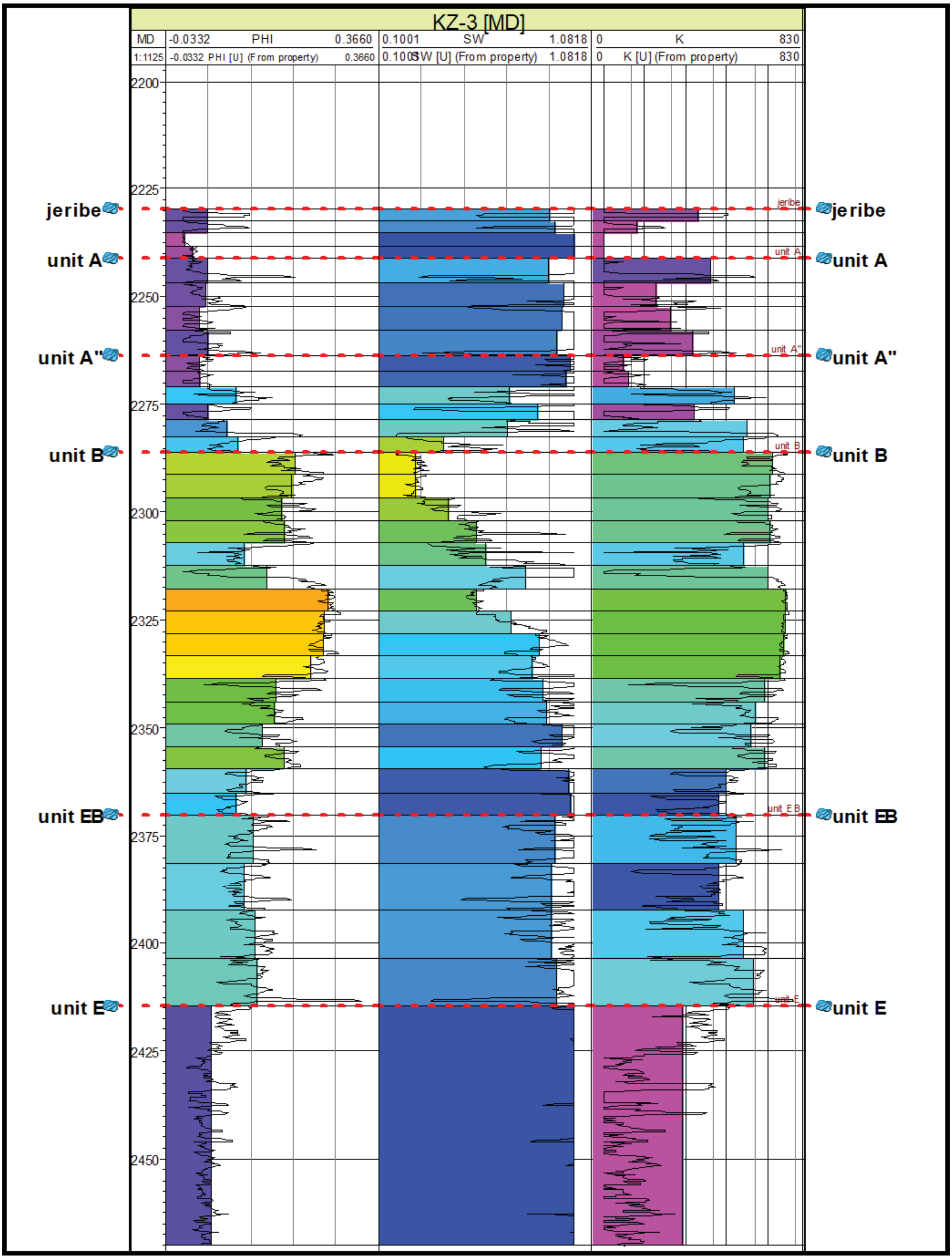

Fig. (8) Scale up for (Kz-3) in tertiary reservoir.

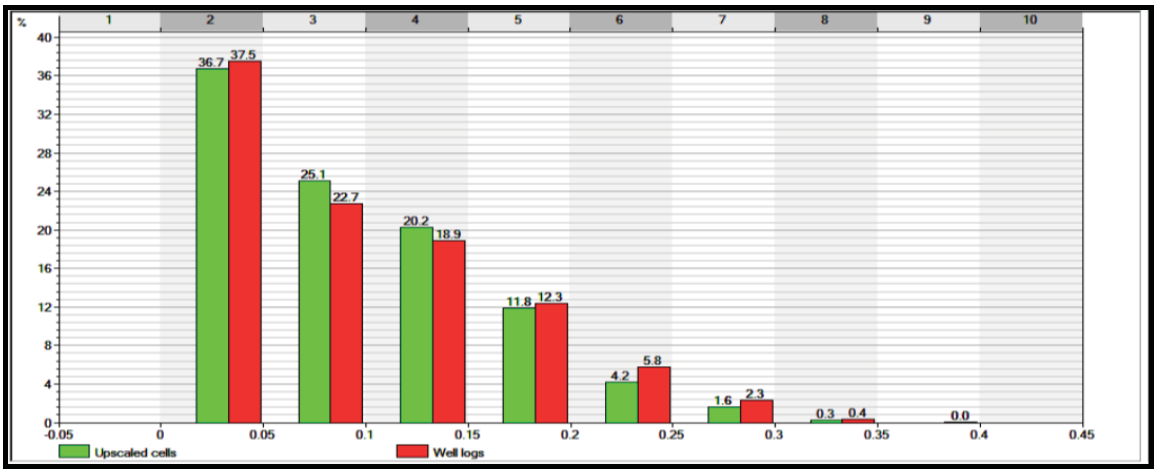

Fig. (9) Quality histogram for PHI in well (Kz-3).

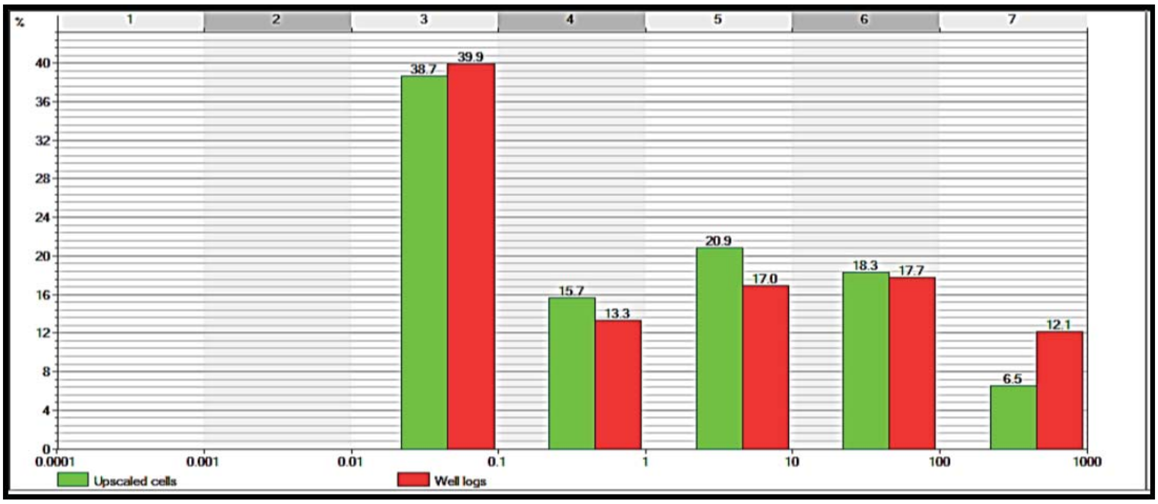

Fig. (10) Quality histogram for Sw in well (Kz-3)

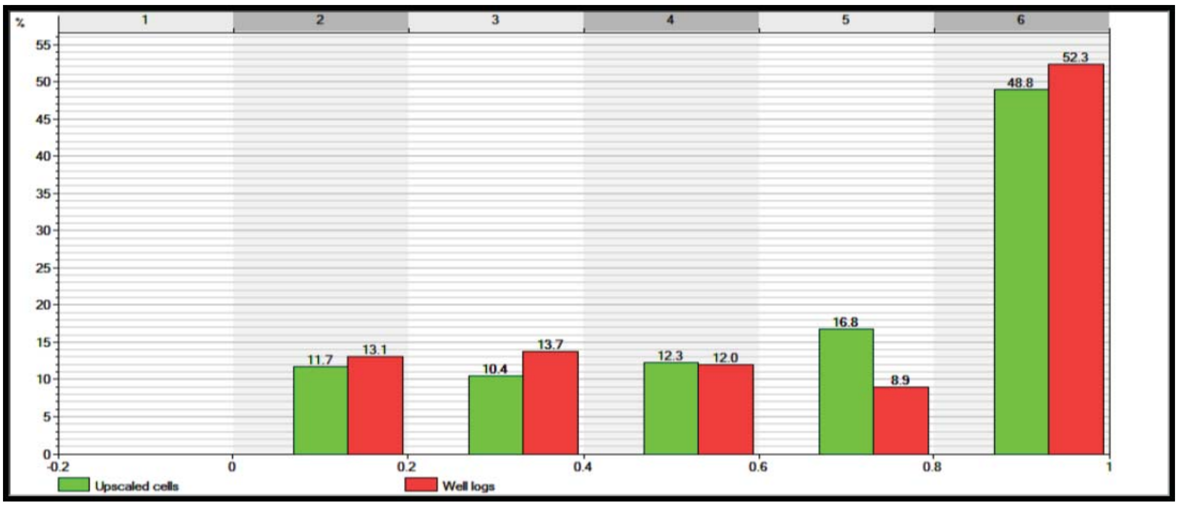

Fig. (11) Quality histogram for K in well (Kz-3).

Petrophysical Modelling:

The Petrophysical modelling is a distribution reservoir properties in 3D grids cell at static model. Petrophysical model was constructed by Sequential Gaussian Simulation Algorithm (SGS) was performed as statistical method to agree with magnitude data available [13].These properties are consist of:

Porosity Model:

Porosity model was constructed based on porosity logs (density, neutron and sonic) logs have been corrected to 3D grid cells. One of famous method in geo-statistics which is used as statistical method to construct porosity model is (SGS). Histogram window has been applied to recognize Petrophysical properties of original log data and up scaling log data in order to check accuracy of the final 3D porosity model. Figure (12) shows 3D representation of porosity model for tertiary reservoir.

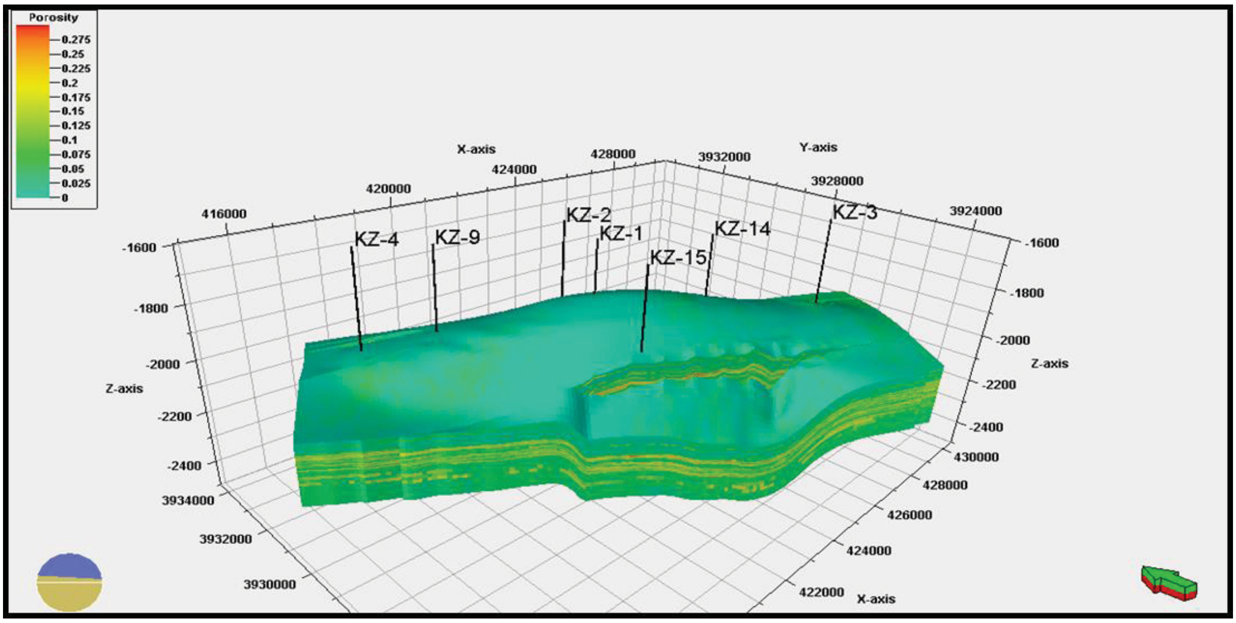

Fig. (12) 3D porosity model for khabaz field.

Permeability Model:

FZI method has been used to estimate permeability in cored well by well log records. Permeability model has been constructed by geo-statistical technique which is used as statistical method is (SGS) to get best permeability distribution in geological model.

Histogram window has been applied to recognize physical properties of original log data and up scaling log data in order to check accuracy of the final 3D porosity model. Figure (13) shows 3D presentation of permeability model for tertiary reservoir.

Water Saturation Model:

After up scaling well logs for water saturation, water saturation model has been constructed for tertiary units in khabaz oil field. Geo-statistical method is the same that used in porosity model (SGS) and in Sw model. Histogram window has been applied to recognize Petrophysical properties of original log data and up scaling log data in order to check the accuracy of water saturation model. Figure (14) shows 3D representation water saturation model for khabaz field.

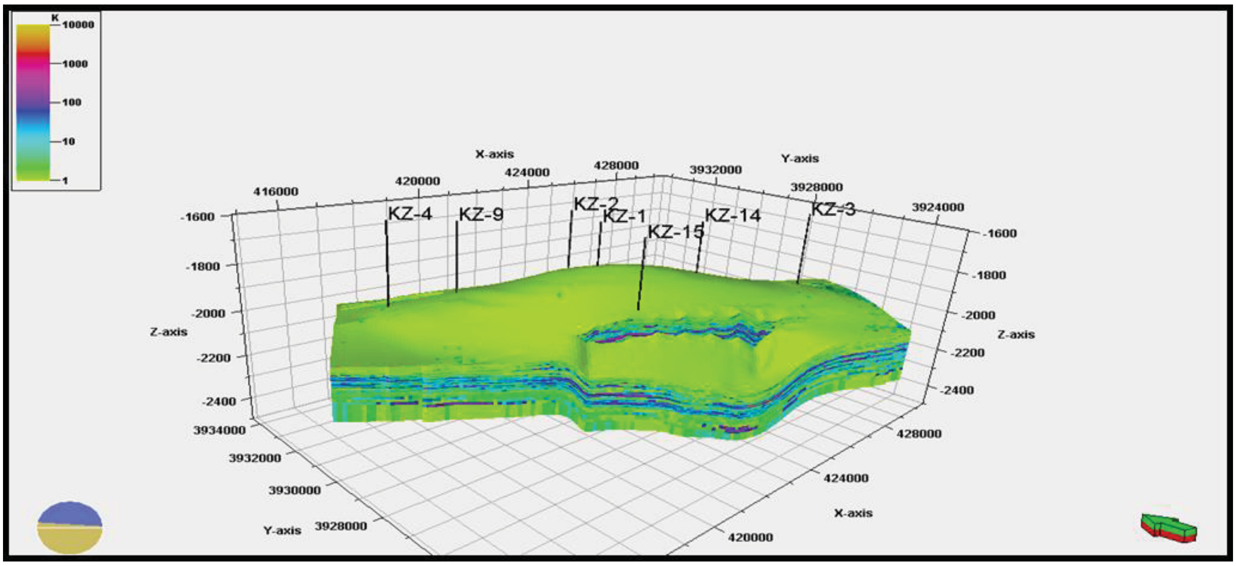

Fig. (13) 3D permeability model for khabaz field.

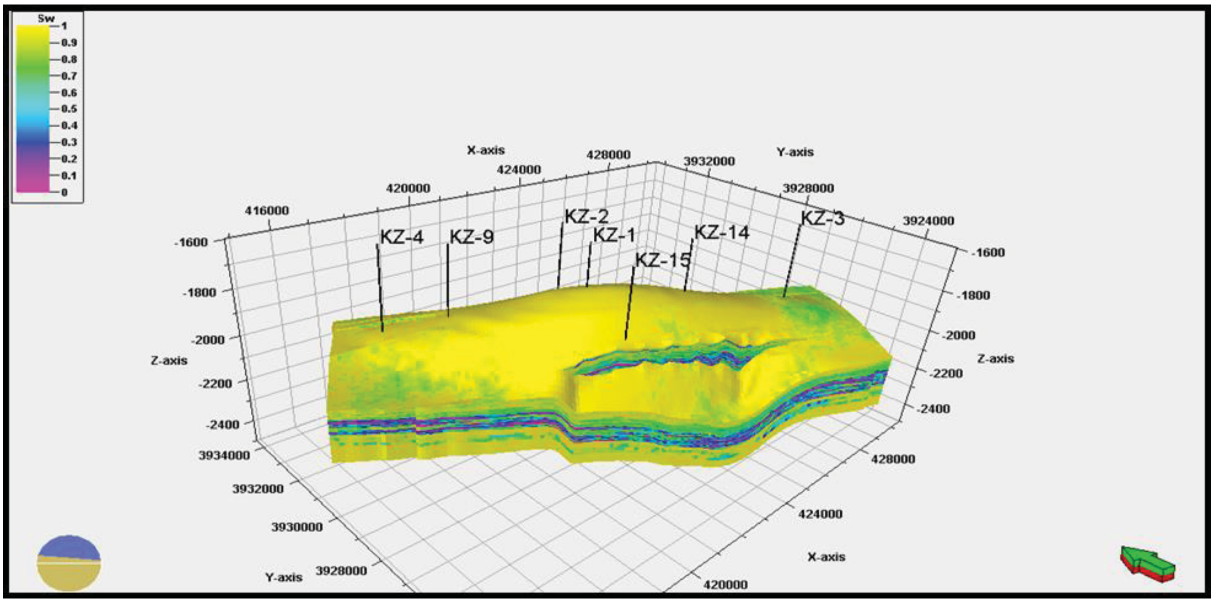

Fig. (14) 3D water saturation model for khabaz field.

Net to Gross Modeling:

Net pay is extremely essential parameter in the reservoir characteristics due to the clarification of the penetrated geologic section which contains rich hydrocarbon content and best reservoir quality to apply for producing intervals in the reservoir. Net pay illustrates facilities reservoir simulation because non- reservoir rocks does not take into consideration. Net pay zone can be assessed by using cutoff applications on Petrophysical well logs. Cutoff has specific value for formation parameters and producing zones is not considered[14]. Figure (15) represents 3D net to gross (NTG) model for tertiary reservoir.

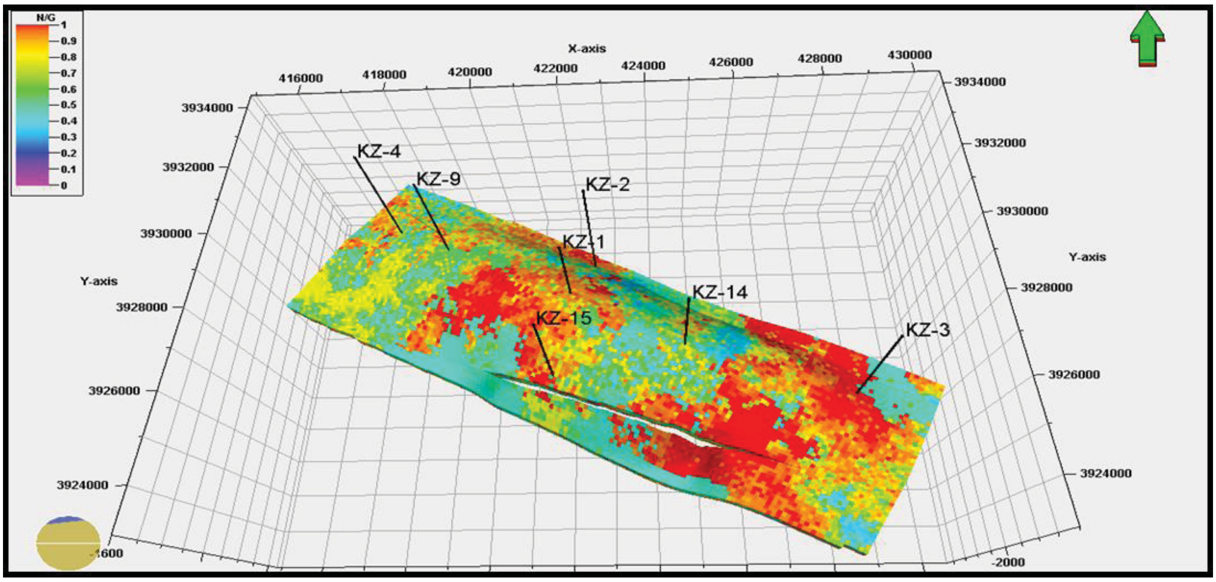

Fig. (15) 3D Net to gross for tertiary reservoir.

Results and Discussions

Depending on reservoir characterization, tertiary reservoir is divided into different reservoir units. These are (Jeribe, Unit A, Unit A', Unit B, Unit BE, and Unit E). These Units are characterized by Petrophysical properties (porosity, water saturation, and permeability).

1. Jeribe and Unit A are located at top of tertiary reservoir in khabaz oil field, characterized by lowest porosity rate about (3%) and lowest rate of hydrocarbon content except in some region in zone, where rate of permeability in Jeribe formation is too low nearly (0.1 md) and Unit A rate pf permeability predicated about (2md).

2. Unit A' is second unit of tertiary reservoir after (Jeribe and Unit A). This unit characterized with good rate of porosity about (5.3%) and permeability rate about (1md). This Unit has less amount of hydrocarbon with big amount of water saturation range between (40-65) percent.

3. Unit B has best Petrophysical properties and consider an active unit include tertiary units, having high rate porosity about (20-26)% and this rate increased toward crest , high permeability rate estimated about (24md) , also rate of water saturation in this rate about (10-24)%. So, it represents an active zone.

4. Unit BE is second active zone includes tertiary reservoir units, consider porous and permeable zone about (9.5-18) % especially top region of this unit and (10-20) md.

Hydrocarbon content concentrated at upper part of this unit with water saturation estimated (20-40) %.

5. Unit E is represented worst Petrophysical properties and consider water zone, where rate of water saturation estimated 100%. Also rate of permeability less than (0.1 md).

Conclusions:

1. Depending on structure model which constructed by petrel, Tertiary reservoir in khabaz oil field clarify a symmetrical small anticline fold with four faults.
2. Layering were constructed for each zone of tertiary reservoir according to reservoir characterization. Jeribe (4 layers), Unit A (6 layers), Unit A' (8 layers), Unit B (25 layers), Unit BE (15 layers), and Unit E (4 layers).
3. Unit B and Unit BE are regarded an active zone which have best Petrophysical properties (sw, phi, and k) and contain big amounts of hydrocarbon.

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List of Symbols:

NW: North West.

FWR: Final well reports.

FGR: Final geological reports.

TMD: Total measured depth.

SGS: Sequential Gaussian simulation algorithm.

FZI: flow zone indicator.

NTG: Net to gross.

IOIP: Initial oil in place.

Kz: Khabaz oil field.