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# A Comprehensive Method for Building a Three-Dimensional Geological Model of Khasib Formation, Amara Oil Field

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## Abstract

Understanding the stratigraphy and structure of the examined reservoir requires knowledge of the geological model. Moreover, the volumetric approach can be used to estimate the amount of oil that was initially present.

Modeling a reservoir in the form of a three-dimensional computer depiction that serves as a tool for integrating disparate disciplines and sets of data

To create a good representation of reality that is suitable for research purposes, 3D static modeling uses reservoir parameters such as facies, saturations, porosity, and permeability. Finally, all data from petrophysical, seismic, geological, and engineering sources are integrated into the model.

An integrated 3D static model has been constructed for Khasib formation in Amara field, which is considered one of the main reservoirs in this field. Wireline logging data for the eighteen wells, the core analysis information for three wells (Am-01, Am-02, and Am-03) and reservoir characterization information have been utilized to accomplish this study.

In the geological model, Khasib formation was divided into seven zones, where the reservoir units were represented by KH11, KH12, and KH2. The petrophysical property modeling and the net-to-gross model have been built using the SGS algorithm as a statistical method, and the rock-type model has been used as a guide for the distribution, indicating the improvement of property distribution in the north and west of the field and demonstrating that KH11 is regarded as the Khasib formation's primary reservoir unit, KH12 has a substantial oil concentration, and KH2 is recognized as the second reservoir unit that contains hydrocarbons.

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## 1. Introduction

The primary goal of 3D static characterization is to capture and anticipate the spatial variation for variable attributes to achieve a 3D characterization of geology [1]. Structural modeling and Petrophysical modeling are the two basic phases of building geological models: structural modeling involves assessing the geophysical information, while petrophysical modeling involves applying geostatistical techniques to distribute petrophysical log characteristics throughout the reservoir [2].

Understanding the distribution of formation characteristics and fluids within heterogeneous reservoirs is largely dependent on reservoir characterization. With the use of this information, a precise three-dimensional model of the reservoir may be created, making predictions about its porosity, permeability, and fluid flow distribution possible [3].

A reservoir geological model, or 3D static model, is a model constructed utilizing reservoir characteristics such as facies, fluid saturations, porosity, and permeability. Finally, all relevant petrophysical, seismic, geological, and engineering data are integrated to create a realistic model that is suitable for research needs [4]. This model is important for understanding the stratigraphy and structure of the studied reservoir. Furthermore, the amount of oil initially in place can be estimated using the volumetric method. The initial oil in place is a key element governing production and field life economic planning. As a result, this parameter needs to be carefully and accurately determined [5].

The logging interpretation data for 18 wells (including porosity, permeability, water saturation, and facies) were used to build the integrated 3D geological model for Khasib formation using PETREL software. The resulting model describes the distribution of each property and the fluid within the formation to determine the direction for improving the properties and which is the main hydrocarbon-bearing unit.

## 2. Materials and Methods

The data required to build the geological model with PETREL software can be summarized below.

1. Wellhead data: is represented by the well name and location (described by the northeast coordinate), the elevation of RTKB, and the total depth of each well.

2. Well top data: is represented by the well name and coordinates with the depth of the tops of each unit.

3. The contour map: is represented by the structural map for the top of Khasib reservoir in Amara oil field.

4. Well log data: is represented by the log interpretation data, including porosity, water saturation, and facies data.

### 2.1. Wells Correlation

The concept of wells correlation is used to understand the vertical and horizontal distribution of the petrophysical properties and distinct lithological units' extents and thicknesses in reservoirs. The wells correlation was characterized using cross-sections, the first one extending from well Am-01 in the northwest to Am-07 in the southeast of the field and passing through Am-04 on the top of the structure dome, while the second cross-section was from the north to south.

The locations of the wells drilled in Amara field are shown in Fig 1. The two cross-sections for creating the wells correlation are demonstrated in Fig 2 and Fig 3.

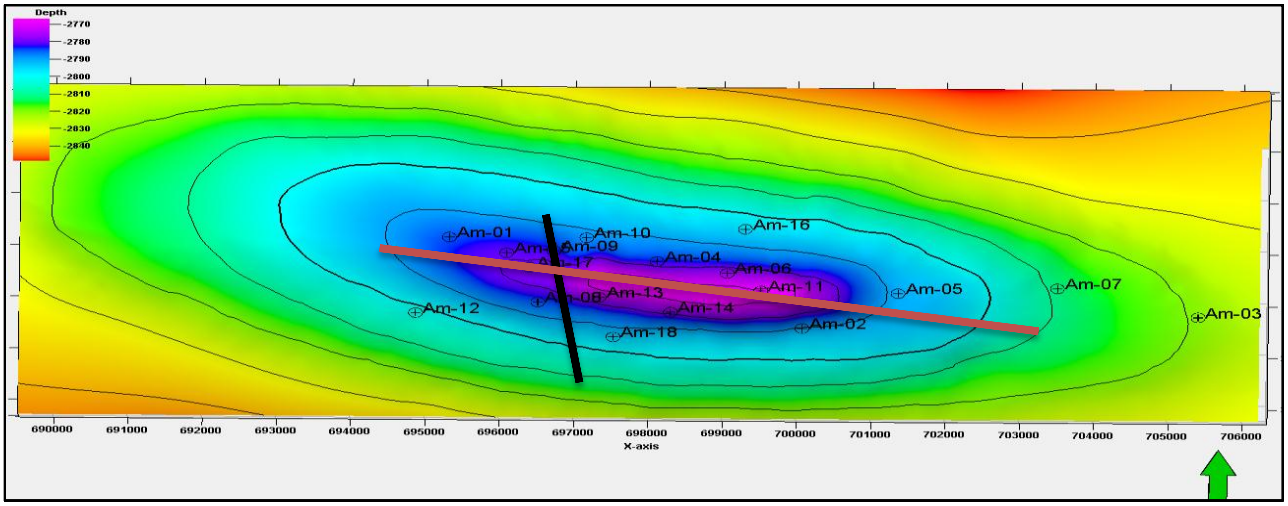


**Figure 1:** The location of the wells drilled in Amara oil field.

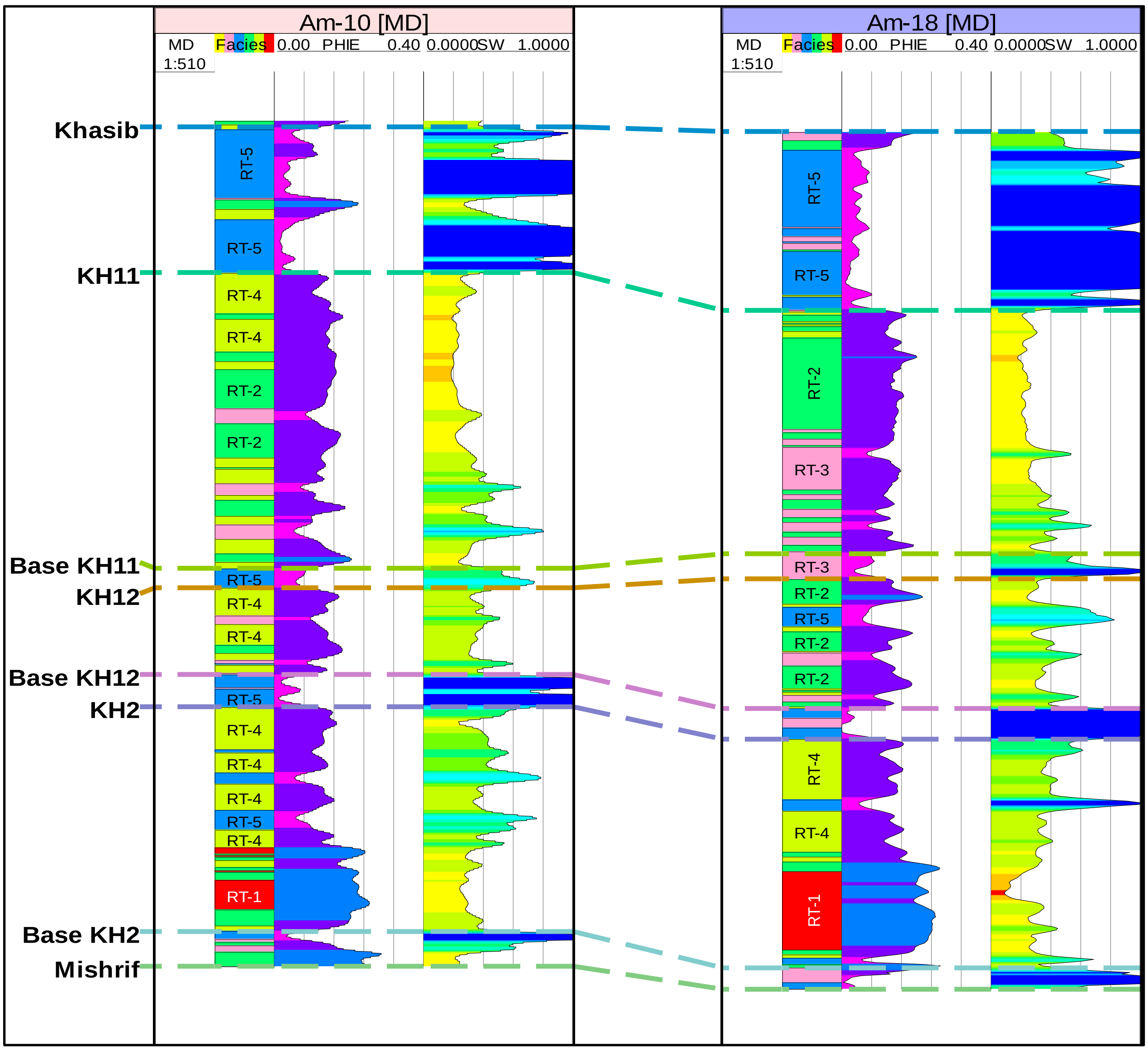


**Figure 2:** Cross-section from the north to south of the field.

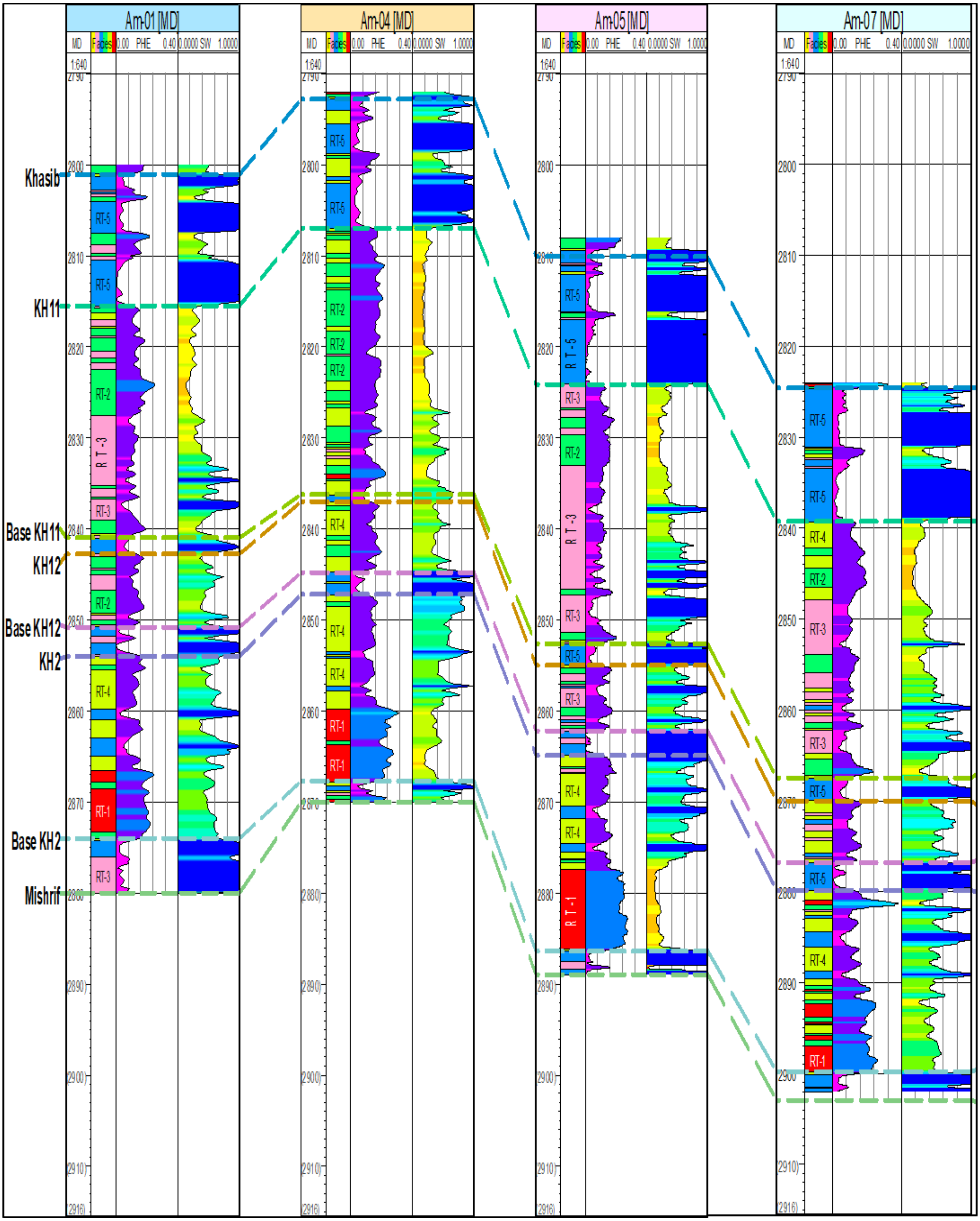


**Figure 3:** Wells correlation from northwest to southeast of the field.

It is obvious from Fig 2 and Fig 3 that the formation is better divided into seven units for accurate representation in the 3D geological model. According to the new division, the units KH11, KH12, and KH2 represent the reservoir units, and the rest as non-reservoir units.

The new division for Khasib formation that has been used to represent the formation in the geological model with the corresponding division from the petrophysical properties evaluation is described in Table 1.

**Table 1:** The units that are used to represent Khasib formation.

| Khasib Units (Formation Evaluation) | Khasib Units (Geological Model) |
|---|---|
| KH1 | Khasib |
| KH2 | KH11<br>Base KH11<br>KH12 |
| KH3 | Base KH12 |
| KH4 | KH2<br>Base KH2 |

### 2.2. Structural Model

The structural model is regarded as the most important stage in modeling geological and numerical simulations for a formation [6].To construct the structural modeling for the formation, the data from the well top and the contour map of the Khasib reservoir obtained from the 2D seismic survey were used. The structural map for Khasib reservoir consists of an anticline semi-symmetrical with NW-SE trending. For each of the seven units of Khasib formation, a structural map was created to represent the top of that surface resulting in eight structural maps. Fig. 4 represents the top surface of Khasib zone.

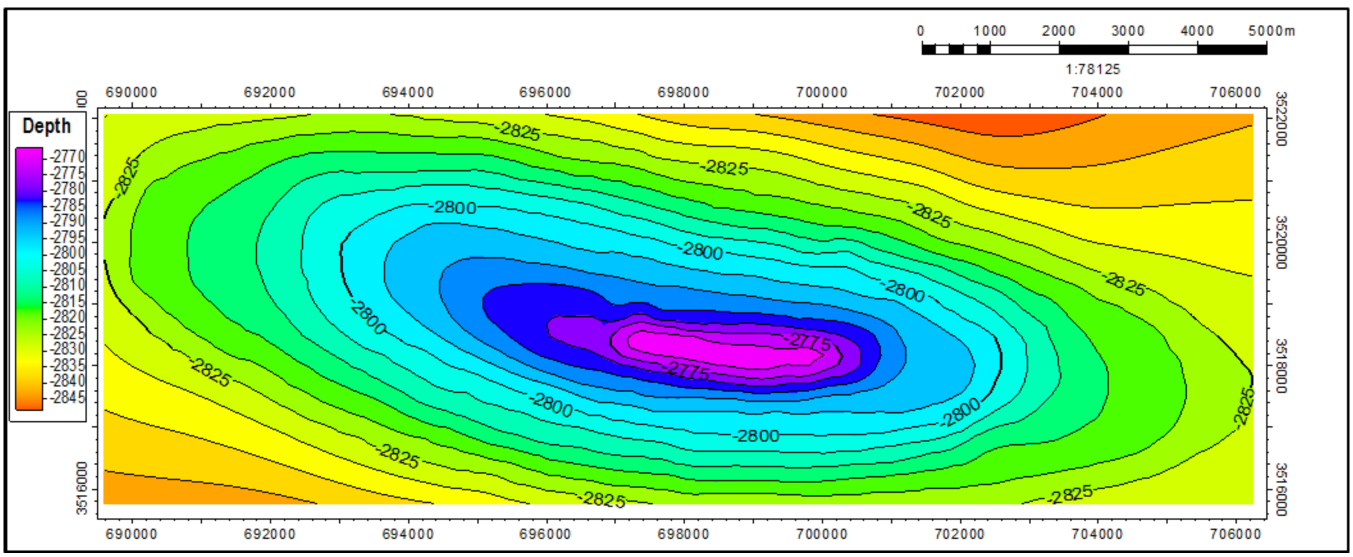

**Figure 4:** The structural map for the top of Khasib zone.

### 2.3. Make Simple Grid

The first step for constructing a 3D model is to characterize the model with grid cells so that each cell will have one value for each petrophysical property and rock type. The two-dimensional skeleton grids for Khasib formation were constructed by a 100*100 grid cell resulting 167 cells in the x direction and 64 cells in the y direction. The two-dimensional structure is expressed in Fig. 5.

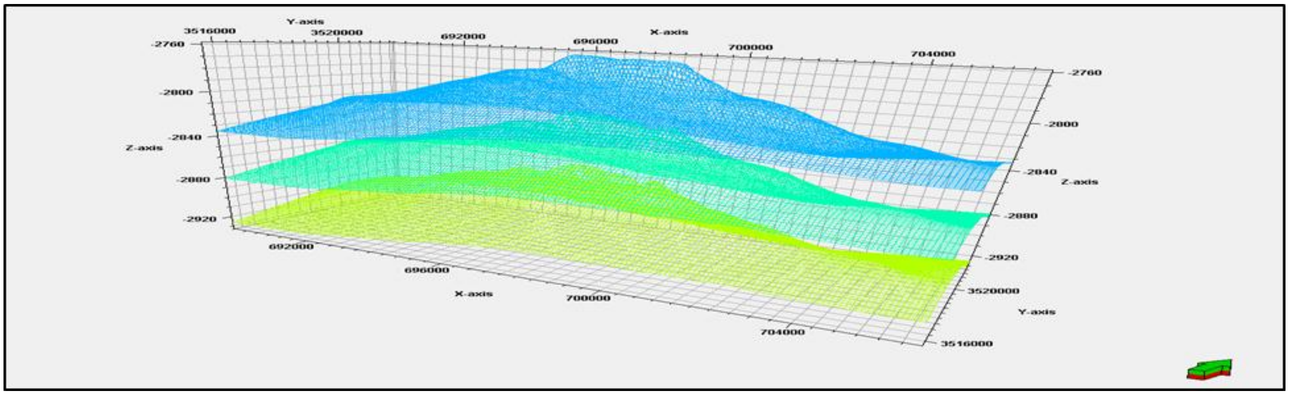


**Figure 5:** The skeleton grids for Khasib formation in Amara oil field.

### 2.4. Layering

To improve the accuracy of the property distribution, particularly in the reservoir units, layering aims to divide each zone into several layers in the vertical direction. The number of layers for each unit in Khasib formation is illustrated in Table 2, and Fig. 6 shows the zones after layering.

**Table 2:** Number of layers for each zone in Khasib formation.

| Zones | No. of layers |
|---|---|
| Khasib | 1 |
| KH11 | 20 |
| Base KH11 | 1 |
| KH12 | 10 |
| Base KH12 | 1 |
| KH2 | 20 |
| Base KH2 | 1 |

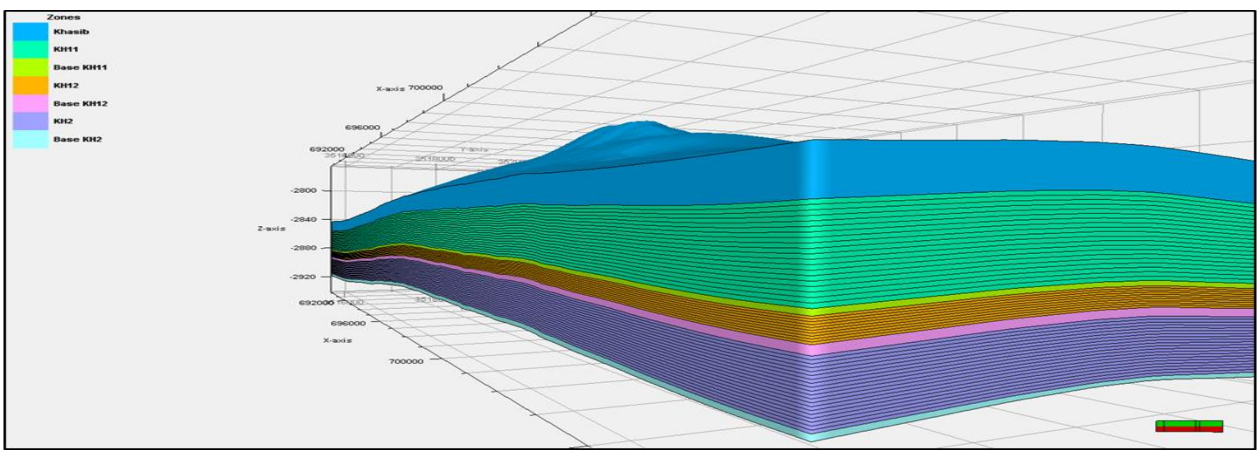


**Figure 5:** The layering of Khasib zones.

### 2.5. Scale-up Well Logs

The step of averaging the well log data in the 3D model depends on the averaging algorithm being selected so that one log value for each grid cell penetrated by a well is produced [7]. Scaling up the log data can be accomplished using several averaging procedures, such as arithmetic, harmonic, and geometric. The arithmetic averaging method has been selected for porosity and water saturation scaling up and the (most of) averaging for scaling up the rock types. Fig. 7 illustrates the scale-up of porosity, saturation, and rock types for Am-01.

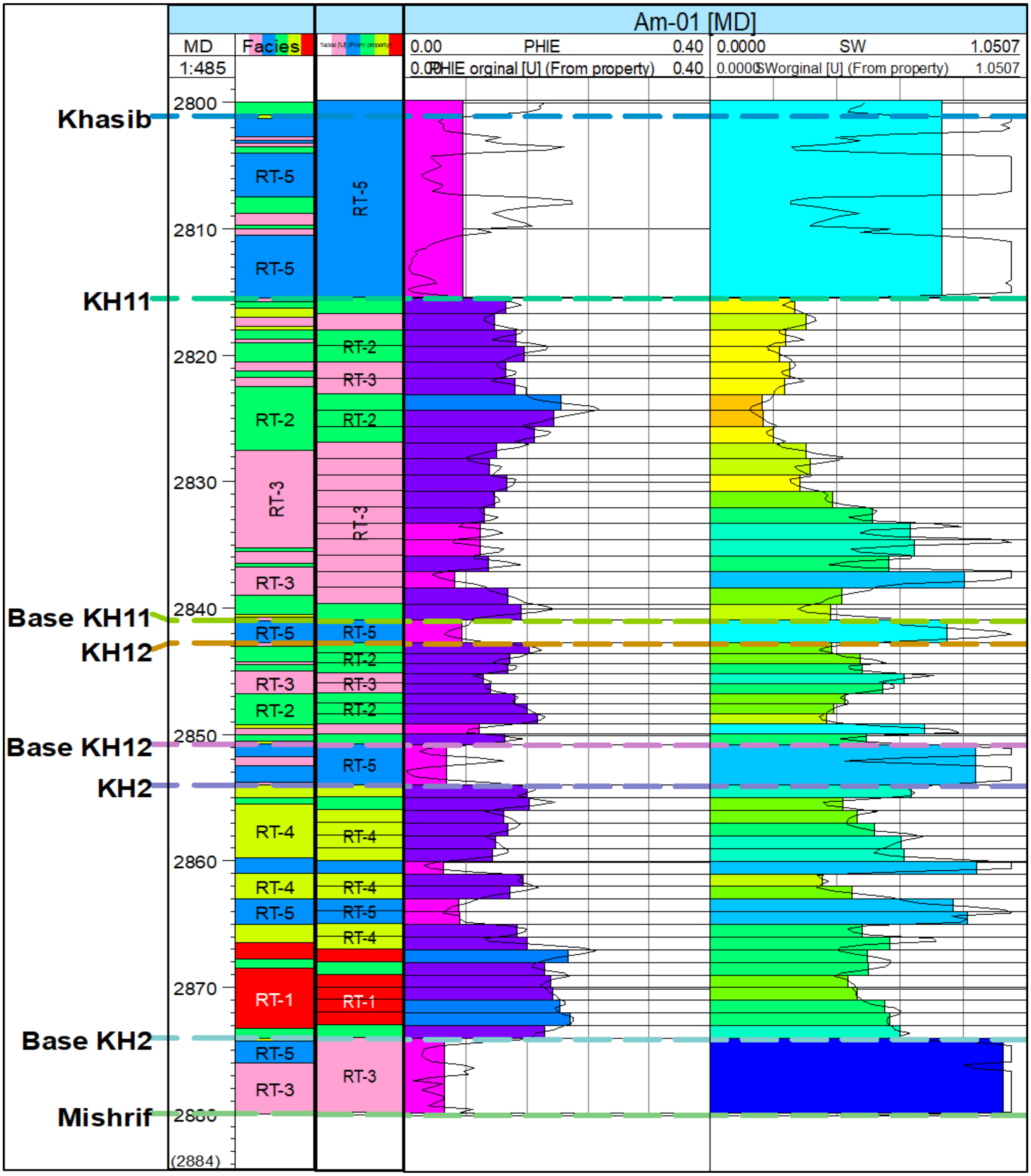


**Figure 6:** Scale-up results for porosity, water saturation, and facies for Am-01.

### 2.6. Rock Type Modeling

Utilizing the facies interpretation acquired from the electrofacies of the cluster analysis and combining the cluster analysis facies with the HFUs of the FZI approach, five different rock kinds were acquired to describe the various units of the Khasib formation [8]. The distribution for the rock-type model of Khasib formation is described in Fig.1١.

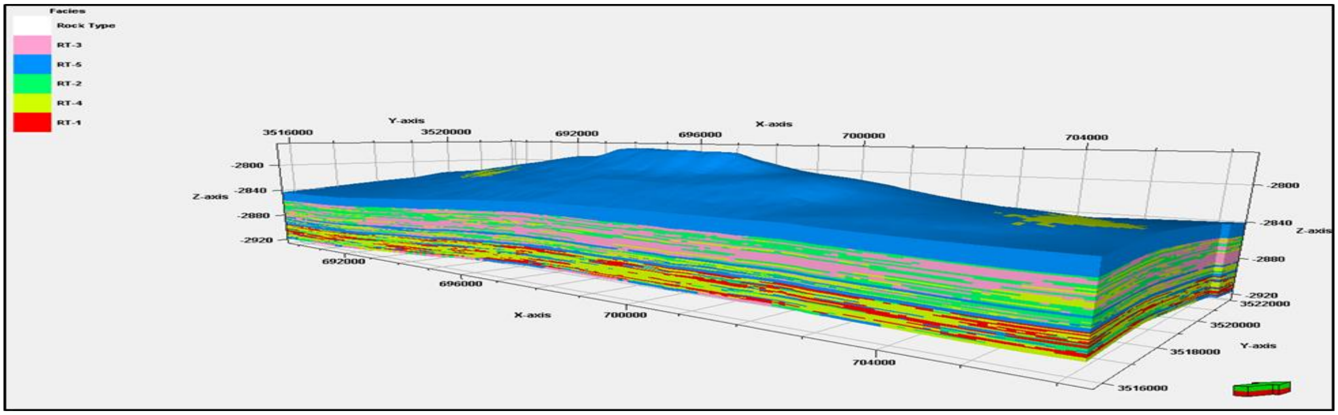


**Figure 7:** The modeling for the rock types of Khasib formation in Amara oil field. [9]

### 2.7. Petrophysical Modeling

Property modeling is the step of associating each grid cell in the model with a single property value. The essential goal of modeling a reservoir is to maintain the fundamental characteristics of the reservoir's geology and heterogeneities [10].To construct the petrophysical model the Sequential Gaussian Simulation (SGS) algorithm was employed as a statistical technique, which was the most appropriate method for Khasib reservoir to create the petrophysical model and distribute the porosity, permeability, net to gross, and water saturation data. The distribution of the petrophysical properties (porosity, water saturation, net to gross, and permeability) has been built depending on the rock type model.

## 3. Results and Discussion

### 3.1. Porosity Model

Using the effective porosity interpreted from the neutron-density logs and scaling up with PETREL to construct the porosity model. Porosity distribution has been made depending on the rock type model and using the SGS algorithm. Each rock type has a mean value for the porosity evaluated from cluster analysis [9]. The 3D porosity model for Khasib formation is presented in Fig.8 while the cross-sections for porosity distribution in Khasib formation are illustrated in Fig.9 and Fig.10.

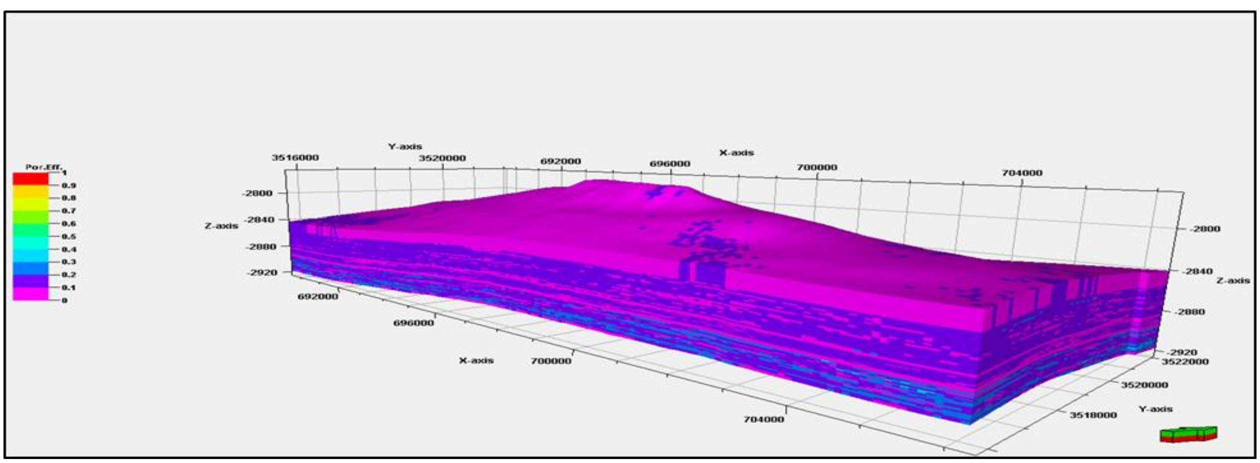


**Figure 8:** Porosity model for Khasib formation, Amara field.

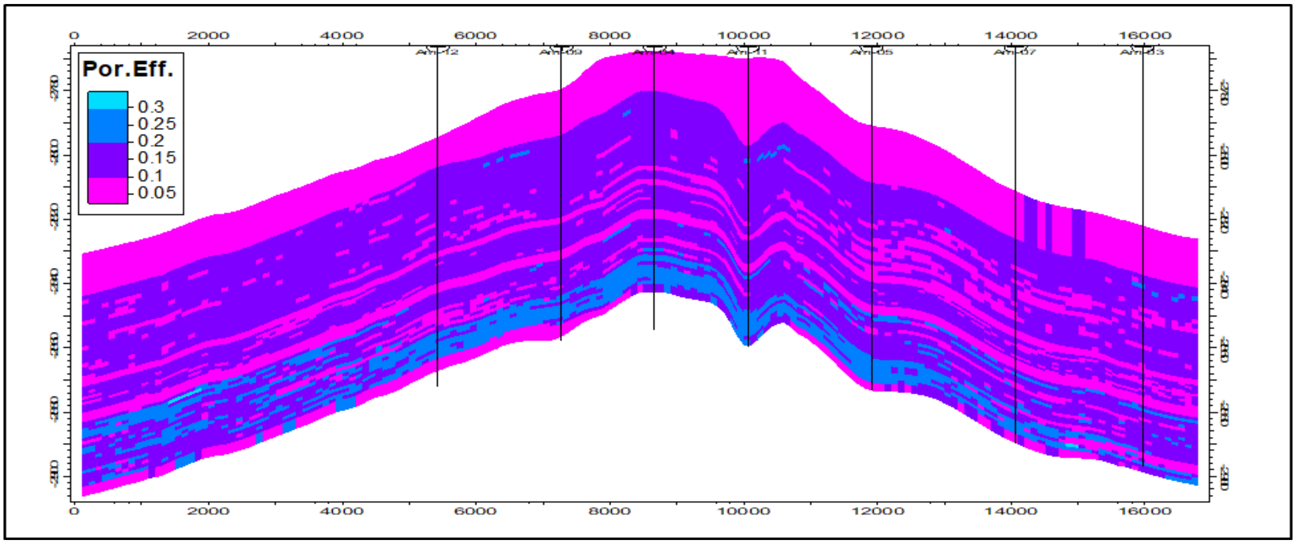


**Figure 9:** East-West cross-section for porosity distribution.

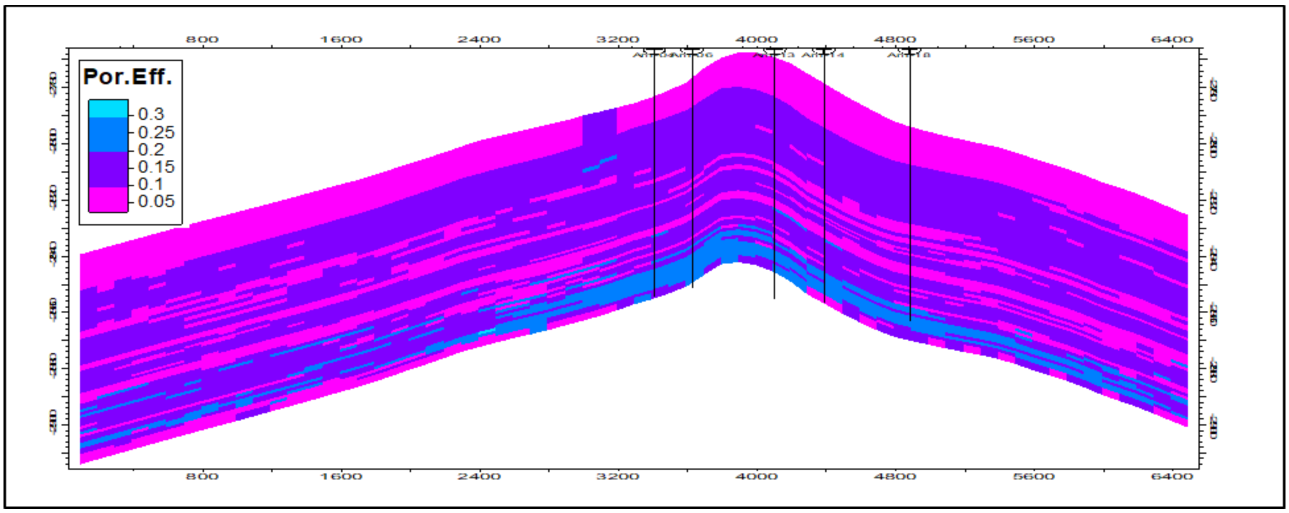


**Figure 10:** North-South cross-section for porosity distribution.

The major characteristics of the porosity model for Khasib reservoir are observed as:

- The non-reservoir zones (Khasib, Base KH11, Base KH12, and KH2) show very low porosity values.
- KH11 zone has good porosity values associated with the RT-2 that reach 20%. There was a trend for porosity enhancement towards the west and also toward the north direction of the field.
- KH12 also shows good porosity values that reach 20%. The porosity improved in the west and south directions.
- The higher porosity value was found in the KH2, zone which is associated with the RT-1 that is concentrated at the crest and extends to the west and north of the field.

### 3.2. Water Saturation Model

The water saturation model for Khasib formation has been constructed depending on the water saturation calculated using the Archie equation in Techlog software and scaling up with PETREL. The Sequential Gaussian Simulation method is also being used for the water saturation model, and the distribution depends on the rock type model. Each rock type yield from the cluster technique has a ranges for water saturation [9].The resulting 3D model of water saturation for Khasib reservoir is shown in Fig. 11 and the cross-sections that described the variation in the property are expressed in Fig. 12 and Fig. 13.

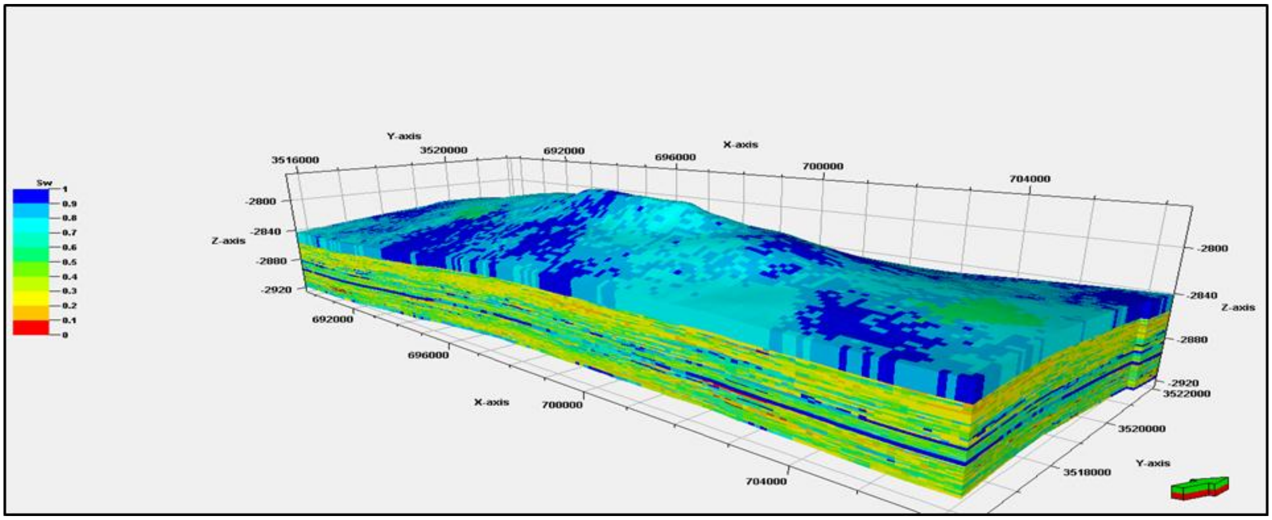


**Figure 11:** Water saturation model for Khasib reservoir.

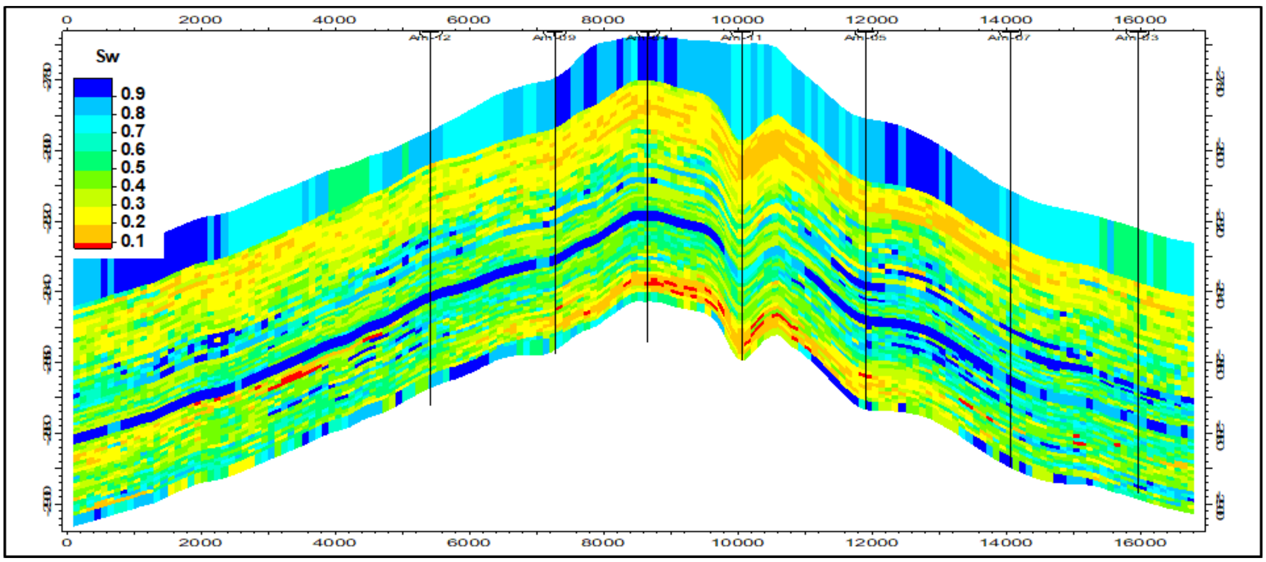


**Figure 12:** E-W cross-section for water saturation.

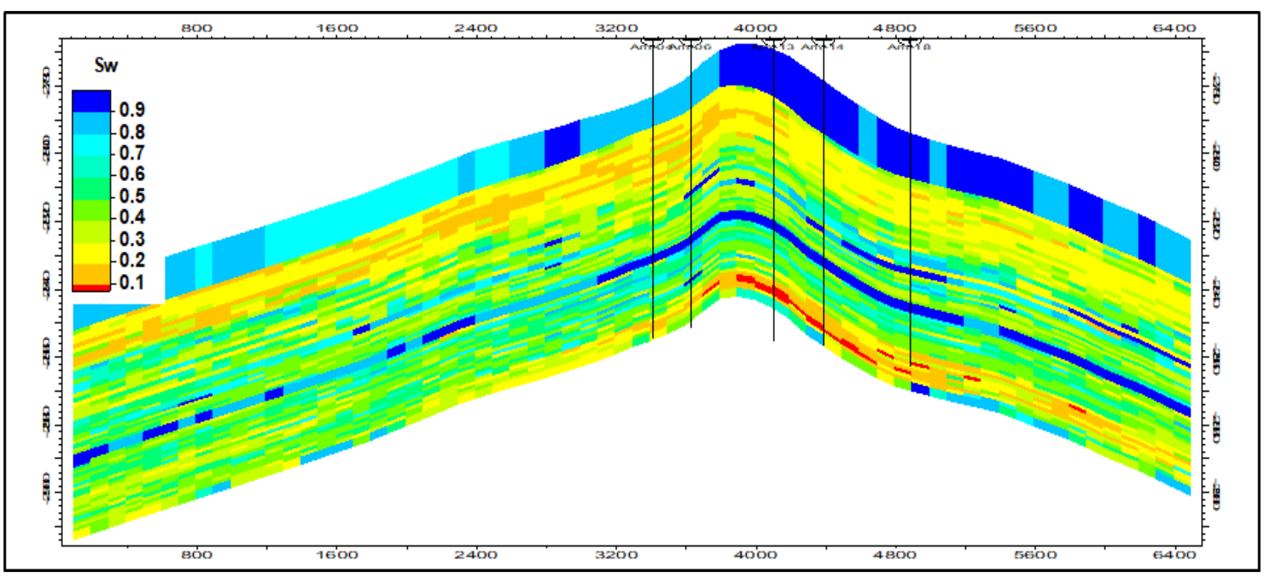


**Figure 13:** N-S cross-section for water saturation model.

The observation of the water saturation distribution along each zone of Khasib formation can be described as:

- The non-reservoir units show very high water saturation.
- KH11 zone shows low water saturation values even though the presence of the RT-4 at the bottom of the flanks shows high water saturation. Better hydrocarbon saturation can be found in this zone and enhanced in the direction of the west and south of the field.
- KH12 zone shows moderate water saturation and increases toward the east flank.
- KH2 displays the lowest water saturation associated with the RT-4, concentrated in the dome and extending to the north of the field. This zone shows high water saturation in the upper east part.

### 3.3. Permeability Model

The permeability model has been built depending on the porosity-permeability relationships established by the FZI method. Each rock type has a specific equation that relates the porosity with permeability, and the distribution depends on the rock type for each unit. There are permeability ranges for each rock type obtained from the FZI method [9]. The 3D permeability model for Khasib formation is described in Fig. 14 and the two cross-sections for the distribution variation throughout the field are shown in Fig. 15 and Fig. 16.

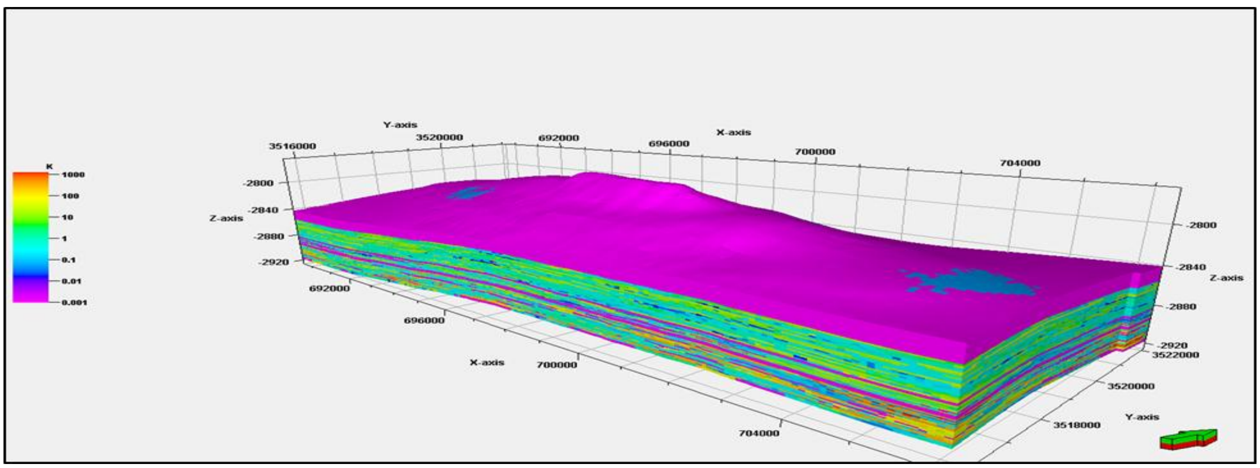


**Figure 14:** Permeability model for Khasib formation in Amara field.

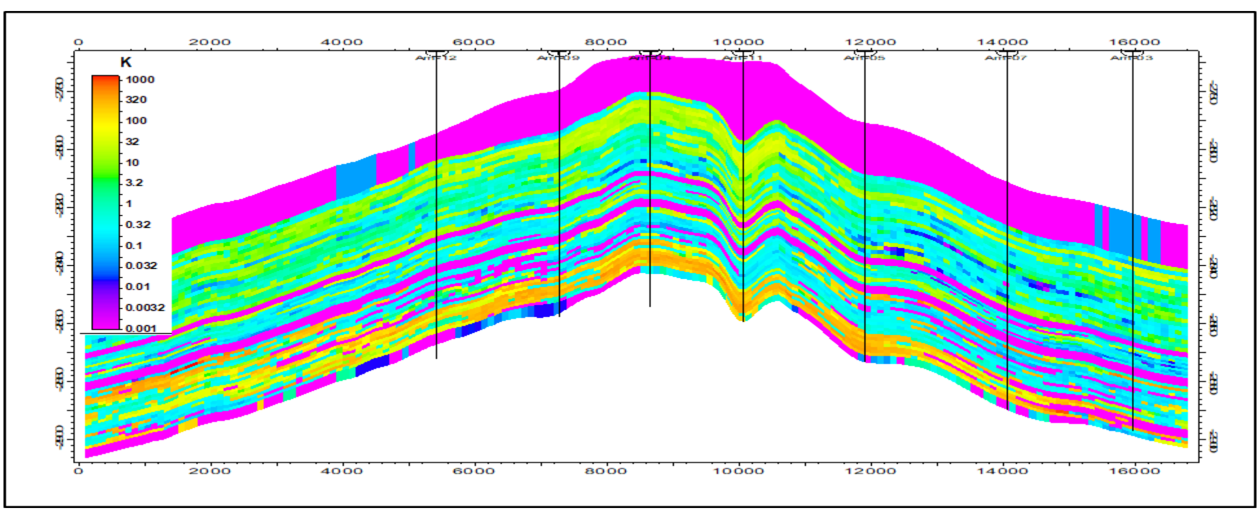


**Figure 15:** E-W cross- section for permeability model.

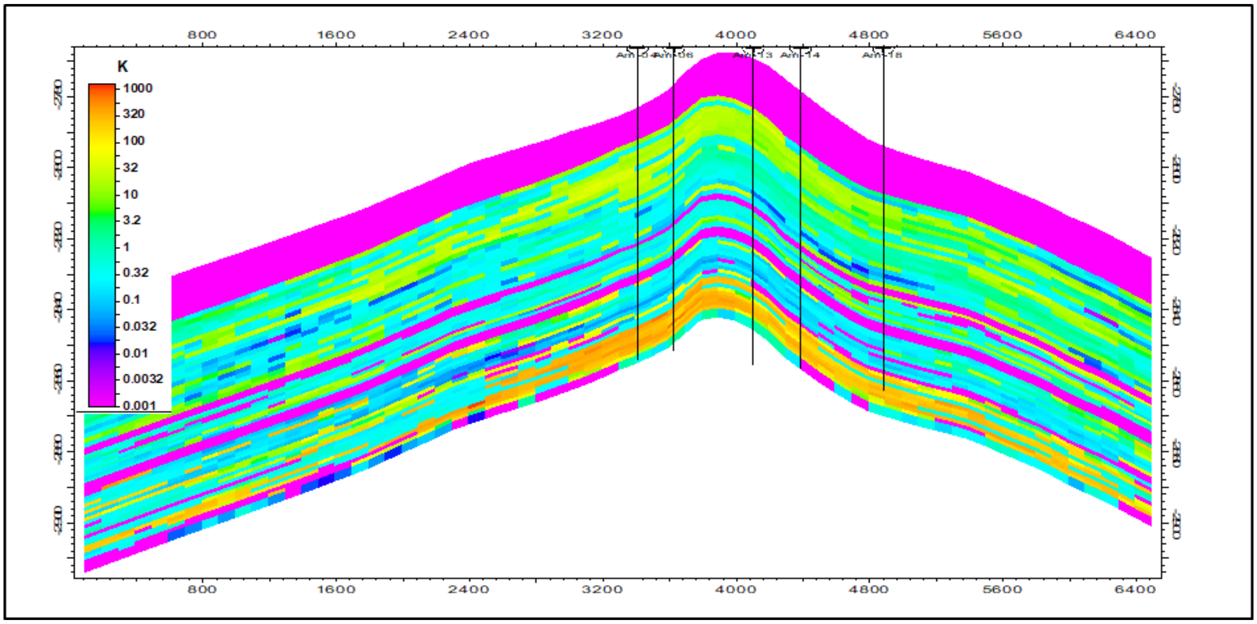

**Figure 16:** N-S cross-section for permeability model.

The permeability distribution model for Khasib formation in Amara oil field can be characterized by the following:

- For the KH11 zone, good permeability values, especially in the upper part, were enhanced toward north and west directions.
- Zone KH12 shows low to moderate permeability values, and the better was toward the west direction.
- KH2 zone has the highest permeability value, concentrated in the zone's lower part and extends to the flanks. The permeability in this zone shows better values toward the north and west directions.

### 3.4. Net/Gross Model

The cutoff values were applied to the porosity, water saturation, and shale volume to calculate the net pay thickness for each zone of Khasib formation. The resulting net Gross values were used to build the model. The 3D model for Net/Gross distribution has been constructed using the Sequential Gaussian Simulation method and depending on the rock type model as shown in Fig 17. The two cross-sections are described in Fig 18 and Fig 19. The net-to-gross model for each reservoir unit in Khasib formation is represented in Fig. 20 to Fig.22.

The model for N/G described the following points:

- KH11: The N/G values for this zone ranged from 0.6-1 and the maximum value was concentrated in the dome and exhibited better toward the north and south and in the west directions.
- KH12: The east direction shows less N/G values than the other directions.
- KH2: The maximum N/G in this zone was associated with RT-1 and N/G ranges of 0.6-1.

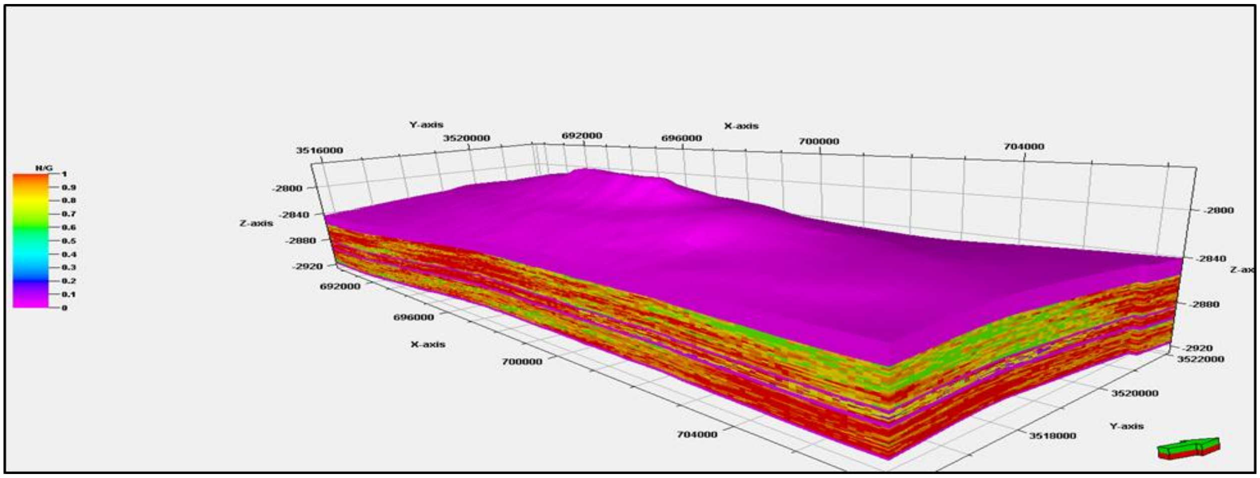

**Figure 17:** Net/Gross model for Khasib reservoir.

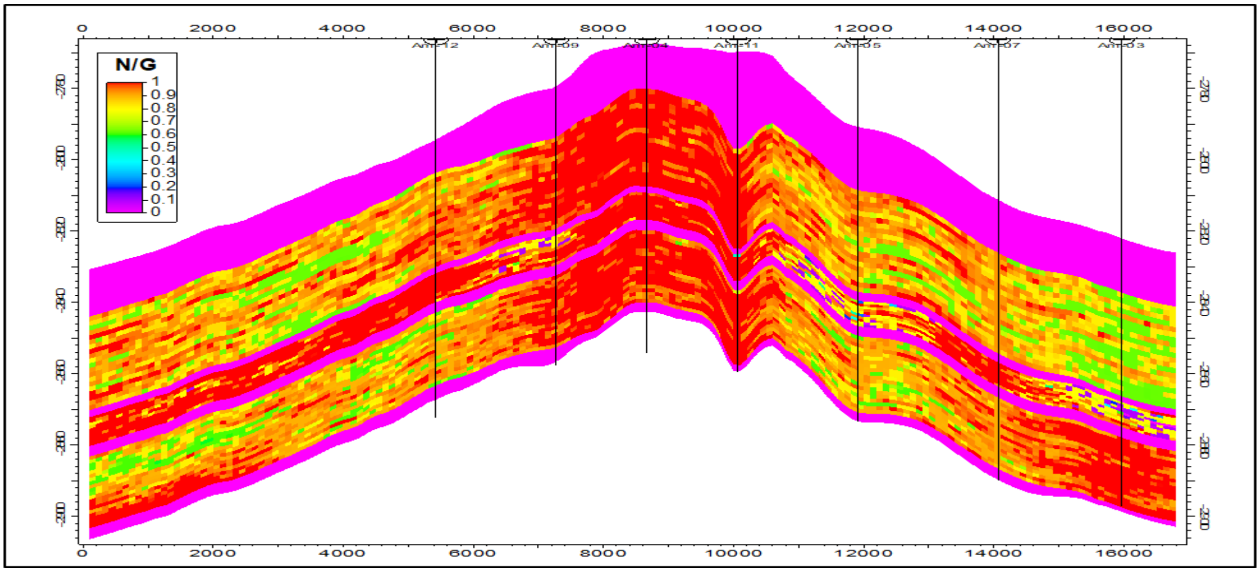

**Figure 18:** East-West cross-section for N/G model.

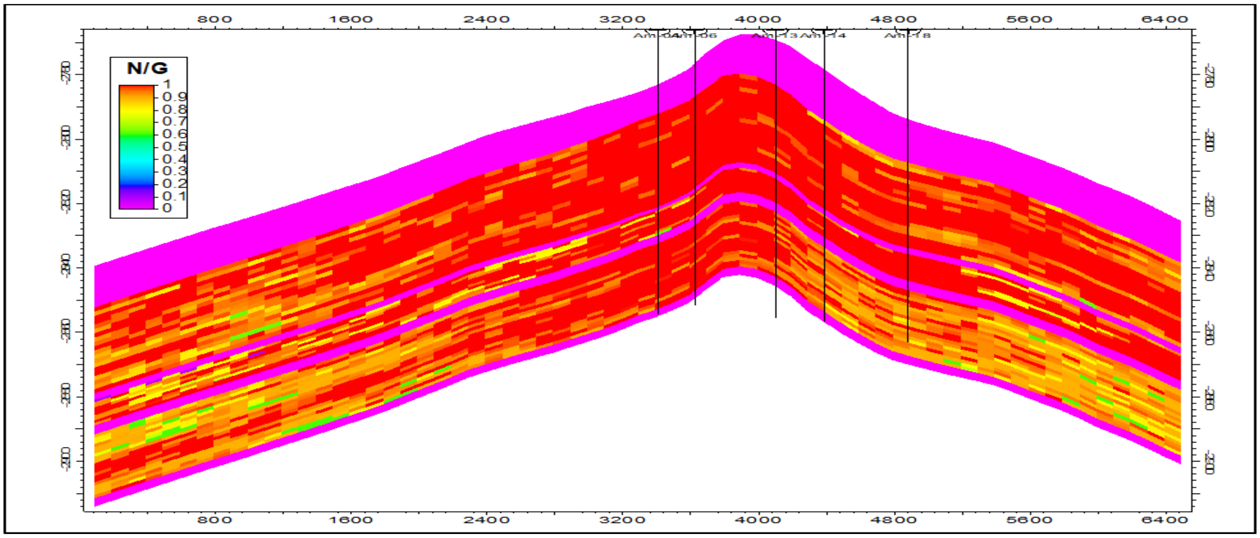

**Figure 19:** North-South cross-section for N/G model.

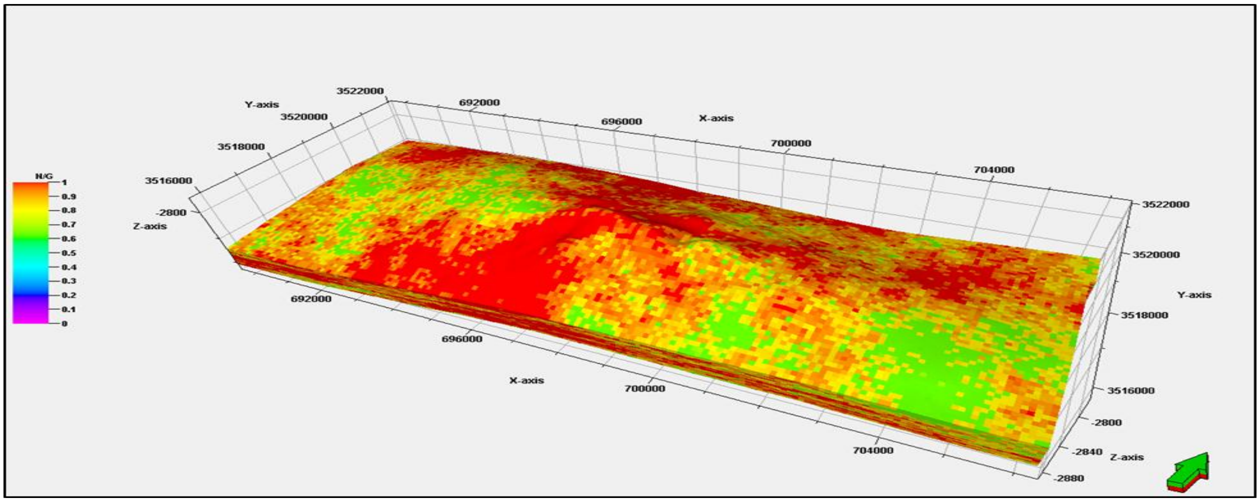


**Figure 20:** N/G model for KH11 reservoir zone.

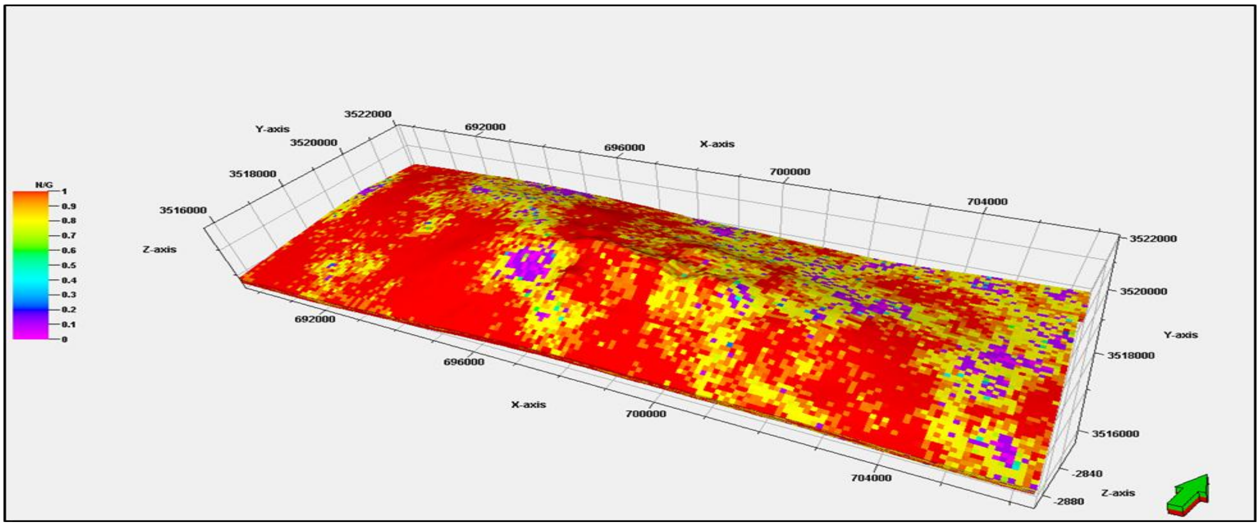


**Figure 21:** N/G model for KH12 reservoir zone.

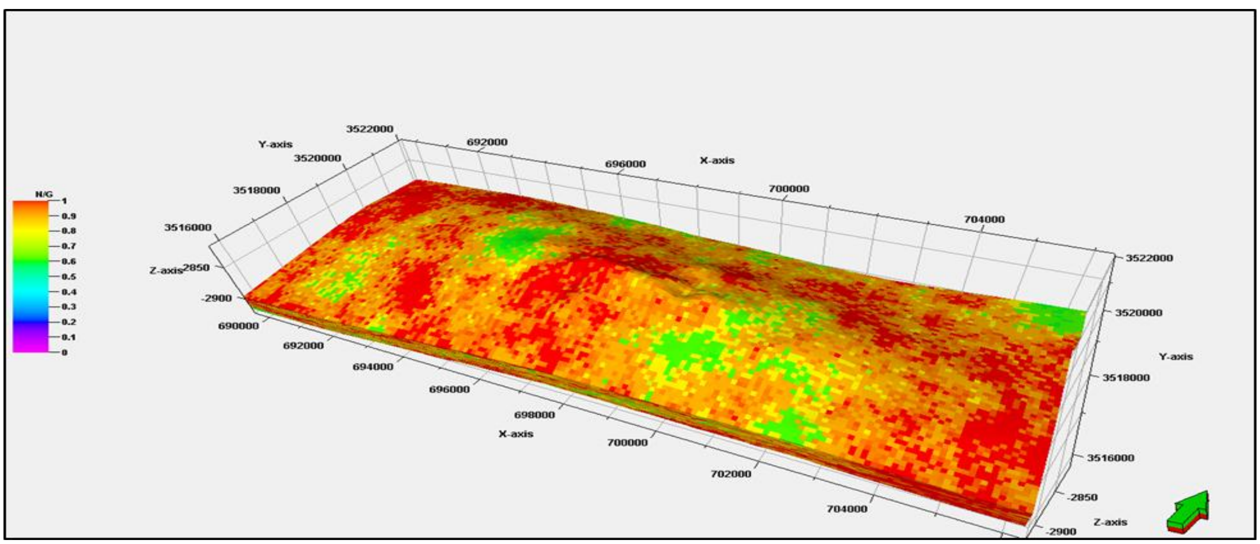


**Figure 22:** N/G model for KH2 reservoir zone.

## 4. Conclusions

- The rock type's model was the main controlling factor for distributing the petrophysical properties of Khasib formation and making the model more representative of the formation's heterogeneities.

- Porosity, water saturation, and permeability models have been built using the SGS algorithm, and the distribution of these properties depends on the rock type model indicating that the petrophysical properties are enhanced in the west and north directions.

- Net to-gross model has been built using the SGS approach showing that KH11 is considered the main reservoir unit in Khasib formation and holds a large hydrocarbon volume, KH12 has high oil content even though its thickness is much smaller than that of the other two reservoir zones, and KH2 is considered the second reservoir unit in holding hydrocarbon content.

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