3D Geological Modeling Using Seismic Data for Yamama Formation between Nasiriya and Gharaf Oilfields in Dhi Qar, Southern Iraq

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Abstract
This research addresses the construction of a 3D geological model for the Yamama Formation in the Dhi Qar Governorate, southern Iraq. Since the formation is economical due to its deposition period, which represents about 80% of the Iraqi oil reservoirs, and since no study was carried out in this area, this study was performed to explore the reservoir properties using Petrel software. Seismic data, well logs, and previous studies were used. As a result, the structure depth map was established and showed that there are two structure noses at the top of the Yamama Formation. Consequently, the Yamama reservoir is divided into three productive reservoir units named Ya, Yb, and Yc units. The study indicated that the Yc reservoir unit is the best because of its reservoir properties, where the ratio of water saturation is ranged between 37-40%, the porosity ratio is between 20 and 27%, and the facies consist of wackestone, packstone, and grainstone. As a result, the YC unit is considered one of the most promising hydrocarbon reservoirs.

Keywords: 3D geological model; Seismic Data; Petrophysical properties; Yamama Formation; Well logs

1. Introduction

The 3D Model is a grid that reflects the structure, stratigraphy, and reservoir characteristics (porosity, permeability, and water saturation) in three dimensions (X, Y, and Z) (Kessler et al., 2008; Hamdan, 2010). Typically, the 3D geological model is developed to get the most accurate representation of reservoir properties and subsurface quantities using data linked to reservoir characteristics. The model may be used in several domains, including the production of natural resources, the resolution of geophysical and geotechnical issues, and the estimation of the petrophysical characteristics of rocks, such as porosity and seismic wave velocity. Additionally, it imitates physical processes (Bonham-Carter and Bonham-Carter, 1994; Caumon et al., 2009).

The study area is located in Dhi Qar Governorate (Fig. 1). The Yamama Formation, a heterogeneous carbonate reservoir, is one of the most significant oil-producing reservoirs in southern Iraq. It was deposited during the Lower Cretaceous, during the main retrogressive depositional cycle (Berriasian-Aptian). This cycle is characterized by the Zubair, Ratawi, Yamama, Shuiaba, and Sulaiy formations from the coast to the deep basin (Buday et al., 1980; Jassim and Goff, 2006). The Yamama Formation is one of the most promising carbonate reservoirs because of its extensive geological

DOI: 10.46717/igi.56.1A.13ms-2023-1-25
distribution throughout much of southern Iraq. It also has one of the richest petroleum systems due to the presence of structural traps and stratigraphic traps (Nasser et al., 2017).

Karim and Al-Aaraji (2021) updated the structural picture of the Yammama oil formation in the field. The seismic interpretation of this study of the area approves the presence of some stratigraphic features in the Yammama Formation. The study found that its thickness increases toward the east, which means it increases from the Abu-Amoud field in Nasiriyah towards the East Abu-Amoud field in Missan area. The stratified traps were identified using seismic attributes (relative acoustic impedance) in the East Abu-Amoud field.

The approach of this research is to construct a 3D geological model for the Yamama Formation by using Petrel 2017 software in order to understand the Yamama reservoir behavior and properties for instance, structural modeling, petrophysical and facies modeling.

2. Materials and Methods

The dataset used in this research involves wellheads, well tops, and well logs, including gamma-ray, neutron, sonic, density, resistivity and CPI (porosity and water saturation) for the Yamama Formation in the Nasiriyah oilfield. The construction of the 3D geological model was done using Petrel software. There are several steps used to construct a 3D geological model (Fig. 2).
3. Results and Discussion

3.1. 3D Grid Construction

The Yamama Formation’s 3D grid, seen in Fig. 3, is a network of horizontal and vertical lines used to define a 3D geological model. Creating a 3D grid is the first stage in creating a 3D model by dividing the model into grid cells, which are boxes. A cell, for example, has a single rock type, one value of porosity, one value of water saturation, etc. These characteristics are known as the cell’s properties. There are a total of 104748336 cells. The 3D grid structure facilitates the generation of a representation of reality that may be used in calculations, etc. (Hamdan, 2010; Al-Bahadily and Nasser, 2017; Altameemi and Alzaidy, 2018; Abeed et al., 2019; Majeed et al., 2020).

3.2. Structural Contour Map

A structure contour map is one of the most crucial steps in developing a three-dimensional interpretation of the structure. The computer can generate surface contour maps and correlate between
boreholes (Hamdan, 2010; Al-Yasi et al., 2016; Al-Bahadily and Nasser, 2017; Al-Tameemi and Al-Zaidy, 2018; Alhakeem et al., 2019; Abeed et al., 2019; Majeed et al., 2020). As illustrated in Fig. 4, structure contour map of the top Yamama Formation was created. The structural contour map displays that the Yamama structure in the study area has two asymmetrical structural noses with a northwest-southeast axis; their length is 20 kilometers and their width is 10 Km.

![Structural contour map of the top of Yamama Formation within the study area.](image)

**3.3. Zonation of Geological Model**

Based on reservoir’s log behavior and petrophysical properties, the structural model of the Yamama reservoir in the study area was divided into four zones. Three of them are reservoir units, which are Ya, Yb, and Yc. The rest numbers are barriers or cap rocks, which are B_Ya, B_Yb, and B_Yc, as seen in Fig. 5.

**3.4. Layering of Geological Model**

Internal layering, which represents the geological deposition of a particular zone, is the definition of layering (Schlumberger, 2010; Al-Yasi et al., 2016). In the last stage of constructing the structural framework, the thickness and orientation of the layers inside the horizons of the 3D Grid are specified. The layering allowed the final vertical resolution of the grid to be specified by setting the cell thickness or the number of desired cell layers (Abdullah et al., 2019; Alhakeem et al., 2019; Azeez et al., 2020). As seen in Fig. 6, the reservoir units of Yamama’s structural model were split into a number of layers. The thickness and number of layers are provided in Table 1.
Fig. 5. A cross-section in the SW-NE direction through the 3D Structural Model of Yamama Formation that shows the zonation in this study.

Table 1. Layer thickness of Yamama units.

<table>
<thead>
<tr>
<th>Zones</th>
<th>Average thickness (m)</th>
<th>Number of layers</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-Ya</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>Ya</td>
<td>40</td>
<td>10</td>
</tr>
<tr>
<td>B-Yb</td>
<td>20</td>
<td>1</td>
</tr>
<tr>
<td>Yb</td>
<td>80</td>
<td>10</td>
</tr>
<tr>
<td>B-Yc</td>
<td>20</td>
<td>1</td>
</tr>
<tr>
<td>Yc</td>
<td>85</td>
<td>10</td>
</tr>
</tbody>
</table>

3.5. Scale-up Well Logs

The scale-up procedure averages the values of the 3D grid cells that are penetrable by wells. Each cell has a single value per upscale log; these cells serve as a starting point for property modeling. There are several statistical approaches for scaling up, including arithmetic, harmonic, and geometric methods (Hamdan, 2010; Schlumberger, 2010; Abeed et al., 2019). In the current model, the distribution of water saturation and porosity values was calculated using the arithmetic average, as seen in Fig. 7.

3.6. Property Modeling

Filling grid cells with discrete (facies) or continuous (petrophysics) properties is the objective of property modeling. Petrel ensures that the layer geometry provided for the grid matches the geological layering in the model area. These operations are depending on the current grid's geometry. Petrel propagates property values alongside grid layers during interpolation between data points (Hamdan,
2010; Schlumberger, 2010; Altameemi and Alzaidy, 2018; Al-Hakeem et al., 2019). The basis of a 3D property model is on well logs and trend data (Hamdan, 2010).

![3D structural model of the Yamama Formation](image)

**Fig. 6.** A 3D structural model of the Yamama Formation shows the number of layers in each zone.

![Scale-up of porosity and water saturation for Nasiriya well Ns-1](image)

**Fig. 7.** Scale-up of porosity and water saturation for Nasiriya well Ns-1 using petrel 2017.

### 3.6.1. Facies modeling

The discrete facies throughout the model grid represent facies modeling. As shown in Figs. 8 and 9, the facies model of the Yamama Formation was created based on the electrofacies interpretation findings obtained from logs and other geological data, such as the final geological report of the wells. The outcomes showed that the facies of the Ya and Yb units are wackestone and packstone, with the packstone facies increasing in the northeast, which corresponds to the Gharaf well 1 (Gh-1), and decreasing in the southwest, which refers to the Nasiriya well (Ns-1). Facies of the Yc unit include wackestone, packstone, and grainstone. The grainstone facies expands in the southwest direction.
Fig. 8. A cross-section in the SW-NE directions shows the facies geological model of the Yamama Formation.

Fig. 9. A cross-section in the SW-NE directions shows the facies geological model of the Yamama Formation.
3.6.2. Petrophysical Modeling

A geological reservoir model's objective is to provide a comprehensive set of continuous reservoir parameters, including porosity, permeability, and water saturation, for each cell of the 3D grid; several methodologies are utilized to create these values (Bellorini et al., 2003; Hamdan, 2010; Al-Tameemi and Al-Zaidy, 2018).

- **Porosity Model**
  The porosity model is constructed based on the corrected and interpreted porosity log findings (density and neutron), which are analyzed using IP software. As a statistical technique, a statistical sequential Gaussian simulation algorithm was utilized (Bellorini et al., 2003; Hamdan, 2010; Abdullah et al., 2019). The crucial phase in the "porosity model" is to scale up the porosity from the well grid cells to the entire model, to distribute the porosity from the well log data to the 3D grid cells. This is to preserve the variability of the subsurface geology (Al-Hakeem et al., 2019). Fig. 10 describes the porosity models of the Yamama Formation where it is noted that the porosity in the Ya and Yb reservoir units is between 15 and 20%, while it is between 20 and 27% in the Yc reservoir unit. Moreover, the porosity model matches with the facies model, so the porosity increases in the northeast direction of the Gh-1 and decreases to the southwest except in the Ns-1.

![Fig. 10. A cross-section in the SW-NE directions shows the porosity geological model of the Yamama Formation.](image)

- **Water Saturation**
  It is one of the most crucial steps in the reservoir study due to its significance in calculating the amount of hydrocarbons in place, determining fluid mechanics, and finally estimating the well productivity (Adams, 2005; Al-Hakeem et al., 2019). After exporting the scaled-up water saturation from IP software, the water saturation model for the Yamama Formation reservoir unit was constructed.
using the same geostatistical approach as the porosity model (statistical sequential gaussian simulation algorithm). In addition, taking into account the facies model, as displayed in Figs. 11 and 12.

Fig. 11. The geological model of the Yamama Formation's water saturation in the study area.

Fig. 12. A cross-section in the SW-NE directions shows the water saturation geological model of the Yamama Formation.
The water saturation model of Yamama shows that the Ya unit is around 40%, Yb unit is between 45 and 50%, and the Yc unit ranges between 37 and 40%. The water saturation model matches the facies and porosity models; so, the percentage of the water saturation decreases in the southwest direction of the Gh-1 and decreases to the northeast except in the Ns-1.

4. Conclusions

Based on the study of the reservoir properties of the Yamama Formation, a 3D geological model was created. The structural model showed that there are two structural noses at the top of the Yamama northwest–southeast axis. The 3D geological model showed that the Yamama Formation is divided into four reservoir units. Three of them are named Ya, Yb, and Yc units, which have good reservoir properties; the rest, which are titled B-Ya, B-Yb, and B-Yc units, are barriers or cap rocks with bad properties. The Facies Geological Model showed types of facies for each reservoir unit. Ya and Yb units are wackestone and packstone, where the packstone facies are improved in the direction of the northeast and worsens in the opposite direction. While, the facies of the Yc unit consists of wackestone, packstone and grainstone where the grainstone increases in the direction of southwest. In terms of the porosity, the ratios of the Ya and Yb reservoir units ranged between 15 and 20% while for the Yc reservoir unit is 20 and 27%. While the water saturation model displayed that the ratios of Ya unit is around 40%, Yb is between 45 and 50, and Yc unit ranged between 37 and 40%. The percentages of the water saturation decreased in the southwest direction and decrease to the northeast. Based on the reservoir properties mentioned above, the Yc unit has the best reservoir properties and is considered one of the most promising hydrocarbon reservoirs.

References


