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Geological Modelling to Predict New Potential Oil Zones in Yamama Formation /Siba Field/ southern Iraq

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A B S T R A C T

A geological model was constructed using Petrel software for the Yamama Formation in the Siba oil field, southern Iraq. Information from four drilled wells in the area was used to define water saturation, porosity, and permeability. In addition, well-log data including sonic, density, neutron, gamma-ray, spontaneous potential (SP), and resistivity logs readings were used to determine the petrophysical properties of the formation. This work aims to study the occurrence of potential oil zones within the formation. Results indicate that zone 1 has low water saturation, high porosity, high permeability, and a high value of net to gross. For instance, the average porosity of the reservoir in Zone 1 is approximately 7.33%, compared to only 2% in Zone 2. Additionally, Zone 1 has a permeability value of 7 mD compared to only 0.2737 mD for Zone 2. Finally, Zone 1 has a water saturation value of 63%, while Zone 2 has a saturation of 89%. Based on the collective analysis of these factors, it was concluded that Zone 1 is more favorable for hydrocarbon development and production than Zone 2. Therefore, these findings can be valuable for optimizing well placement, production strategies, and overall reservoir development planning for oil resources.

A R T I C L E I N F O

Keywords:
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1. Introduction

Accurate petrophysical analysis is essential for identifying hydrocarbon- and nonhydrocarbon-bearing sections, which is vital for reservoir characterization [1],[2],[3]. The petrophysics of a field includes the parameters of reservoir fluids and the characteristics of reservoir rocks that can influence oil recovery [4]. Moreover, reservoir heterogeneity plays a significant role in fluid flow in porous media [5],[6],[8],[9], [10], [11]. These characteristics may encompass permeability (K), porosity (Φ), and fluid saturation (S). Data derived from well logs are considered a crucial source for the geological and petrophysical characterization of reservoir formation. Furthermore, well logging is an essential tool for assessing the potential hydrocarbon reservoir production zones [12], [13]. Effective evaluations of these qualities facilitate the prediction of the complex behavior of reservoir conditions. In addition, this analysis is crucial for predicting reservoir system performance and estimating the available hydrocarbon volumes [14]. Therefore, creating accurate geological models of reservoirs is an essential tool that is commonly utilized in the oil and gas sector [15],[16]. The Yamama Formation is one of the most important oil-producing reservoirs [17]. For instance, it contains hydrocarbons at 26 structures in southern Iraq [18]. Aside from being a homogeneous carbonate reservoir, it is primarily composed of limestone [19]. The Yamama Formation dates back to the Late Berriasian to the Early Aptian period and is a crucial Middle Eastern reservoir [20]. The Yamama Formation overlies the underlying Sulaiy Formation in a conformable manner and changes upward gradually into Ratawi Formation [21],[22],[23]. They were deposited within the Lower Cretaceous period in association with the principal retrogressive depositional cycle

(Berriasian - Aptian) [24],[25] (see Fig. 1). To date, many petroleum generation studies on the Yamama Formation have been done [18],[12],[26],[27], sedimentation [22],[28],[29],[30], diagenesis [31],[32], sequence [33], reservoir characterization [34],[35],[36], and geological modeling [24]. However, only a small fraction of the potential reservoirs was produced, and the Yamama Formation proved to have more complicated characteristics than expected. Geological modeling can be defined, in most operations, as the best description of reservoir quantities and properties beneath the subsurface by utilizing information associated with reservoir features [37]. Therefore, in this study, a geological model will be constructed. This model will incorporate data and interpretations, including its lithology, structural features, and depositional environment. Careful representation of the Yamama Formation within the broader geological context of the Siba field. This model will provide valuable insights into the spatial distribution of reservoir fluids. Moreover, integrating petrophysical data with geological information is necessary to simulate fluid flow and behavior in the reservoir. The reservoir's parameters are estimated using a static modeling approach based on geostatistical methods, including sequential Gaussian simulation (SGS) [38]. The properties in the reservoir that are necessary for understanding and describing most of the geological features comprise water saturation, porosity, permeability, and net to gross for the understanding of the oil quantity in the reservoir. Therefore, the reservoir model will provide a more detailed understanding of the reservoir's dynamics and performance. Various scenarios for hydrocarbon recovery could be implied. Furthermore, reservoir engineers can determine which recovery choices would provide the safest, most economical, most efficient, and most effective development plan for a reservoir.

2. Area of Study

The area of study is situated near the city of Siba, which falls within the administrative boundaries of Basra Province, in the southeastern corner of Iraq [39]. Seismic studies have revealed the occurrence of two domes with a central marked saddle. The northern dome is located in the northeast (see Figure 2) and is truncated by the Shatt Al-Arab River; it is expected to extend into Iranian territory. The other dome is situated in the southwest. The southwestern part of the project area is predominantly characterized by a sabkha, which is a unique salt flat or salt marsh formation. Sabkhas are known for their saline deposits and distinctive ecosystems, presenting potential challenges and considerations for field development activities.

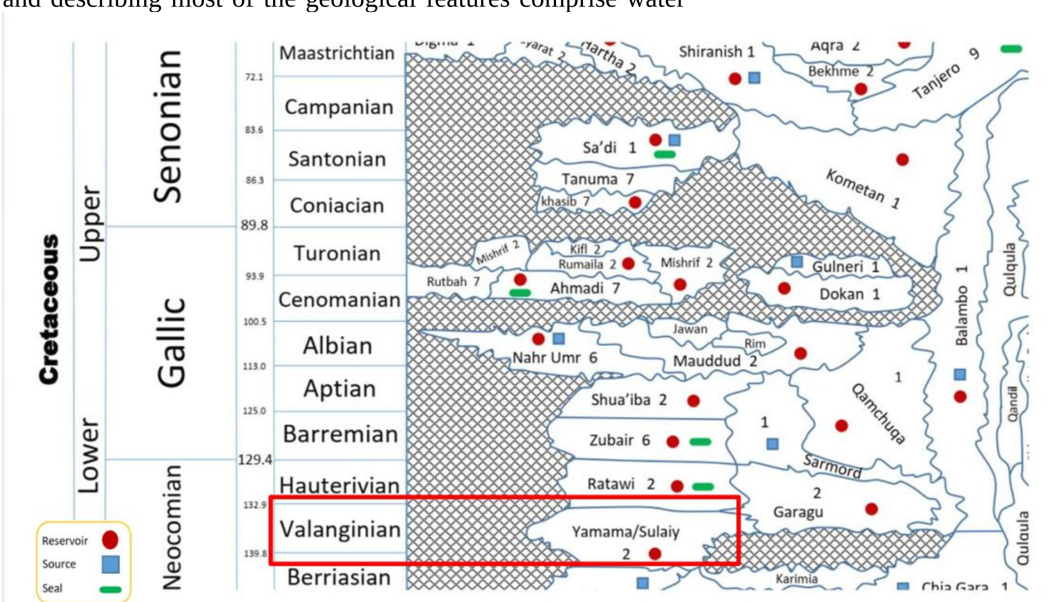

Fig. 1. Chronostratigraphic diagram of the Yamama Formation.

3. Materials and Methods

This study has employed field maps, reports, and well data records that are publicly available. Four wells—SB-2, SB-3, SB-4, and SB-6-were selected for analysis in this study. To this end, Neaura Map software and Interactive Petrophysics (IP) software (version 2018) were used to prepare this data for use in the Petrel program. While the latter has developed geological models through the creation of structural and property models.

4. Results and Discussions

The reservoir engineer's first duty in creating the static model is to determine the formation tops. It is possible to determine comparable rock qualities in adjacent wells. The primary goal is to define the horizons of formation units and their succession in order to accurately calculate oil in place. The data utilized to compare the formation top with the log includes the depth of the invasion, associated gamma ray log, the density log, the sonic log, and the neutron log. The reservoir petrophysical properties and their distributions including reservoir porosity, water saturation, and permeability-along with the thicknesses of different lithological units, can be interpreted using well-correlation concepts [40]. Table 1 below clarifies the quantity and depth of Yamama Formation units, and Figure 3 demonstrate the correlation between wells and units.

The Yamama Formation's structural contour maps are depicted in Figures 4-6. These maps with structural tops define the reservoir's structural properties and the locations of drilled wells. The results from the formation units can be used in conjunction with geological survey data to construct a structural model.

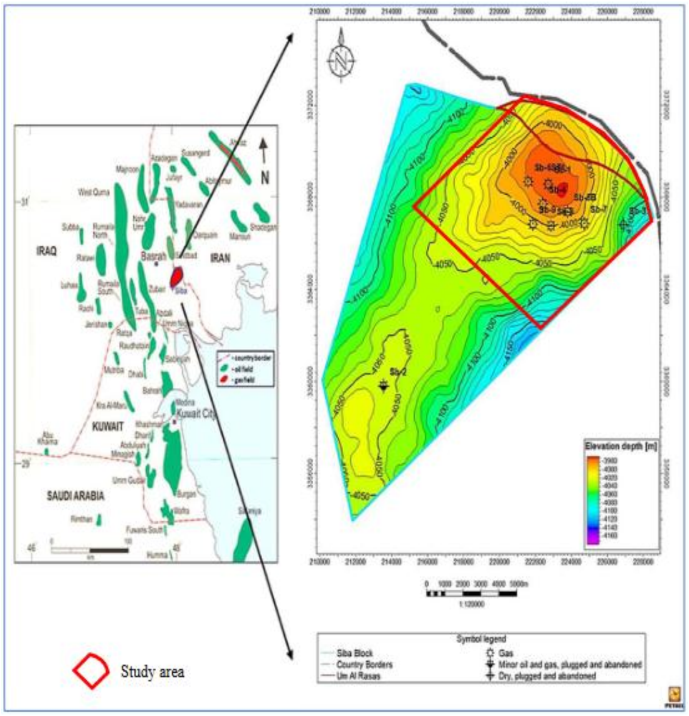

Fig. 1. Location and structural maps of Siba Field [39].

Table 1. Tops of the Yamama Formation's zoning.

Well tops names	Wells			
	SB-2	SB-3	SB-4	SB-6
Upper Yamama	4047.5	4096.8	3983	3984.5
Lower Yamama	4072.5	4124.5	4009	4009.9
Bottom Yamama	4090	4150	4035	4034

The quantitative description of well log data is developed to estimate the key reservoir rock characteristics: porosity, permeability, water saturation, clay volume, and net to gross for indicating high-quality zones. The geological model serves as a starting point for the initialization of the dynamic model and is represented as a reference to calculate the reservoir's oil content. The geological model contains a large number of grids, and the properties of these grid cells provide estimates of oil content. The petrophysical property values (i.e., water saturation and porosity) are assigned per cell of the 3D grid. The established model of Petrophysics is built by using geostatistical methods. The geostatistical algorithm used-Statistical Sequential Gaussian Simulation (SSGS)-is a statistical procedure that depends on the quantity of available data [41]. Furthermore, a new model was generated by Petrel based on core porosity after comparing neutron, density, and sonic porosity employing the Interactive Petrophysics program. The SSGS technique is adopted herein as a statistical method [42]. Results showed that the average porosity of the reservoir in Zone 1 is around 7.33%, and 2% in Zone 2. As a result, the reservoir's porosity in Zone 1 is the most significant. The 3D top views of the porosity model for Zone 1 in the Yamama reservoir at the Siba field is presented in Figure 7.

5. Permeability

Consequently, the permeability of the Yamama Formation was calculated using multiple linear regression due to the availability of a limited number of core samples. To incorporate the uncertainty and variability in permeability values, the Sequential Gaussian Simulation (SGS) technique was employed to simulate the distribution of permeability values across the permeability model. The results showed that Zone 1 had a permeability value of 7 mD compared to only 0.2737 mD in Zone 2. Figure 8 illustrates the permeability distribution resulting from the Sequential Gaussian simulation.

Finally, the identification of perforation zones relies mainly on the knowledge of water saturation in formations [43]. Therefore, the water saturation model of the Yamama Formation was built using the Sequential Gaussian Simulation (SGS) technique (see Figure 9). Consequently, water saturation distribution is considered while generating the saturation model. The results showed that Zone 1 has a water saturation value of 63%, while Zone 2 has a value of 89%. The structural model provides useful information on the overall architecture and interconnectivity of the reservoir. It helps identify potential hydrocarbon-bearing zones and supports decision-making regarding the development and production strategies for the reservoir. Coupling the water saturation model with the structural model, the reservoir engineer could assess the reservoir productivity, estimate producible hydrocarbon volume, and optimize field development plans.

6. Conclusions

For wells, SB-2, SB-3, SB-4, and SB-6 information were employed in this study along with available well log data to generate a 3D model using Petrel Software. The reservoir's parameters are estimated using a static modeling approach based on geostatistical methods, including Sequential Gaussian Simulation (SGS). The study area (i.e., the Yamama Formation) consists of two main zones: the first zone is located in the northeastern part of the reservoir, while the second zone lies in the southwestern part. Based on the results and the previously mentioned criteria, it has been determined that Zone 1 is superior to Zone 2. For instance, water saturation values in Zone 1 exhibit a lower value compared to Zone 2. This indicates that a larger portion of the reservoir interval in Zone 1 is filled with hydrocarbons rather than water, making it more favorable for oil or gas production. In addition, a higher porosity in Zone 1 demonstrates the amount of pore space available within the rock formation. This also refers to the occurrence of a greater capacity for storing and transmitting hydrocarbons. Therefore, Zone 1 could have a better reservoir quality and a higher potential for hydrocarbon accumulation. Furthermore, a higher permeability in Zone 1 facilitates the movement of hydrocarbons within the reservoir, enabling better reservoir performance and production rates. Considering these factors collectively, it is concluded that Zone 1 located in the northeastern part of the reservoir, is more favorable for hydrocarbon production compared to Zone 2. These findings are valuable for optimizing well placement, production strategies, and overall reservoir development planning of oil resources in the Siba oil field.

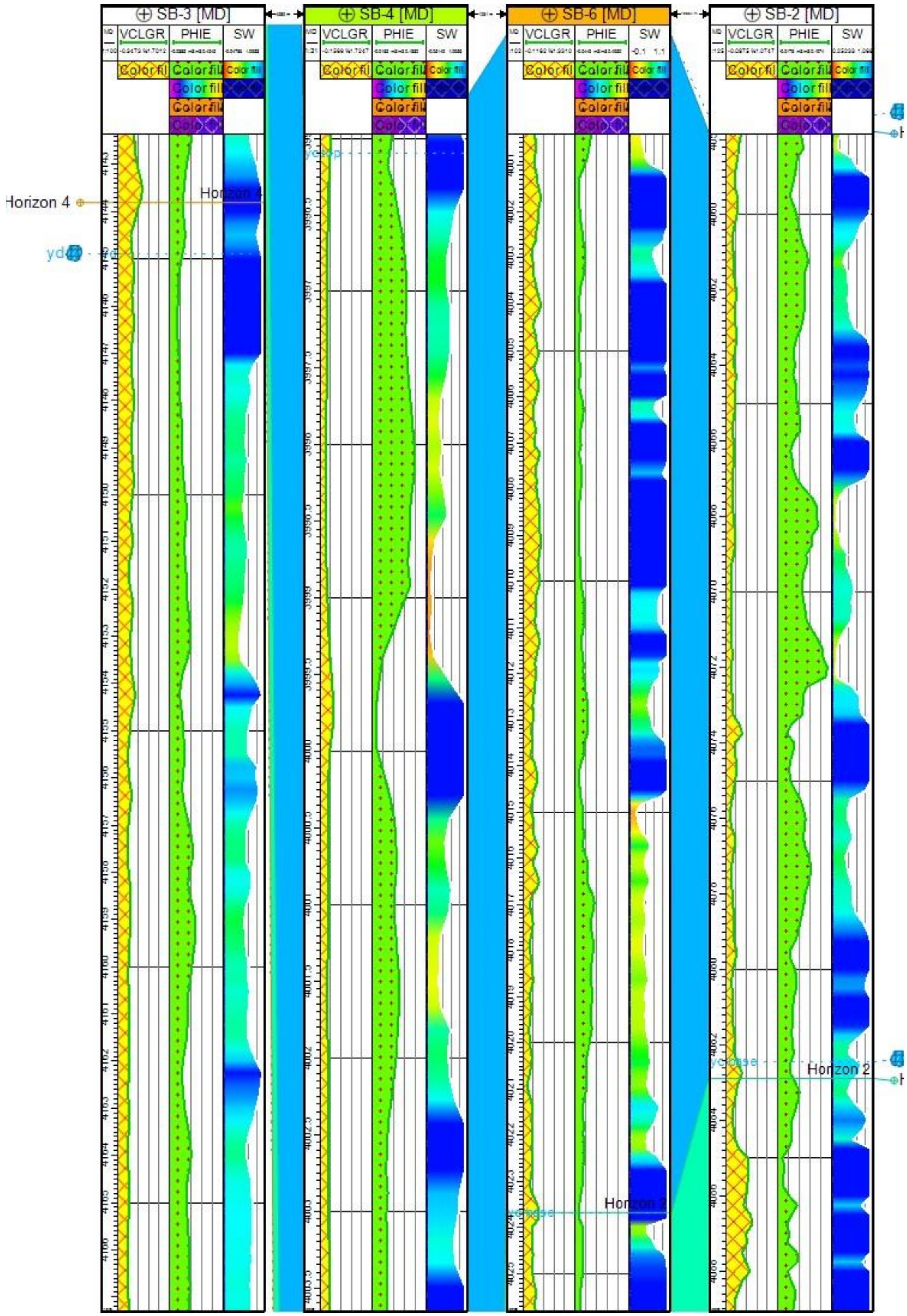

Fig. 3. Correlation between SB-2, SB-3, SB-4 and SB-6.

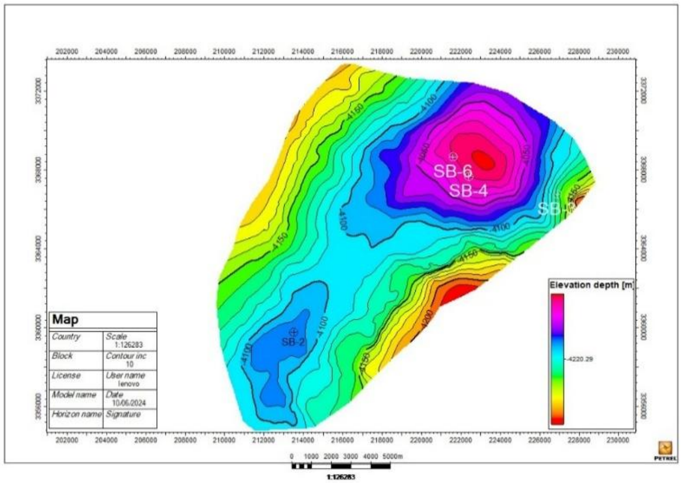

Fig. 4. Counters map of Yamama Formation.

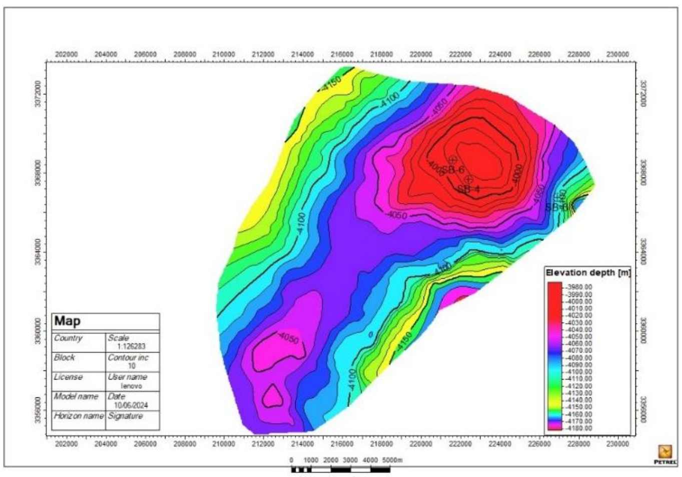

Fig. 5. The counters map located at the top of Yamama Formation.

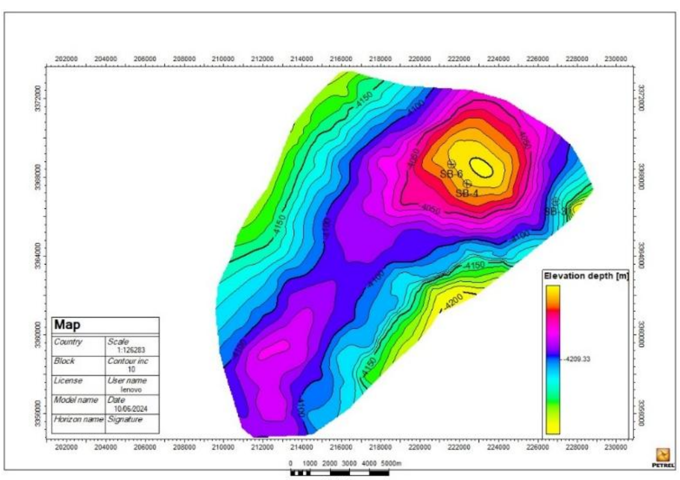

Fig. 6. The counters Map located at the bottom of Yamama Formation.

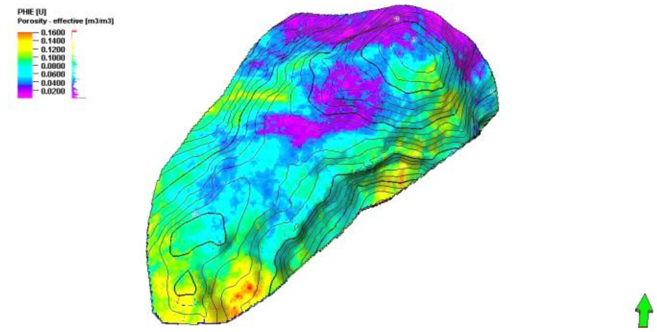

Fig. 7. 3D top views of the porosity model for the Zone 1 unit in the Siba field's Yamama reservoir.

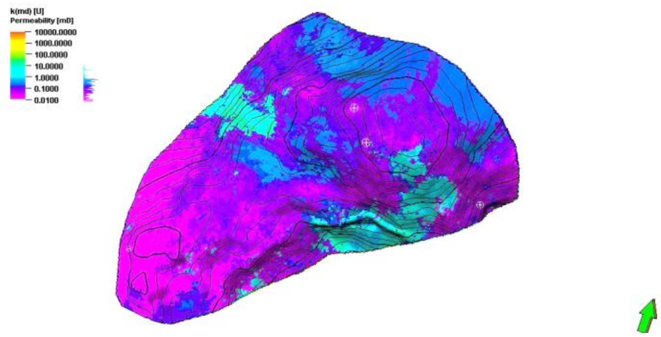

Fig. 8. 3D top views of the permeability model for the Zone 1 unit in the Siba field's Yamama reservoir.

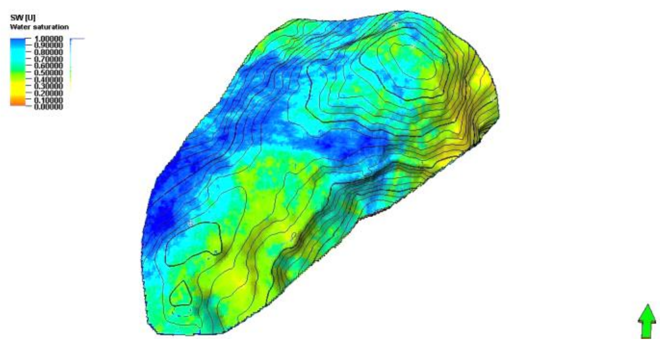

Fig. 9. 3D top views of the Water saturation model for the Zone 1 unit in the Siba field's Yamama reservoir.

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