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Involvement in the extraction of sediment layers from the productive strata within the Palchig Pilpilesi formation with a 3D geological model

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Abstract. The analysis of existing geological and geophysical research as well as excavation works reveals that despite the prolonged search and exploration of the Productive Layer (PG) sediments in the South Caspian Basin (SCA), their hydrocarbon reserves remain insufficiently explored. Examination and consolidation of geological-geophysical data, drilling information, and the established 3D geological model indicate specific patterns in the distribution of oil and gas deposits within local elevations. These patterns are primarily influenced by tectonic processes. In the 3D geological modeling of the Palchig Pilpilesi deposit, the study accounted for tectonic processes occurring in the sedimentation basin of the sedimentary complex. This included the development of uplifts, their complication due to tectonic disturbances, and the impact of changes in the lithological composition and thickness of the horizons and layers constituting the productive layer section on the accumulation of hydrocarbon resources.

Introduction. In the development of the 3D geological model for the deposit, three-dimensional modeling was employed to capture the intricacies of the fractures encompassing the structure, leading to the creation of a comprehensive structural model. Subsequent to validating the structural model using well data and trend maps, a 50x50 scale 3D grid was meticulously constructed based on the established structure. Initially, seepage capacity parameter curves, delineated by area and depth, were integrated into the constructed grid.

To ascertain the spatial distribution of rocks within the lithological section of the development horizons, facies modeling was conducted. This process contributed to a nuanced understanding of the field distribution of the various rock types involved in the geological makeup of the deposit.
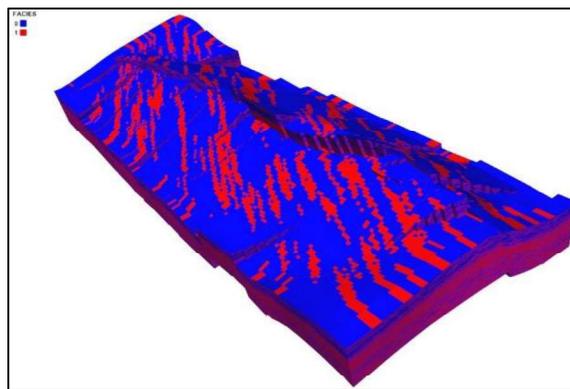

Figure 1. Facies model of Palchig – Pilpilesi field

The outcomes of the histogram analysis conducted on the facies model, utilizing the calculated parameters, indicate an overall average sandiness value of 0.5 across the horizons of Palchig Pilpilesi. When examined individually, the sandiness values are as follows: QUG-0.26, QUQ-0.34, QD-0.36, QA-0.75, and QaLD-0.58 (refer to Figure 1). It is important to note that these parameters are derived

from well data. The average values presented were computed based on the data contained within the contour, with information outside the delineation exerting no influence on these statistical measures.

Following the establishment of the facies model, petrophysical modeling was undertaken, encompassing the assessment of porosity, permeability, and water saturation. Based on the data derived from petrophysical modeling, the average porosity value across the horizons of the deposit is determined to be 0.183.

When examining porosity values individually, specific averages are identified:

QUG: 0.19

QUQ: 0.20

QD: 0.20 (QD1-0.20, QD2-0.18, QD3-0.19, QD4-0.21, QD5-0.22)

QA: 0.20 (QA1-0.20, QA2-0.216, QA3-0.194)

QaLD: 0.17 (QaLD1-0.17, QaLD2-0.16, QaLD3-0.17, QaLD4-0.18).

These values provide a detailed insight into the porosity characteristics of each specific horizon within the deposit, aiding in a comprehensive understanding of the petrophysical attributes of the geological formation.
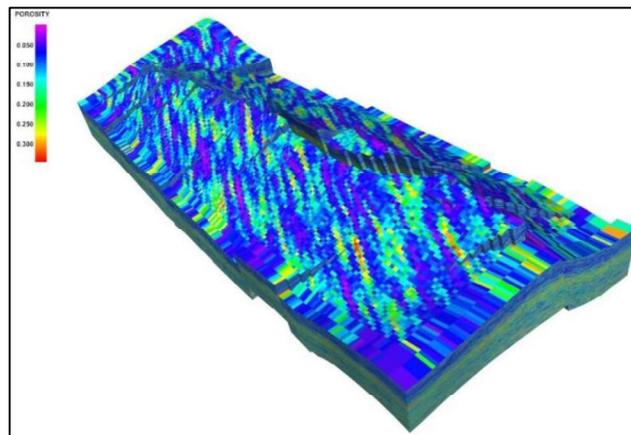

Figure 2. 3D porosity distribution for the Palchig Pilpilesi field (QUG – QaLD).

A 3D porosity (Phie) model was developed utilizing stochastic distribution through kriging simulation under the condition of NTG=1 (where NTG=1 signifies a reservoir, and NTG=0 denotes a non-reservoir) following extensive analyses of well data. The variogram model employed for this simulation includes an azimuth with an exponential curve set at 170 degrees, parallel - 150 m, normal - 100 m, and vertical direction - 4 m. This modeling approach leverages geostatistical methods to estimate porosity values in three dimensions, providing a spatial representation of porosity distribution within the reservoir.

The porosity coefficient, derived from an analysis of rock samples obtained from 42 wells, is based on a total of 218 samples. This coefficient has been computed for both horizon and bed areas. The accurate calculation of the porosity coefficient by area is intricately tied to variations in lithological composition and reservoir thickness

Among the 218 samples collected from exploratory wells, 184 have been attributed to collectors. The calculated porosity coefficient for these samples falls within the range of 0.15 to 0.26.

It is noteworthy that, consistent with core analysis results and experiences gleaned from other fields in the region, there exists a direct correlation between permeability and porosity. This relationship underscores the importance of understanding and considering both parameters in the assessment of reservoir characteristics.

$$y = 1.4868e{+}05*x^{\wedge}3 - 24072*x^{\wedge}2 - 2260.2*x^{\wedge}1 + 379.41 \quad (1)$$

Permeability was derived from porosity using the formula above, which reflects the increasing relationship between permeability and porosity.
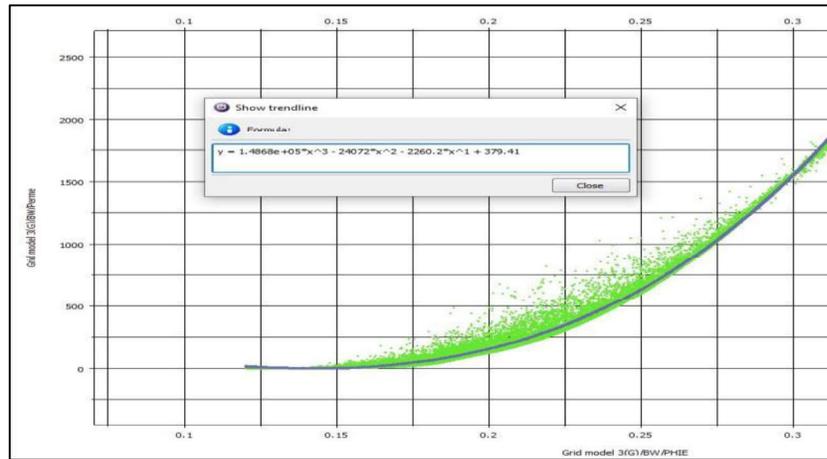

Figure 3. Permeability vs. porosity plot.

In the subsequent phase, a water saturation model was developed. The average water saturation value calculated within the contour is determined to be 0.31 for the CG - QLD. When categorized by horizons, the water saturation values are as follows: QUG -0.33, QUQ -0.25, QD -0.35, QA-0.28, and QALD -0.32.

The modeling of water saturation (Sw) employed a simplified J-function method, incorporating porosity (Poro), permeability (Perm), height above the free water level (FWL) (H), and petrophysical constants (a, b). This approach enhances the understanding of water saturation dynamics within the reservoir, integrating various key parameters for a comprehensive modeling outcome.

$$J = H\sqrt{\frac{Perm}{Poro}}$$

$$S_{wn} = \frac{1}{H_{top} - H_{bottom}} \int_{H_{bottom}}^{H_{top}} \left(\frac{J}{a}\right)^{\frac{1}{b}} dH$$

$$S_w = S_{wirr} + (S_{wmax} - S_{wirr}) S_{wn}$$

$$(2)$$

S_{wn} – water saturation value by height above free water level
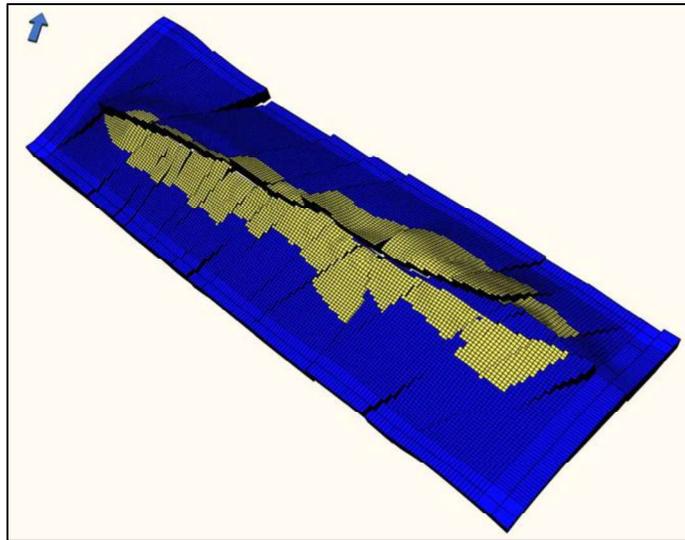S_{wirr} – saturation value with non-extractable (residual) water

Figure 4. 3D water saturation distribution of Palchig Pilpilesi field

History Matching. In the realm of reservoir management, the significance of accurate reservoir models cannot be overstated. These models play a pivotal role in forecasting reservoir performance across diverse operating scenarios, thereby mitigating investment risks in field development. The conceptual equivalence of a reservoir model to the actual reservoir is imperative for its precision and reliability. [2]

History matching emerges as a critical procedure in this context, serving to evaluate and validate the similarity between the simulation model and the real reservoir. During history matching, the historical performance of the reservoir is simulated, and the model is systematically adjusted to align with observed historical data. The objective is to ensure that the final history-matched model faithfully represents the reservoir's behavior and possesses the capability to reliably forecast its performance in the future. This iterative process enhances the accuracy of the reservoir model, fostering informed decision-making in reservoir management and development endeavors.[3]

The primary objectives of history matching reservoir models include the reduction of uncertainty, enhancement of reservoir understanding, validation of reservoir simulation models, and improvement in the accuracy of predictions regarding reservoir performance. The fundamental premise is that, if a reservoir model can faithfully replicate historical reservoir performance, it can reasonably forecast future performance.[5]

The method of "history matching" is employed to align model input with recorded data, encompassing fluid characteristics, geological descriptions, and other pertinent information. Recorded data may include phase rates, cumulative production, pressures, tracers, temperatures, salinity, and more. Maximizing the alignment of model inputs with historical data contributes to a more effective reduction of ambiguity and a heightened confidence in the current reservoir characterization.[1]

History matching, a critical process in reservoir engineering and oil production, involves adjusting the parameters of a reservoir simulation model to align with observed field data, particularly oil production rates and well performance. The primary goal of history matching is to enhance the accuracy and reliability of the reservoir model, rendering it a valuable tool for reservoir management and production optimization.[6]

The alignment between the model predictions and actual production data achieved through history matching enhances the model's accuracy and reliability. It allows for more informed decision-making

in reservoir management, enabling the optimization of production strategies, the evaluation of reservoir performance, and the reduction of operational uncertainties. This successful history matching process stands as a testament to the refinement and validation of the reservoir model, elevating its utility in guiding effective and efficient reservoir management practices.[4]

The outcomes unmistakably demonstrate the successful achievement of this undertaking, with the model's projections closely aligning with the observed production data from the well. This noteworthy accomplishment in history matching, a pivotal phase in reservoir engineering, underscores the meticulous and accurate adjustments made to the reservoir model, ensuring its faithful representation of real-world conditions. Consequently, the refined model emerges as a highly valuable asset, empowering improved reservoir management and the optimization of production processes.[7]
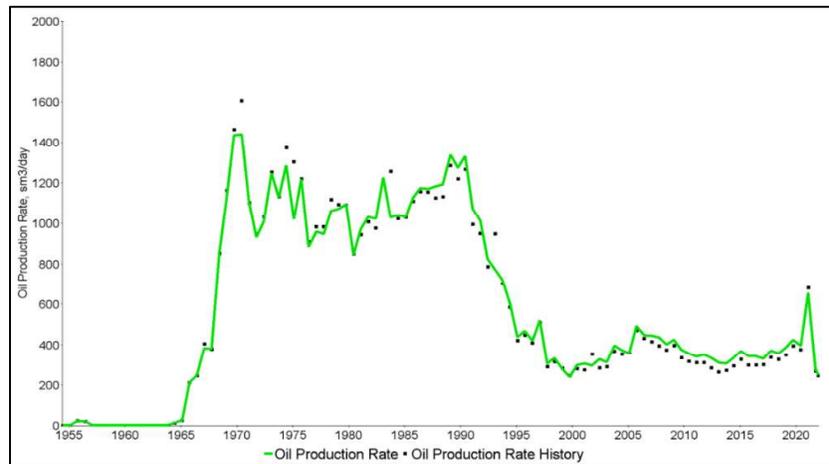

Figure 5. History matching results of field oil production rate

Figure 5 serves as a visual representation of the outcomes stemming from the effort to align the production rates in the oil field. In the subsequent stages of the process, particularly for predictive purposes, the crucial milestone of history matching must be achieved. This integral step involves ensuring that the reservoir model aligns closely with actual production data, faithfully reflecting real-world conditions. It is only through the successful attainment of history matching that the model evolves into a reliable tool for forecasting and optimizing production processes within the oil field.

The importance of history matching lies in its ability to enhance the accuracy and credibility of the reservoir model. When the model closely mirrors observed production data, it becomes a valuable asset for making informed decisions in reservoir management. This includes forecasting future production rates, optimizing recovery strategies, and minimizing uncertainties in the production processes.

The depiction in Figure 5 signifies the successful alignment of the reservoir model with actual production data, marking a significant step towards the model's reliability and its utility in guiding efficient and effective reservoir management practices.

In the subsequent stages of the process, particularly for predictive purposes, the critical achievement of history matching becomes imperative. This essential step involves ensuring that the reservoir model aligns closely with actual production data, establishing a faithful representation of real-world conditions. It is only through the successful attainment of history matching that the model becomes a reliable tool for forecasting and optimizing water field production processes.

History matching is pivotal for refining the accuracy and reliability of the reservoir model, allowing it to closely emulate observed production data. This alignment enhances the model's utility in making informed decisions for water field reservoir management, including the prediction of future

production rates, optimization of recovery strategies, and mitigation of uncertainties in production processes.

3. Conclusion
Here is a refined and structured presentation of the provided information:

3D Geological Modeling:

Utilizing the RMS software package from ROXAR, a comprehensive 3D geological model of the Mud Pilpilesi deposit was created.

The process commenced with the establishment of a field database, followed by the construction of a structural model encompassing the development horizons (QUG, QUQ, QD1, QD2, QD3, QD4, QD5, QA1, QA2, QA3, QaLD1, QaLD2, QaLD3, QaLD4).

Facies and petrophysical modeling were conducted, and the resulting model enabled the calculation of the initial balance hydrocarbon reserve for the field.

Grid Upscaling for Hydrodynamic Modeling:

The 3D geological grid underwent "upscaling" to align with the hydrodynamic grid, a crucial step for forecasting and applying various methods to restore history and enhance processing efficiency.

Sensitivity Analysis and Uncertainty Study:

To evaluate the impact of parameters on the calculation of the initial balance hydrocarbon reserve, a sensitivity analysis was performed.

The study also delved into the effect of uncertainties, providing insights into the robustness of the modeling results.

History Matching:

The history matching process involved:

Determining the optimal horizontal section for horizontal wells.

Finding the optimal gas-lift gas injection volumes.

Establishing gravel pack parameters.

Defining parameters for water quifer models.

This comprehensive workflow highlights the systematic approach taken in building, refining, and validating the 3D geological model of the Mud Pilpilesi deposit. The integration of sensitivity analysis and uncertainty studies enhances the reliability of the model, while history matching contributes to the optimization of production strategies and reservoir management.

Conflict of interest
The authors declare that they have no conflict of interest in relation to this research.

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