Unlocking Potential in Multilayered Heterogeneous Reservoirs in Poor Seismic Regions Through Integrated 3D Geo-Cellular Reservoir Modeling Approach

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Abstract

Poor seismic regions underneath a thick salt succession showed great challenges in subsurface description especially at offshore fields where investment budget is a challenge. Therefore, Integrated subsurface studies incorporating advanced static and dynamic reservoir modeling workflow have proved its great impact on investment decisions upon such uncertainties. Modeling intersected lobes of bars and channels, quality, and lateral and vertical connectivity are major uncertainties in heterogeneous multilayered Cretaceous Nezzazat group at Gulf of Suez. Such a heterogonous reservoir requires high-quality facies modeling to honor Gulf of Suez depositional environment for sand presence risk. This also involved petrophysical characterization of Nezzazat group into different hydraulic flow units honoring the lithostratigraphy of the basin, Mattula, Wata and Raha formations. Despite the short production history, the team set a proactive surveillance plan including several static reservoir pressures surveys, PBU tests, and Production logs. The Big Loop 3D reservoir simulation approach is applied to overcome geological, petrophysical, and reservoir engineering uncertainties.Dynamic data has been integrated with RFT data and HFUs permeability distribution scenarios in history matching.

Nezzazat Group showed high layer-by-layer permeability variations and consequently, its distribution was a key sensitivity parameter to estimate wells interference and incremental recoverable reserves for early, consolidated and economically viable development options. permeability distribution was controlled using conventional core data, PBU permeability estimation, and Nodal analysis.Observed different reservoir pressures at offset wells recorded at the same time indicated limited lateral connectivity and vertical heterogeneity; has been matched with distributed facies. Within Big Loop reservoir simulation several sensitivities have been run to cover the uncertainty range in fluid properties, aquifer strength, vertical heterogeneity, relative permeability, and absolute permeability distribution. This opened a window towards drilling more two new production wells to increase the ultimate recovery factor for the field with ± 6:7 % and one water injection well to increase the ultimate recovery factor by ± 3:4 %; with high certainty for the incremental recoverable reserves for each scenario. Therefore, the proposed methodology helps to evaluate multi-layered heterogeneous reservoirs helps to understand hydraulic flow units' architecture for better development plans and further secondary recovery proposals.

This paper will help most of the reservoir engineers and geoscientists working on heterogeneous multilayered reservoirs with a lack of data, especially at offshore fields. Integrated approach workflow will help in weighing uncertainties considering static and dynamic data to minimize required simulation runs. It will be helpful to understand complex heterogeneous reservoirs and consequently shows how much does this impact new well delivery decisions considering location and time plan.

3D geocellular static models are the key input for fluid flow simulations with the main aim to predict the future reservoir performance for a particular recovery scheme. Since the predictability of the dynamic model depends on the quality of the geocellular model, it is imperative that the input data, the modelling workflow, methodologies and approaches are verified and validated prior to the sanction of the geocellular model. The objective of this paper is therefore to discuss the process of performing quality assurance and quality control (QA/QC) of 3D geocellular models exhibiting real field examples from the Middle East carbonate reservoirs. 3D static models are built using data from multiple sources, at different scales and with different degrees of uncertainty. The validation and reconciliation of all the data is of paramount importance. The procedure to build any geological model is very similar provided all the data is available. Some variations in the procedure are expected depending on the complexity of the phenomena to model, but must of the time workflows divert based on data quality and data availability. In this paper we discuss the use of key validation checks for each step of the modelling process taking into account the data quality and field maturity, namely for the structural framework modelling, facies modelling, porosity modelling, permeability modelling, rock type modelling,water saturation modelling, upscaling and uncertainty analysis.

The use and validation of the applicability of secondary variables in the petrophysical modelling, such as acoustic impedance from seismic inversion, is also addressed. From the analysis of multiple geocellular models, inconsistencies were detected at different stages of the modelling process, starting from the well surveying with implications to horizontal well positioning within the framework, to the modelling of facies and petrophysical properties, with inconsistencies on variogram model parameters. Also, the validation of the velocity modelling and time-depth conversion used for the structural framework was validated by comparing FWLs depths against spill points.

Furthermore, the quality of the facies model could be verified against regional facies belt maps (similar variogram azimuths are expected) while the validation of the permeability scale-up at well level could be achieved by reconciling with well test kh data. These are just a few examples of the material discussed in this paper. The novelty of the quality assurance process pertained to 3D geological models is the identification of appropriate metrics with key performance indicators for each step in the modelling workflow. At the end of the QA/QC process the models are ranked in quality and technical gaps identified for subsequent model improvement. Guidelines and best practices are also presented in this paper.