High-Resolution Reservoir Characterization and Modeling of Deep Marrat Carbonate Reservoir in Minagish Field, West Kuwait*

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Abstract

The reservoir characterization of Marrat carbonates in the Mingaish field has been challenging due to high reservoir heterogeneity, poor seismic imaging, sparse well spacing and compartmentalization. KOC implemented a multidisciplinary field development study to address these challenges. Geostatisitical seismic inversion has been integrated in the multidisciplinary study. Compared with conventional deterministic inversion, geostatistical, or stochastic, inversion delivers multiple realizations of acoustic impedance correlated to porosity consistent with the available well and seismic data. The stochastic seismic inversion workflow applied in this study simulated 100 equi-probable, high resolution realizations of acoustic impedance. All these equi-probable realizations were used innovatively to generate multiple scenarios with 6%, 9% and 12% porosity cut-offs corresponding to P90, P50 and P10 volumetric cases. The powerful utilization of multiple stochastic inversion results highlighted a new technique in quantifying uncertainty of meeting or exceeding a given porosity to manage and mitigate risk.

Introduction

The Marrat formation in Minagish field is a deep, over-pressured, tight carbonate reservoir located in the southwestern part of Kuwait. The reservoir has produced light oil for over a quarter century. Twenty wells have been drilled so far but the field is still under active delineation. At Marrat level, the Minagish structure is a N-S elongated doubly plunging, asymmetrical anticline with gentle dips. Reservoir characterization has been challenging due to high reservoirs heterogeneity with low NTGs, sparse well spacing, poor seismic imaging and compartmentalization. This has made it difficult to predict reservoir facies away from the crestal well control areas. Since 2009, KOC has implemented a multidisciplinary field development study for mapping relatively thin stacked reservoir layers in high resolution to develop field using new / re-entry horizontal wells and multilaterals. The geophysical and petrophysical workflows for the static modeling phase of this study have been published and presented during the last three years in international forums. Present work focuses on advanced 3D geological modeling workflows involving high resolution core-calibrated petrophysical rock typing matched with stochastic seismic inversion based rock type "facies" away from the well control.

Geo-Statistical Seismic Modeling

The workflow of the geo-statistical seismic modeling of middle Marrat Carbonate reservoirs study involved both deterministic and stochastic seismic inversion workflows after advanced data conditioning.

Deterministic Inversion. Five selected wells were used in the deterministic inversion for wavelet estimation and low frequency model building. The acoustic impedance from the deterministic gave a good match with the acoustic impedance from the well logs. The deterministic inversion result was later used as the background model in the stochastic seismic inversion.

Stochastic Seismic Inversion (SSI). This part of the study deals with a novel geo-statistical seismic inversion algorithm to invert post-stack seismic amplitude cubes for acoustic impedance in a high-resolution 3D geological model framework. The algorithm is a geo-statistical simulation approach producing multiple high-resolution realizations of acoustic impedance that tie at the well control and are consistent with the seismic data. A prior model is used to constrain the vertical and lateral trends of acoustic impedance and a variogram model is used to constrain the patterns of spatial variability of the inverted acoustic impedance. A geological modeling grid is used as a framework, and the seismic is inverted directly into the grid in the stochastic seismic inversion workflow.

The model grid used in this study was constructed based on the already existing structural model. The model grid has 197 layers with an average thickness of 0.5 ms (6ft) resulting in 20 million cells. Before running the full inversion, production comprehensive testing was performed in order to obtain the best inversion parameters and ensure that the obtained results make geological sense. The stochastic seismic inversion simulated 100 equi-probable, high resolution realizations of acoustic impedance. Figure 1 shows three different realizations of acoustic impedance at the reservoir level while Figure 2 portrays the 3D perspective along with fence cross-sections and well data.

Two selected wells were not included in the inversion workflow as these were used for blind well tests. Figure 3 shows one blind well test for one realization of acoustic impedance. It should be noted that the well is deviated and no check shots were available for this well. However, the match at the blind well was considered good, demonstrating the robustness of the stochastic inversion results.

The 100 realizations of acoustic impedance were converted to porosity using a rock physics transform developed through rock physics analysis of the available well logs. The resulting 100 equi-probable, high resolution realizations of porosity was used as input to an uncertainty analysis workflow as described by Suleiman et al. (2012). In this workflow good quality reservoir probabilities can be estimated based on porosity cut-offs. Figure 4 shows the 10%, 50% and 90% probability of exceeding a porosity of 9 pu for a given layer in the geological model. The same workflow was applied for porosity cut-offs for 6 pu and 12 pu. The results have been used to characterize P10, P50 and P90 estimates of good reservoir quality, respectively.

Summary

Combination of post stack seismic conditioning and inversion allowed high-resolution reservoir characterization and delineation of Marrat Formation. The powerful utilization of multiple stochastic seismic inversion results showcased a new technique in quantifying uncertainty of meeting or exceeding a given porosity to manage and mitigate the risk in development of this heterogeneous, low net-to-gross, low porosity carbonate reservoir development. The seismically driven and calibrated porosity with well data were used as input in property mapping within the framework of the structural model. In turn, static model successfully provided inputs for the construction of a high-resolution full-field reservoir simulation model, with no upscaling, to finalize the development plans, which are expected to double the reservoir recovery.

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Reference Cited

Suleiman, A., I. Fahmy, and M. Ahmed, 2012, Run Stochastic Seismic Inversions & Then What?: EAGE Workshop on Applications & Challenges of Rock Physics for Quantitative Geophysical Interpretation held in Dubai, United Arab Emirate, Jan. 15-18, 2012.

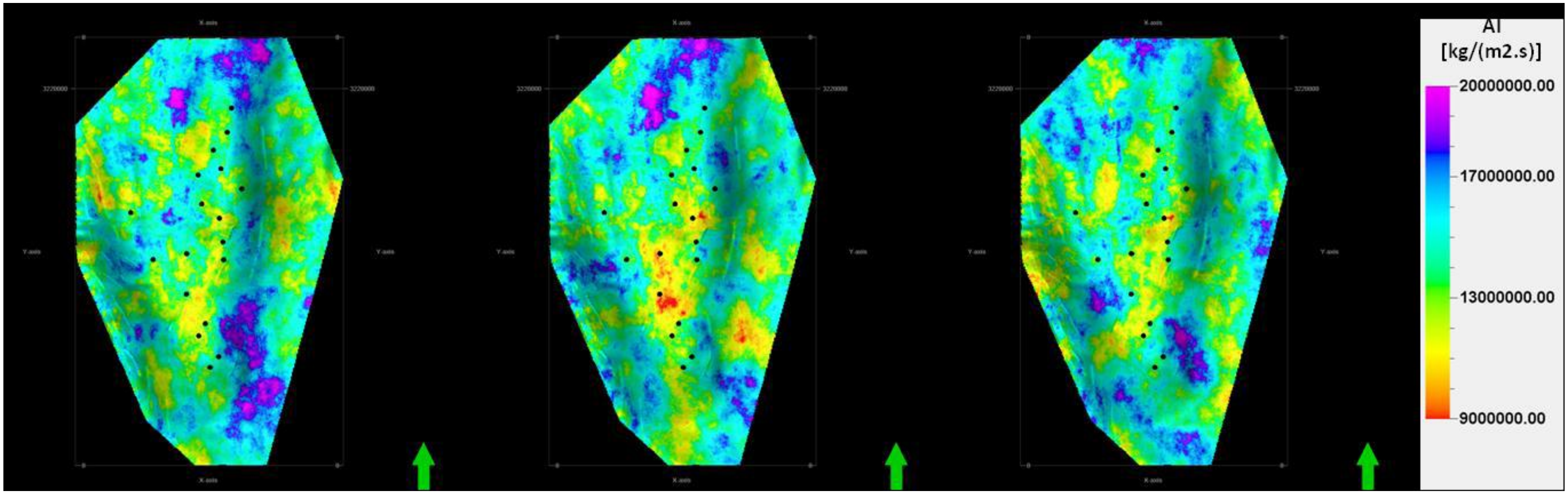

Figure 1. Three of the 100 high-resolution realizations of AI output from Stochastic Seismic Inversion.

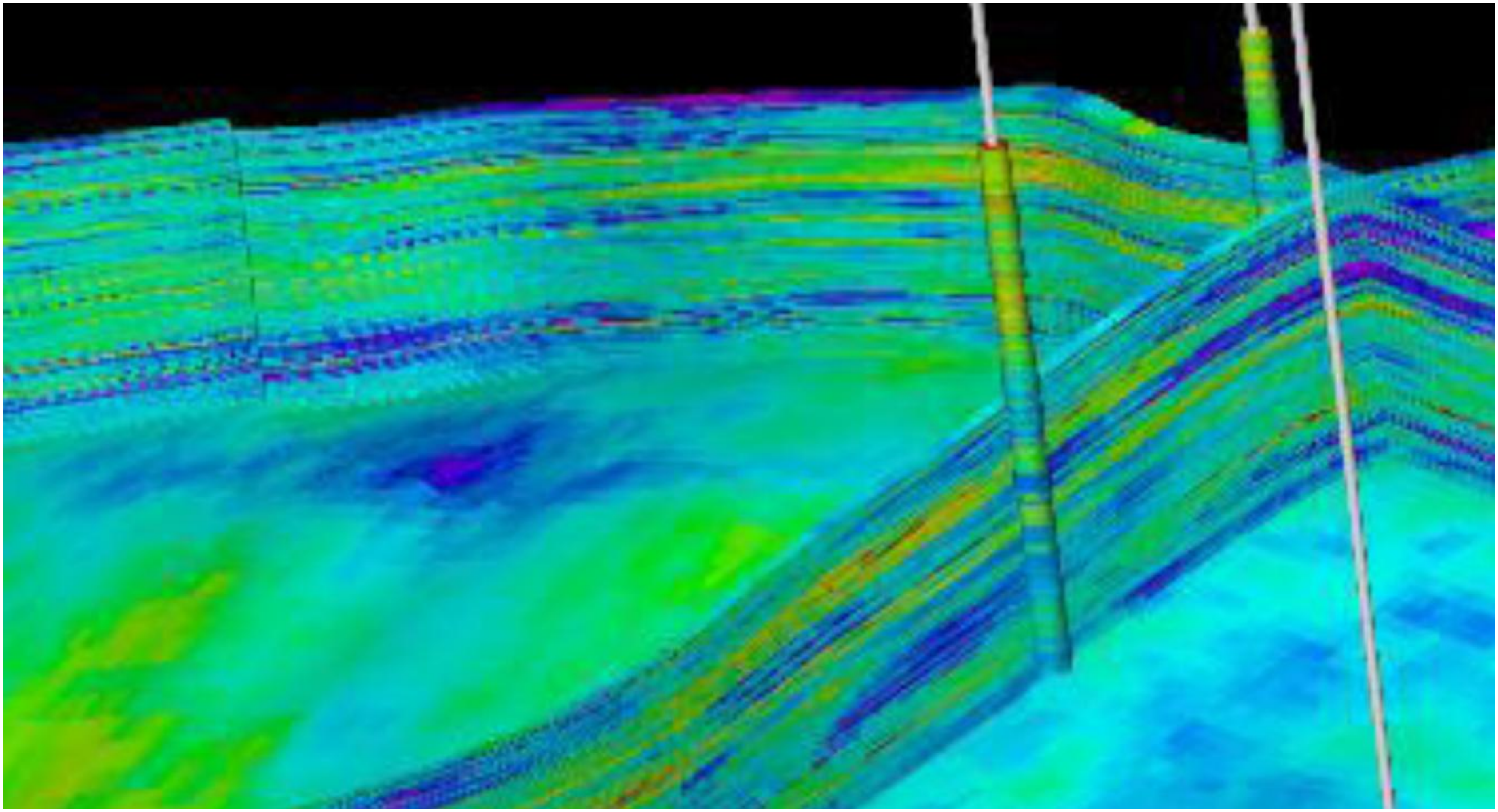

Figure 2. 3D Geomodel view of one the 100 high-resolution realizations of AI showing wells and cross-sections across main reservoir interval.

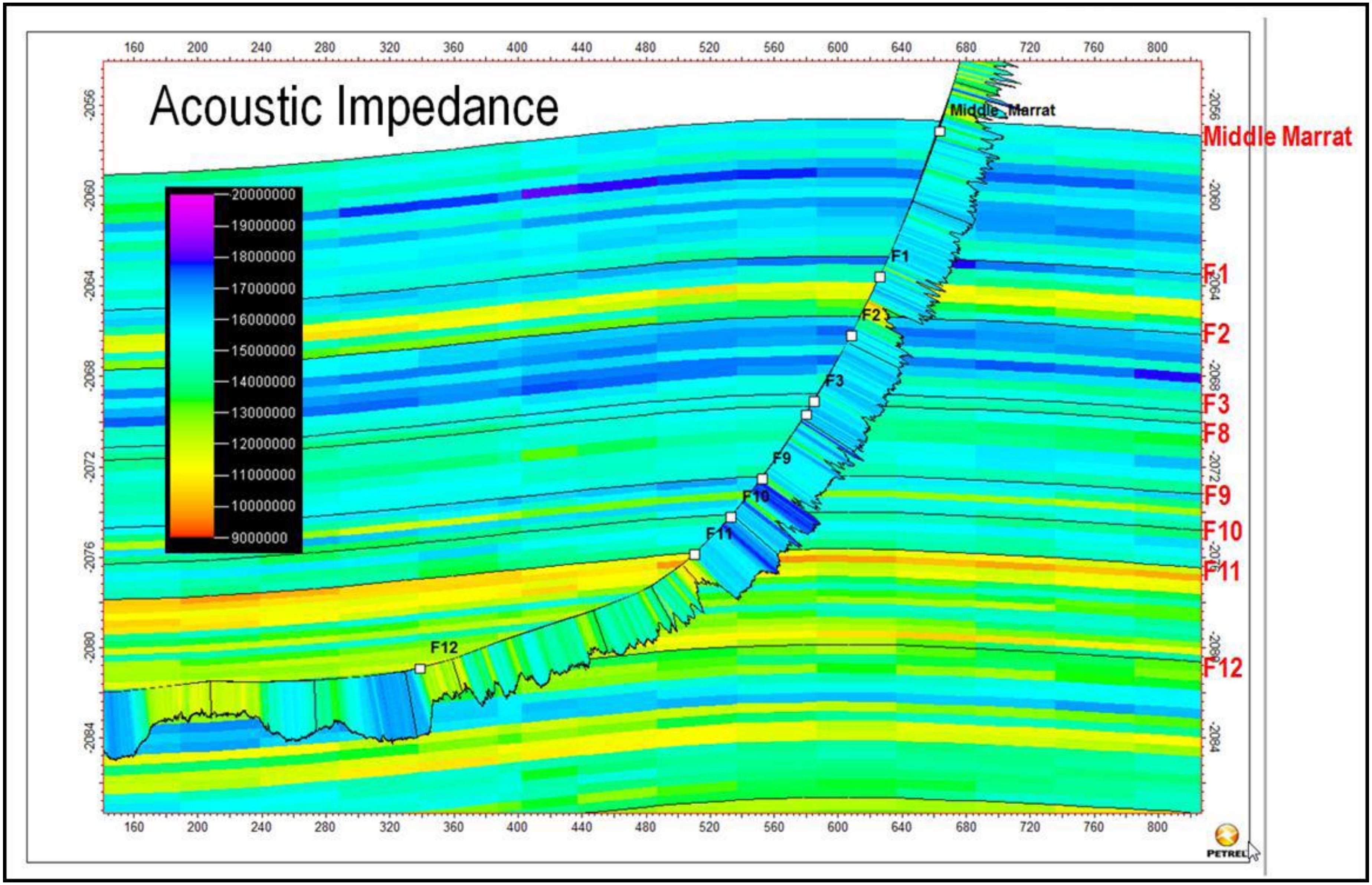

Figure 3. Blind Well Test – Comparison between AI from one realization and AI well log.

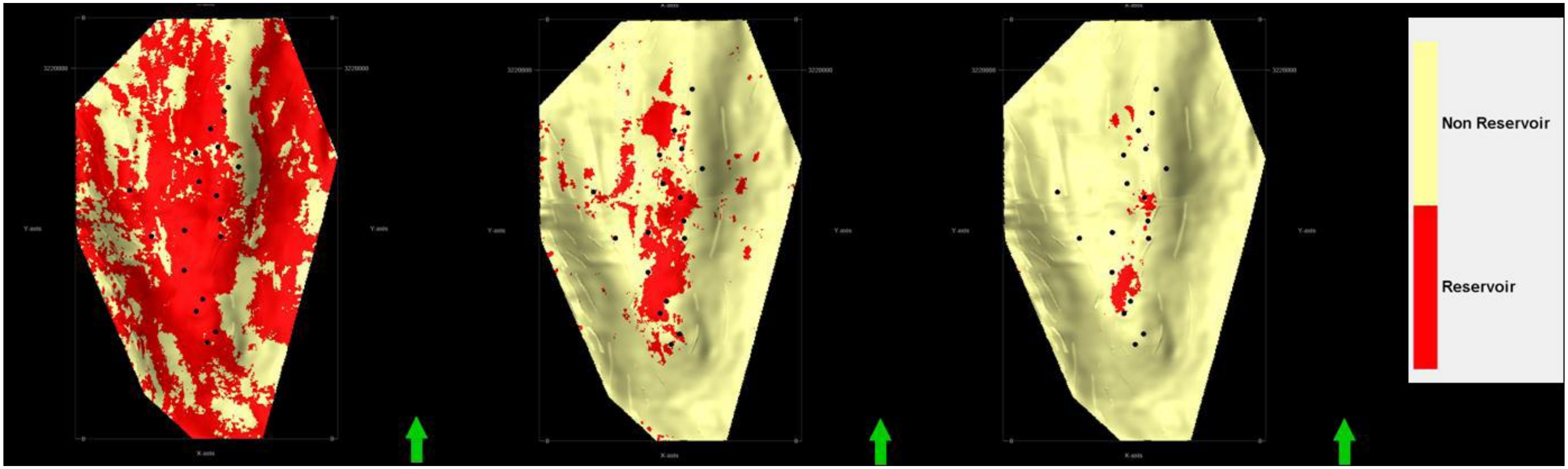

Figure 4. 10%, 50% and 90% probability of exceeding porosity cutoff of 9 pu for a given layer in the geological model.