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A Workflow to Quantify and Model Structural Uncertainty: Application to a Deepwater Giant Reservoir, Offshore Mozambique

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SUMMARY

The uncertainties related to structural seismic interpretation and velocity modeling can have a significant impact on gas in place evaluation. The risks and high investments associated with appraising and developing a deep-water reservoir make reliable quantification of these uncertainties a fundamental step of the risk analysis and ultimately the decision making. These considerations are a key driver for the development plan of the deepwater Mamba Complex, a super giant gas field discovery in offshore northern Mozambique. The magnitude of the discovery and the rapid development planning introduce a series of technical challenges, including the evaluation and quantification of the structural uncertainty, and its integration in the reservoir model.

This paper proposes a workflow that effectively integrates probabilistic and scenario-based approaches, aiming to mitigate the risk associated with the development of the Mamba complex, and to help the decision maker.

Introduction

It is widely acknowledged that the uncertainties related to structural seismic interpretation and velocity modeling can have a significant impact on gas in place evaluation (e.g. Singh et al. 2009, Thore et al. 2002). The risks and high investments associated with appraising and developing a deep-water reservoir make reliable quantification of these uncertainties a fundamental step of the risk analysis and ultimately the decision making (Charles et al. 2001). These considerations are a key driver for the development plan of the deepwater Mamba Complex, a super giant gas field discovery in offshore northern Mozambique. The magnitude of the discovery and the rapid development planning introduce a series of technical challenges, including the quantification and modeling of the structural uncertainty: this paper proposes a workflow and its application to three stacked reservoir units of the Mamba Complex.

Method and Application

The set of top and base horizons of each reservoir, interpreted on the reference seismic volume and tied at well locations, were firstly depth-converted using the available anisotropic PSDM velocity volume, and depth residuals calibrated at well locations. Statistical check of clustering and trend patterns in the data, and cross-correlation analysis were then performed on the residuals (Goovaert 1997). Standard deviation of the residuals, variogram parameters and well influence radii were determined for each of the six key horizons, and used to generate 500 alternative realizations through Sequential Gaussian simulation (Deutsch and Journel 1992), conditioned to well locations. The uncertainty modeling included the variation of both top and thickness of each reservoir level, to account for the lack of correlation of the depth residuals with depth (Vincent et al. 1999, Samson et al. 1996).

The large size of the reservoir and the consequent running time for dynamic simulations imposed the selection of a limited number of structural scenarios. However, the standard scenario selection of P10, P50 and P90 on the cumulative distribution function (cdf) of Gross Rock Volume (GRV) was considered inadequate to properly capture the structural spatial variability in the Mamba field. Instead, the variance map of the 500 realizations was calculated for each reservoir. These maps clearly show the areas where structural uncertainty is comparatively higher, which were delimited by boundary polygons to be used for volumetric calculations. The GRV cdfs, calculated within each of these areas ("local cdfs"), were then plotted against the GRV cdf of the entire reservoir ("global cdf"), and a number of scenarios were chosen, each characterized by a specified probability of occurrence (global cdf) and different spatial allocations of the volume (local cdfs).

For each selected structural scenario, the time-depth pairs of top and base maps were used to construct a multi-layer velocity model, which was used to depth-stretch the 3D geo-cellular grid and the seismic volumes to be used for reservoir characterization.

A different seismic horizon interpretation performed on an alternative seismic volume was integrated in the reservoir model by designing the 3D geo-cellular grid top and base such that it enveloped both sets of interpretations. It was then possible to easily select the two interpretation scenarios by activating grid cells accordingly.

The risk of finding at any development well location a gross thickness above the contact lower than a specified minimum threshold based on the expected well deliverability was also investigated, by the construction of a probability map. Two steps were performed to define this map: first, the 500 realizations of top and base of each reservoir were transformed in binary maps (one in case of thickness lower than the threshold, zero for the contrary); second, a probability map was calculated by simply averaging the 500 binary maps. This approach allowed a quick evaluation of the notional well locations, before performing the final optimization with a full dynamic risk analysis.

The entire workflow is illustrated in *Figure 1*.

Figure 1 Flow-chart of the study's workflow. Dashed boxes indicate steps not covered by this paper.

Conclusions

The significant impact of the structural uncertainties on the volume in place estimations, the dimension of the giant Mamba Complex and the related challenges for reservoir modeling and dynamic simulations, make necessary the implementation of a workflow for uncertainty evaluation and modeling that effectively integrates probabilistic and scenario-based approaches.

The proposed workflow aims to mitigate the risk associated with the development of the Mamba complex, and to help the decision maker.

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