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Integration of Process-Based Modeling: A Paradigm Shift from Geostatistics to Simulation of Geological Systems

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Abstract

Geostatistical approaches have long been the cornerstone of geological modeling, but they bear major uncertainties in capturing the complex dynamics of geological systems. These models do not account for dynamic geological processes such as deposition, diagenesis, and geomechanics, which play a crucial role in shaping the subsurface. Process-based modeling, on the other hand, typically simulates these individual processes independently of each other, due to the different physics and complexities that each process entails. However, this approach leads to a fragmented understanding of the subsurface, as each process is modeled in isolation without considering the interactions and feedbacks between them. Here, we bridge this gap by integrating process-based modeling, allowing for a more holistic and comprehensive understanding of the subsurface.

Our approach utilizes well and seismic data to constrain key boundary conditions for a robust modeling framework. Key boundary conditions include high-resolution chemostratigraphic correlation, reconstruction of depositional bathymetry and analysis of sediment pathways. The integrated modeling process entails forward stratigraphic, diagenetic and geomechanical modeling, with a feedback loop between deposition and diagenesis. Forward stratigraphic modeling simulates deposition, stratigraphic architecture and internal heterogeneities (facies, petrophysical parameters). Forward diagenetic modeling then simulates the chemical and physical alterations during subsequent burial, such as compaction, cementation, and dissolution. Moreover, forward geomechanical modeling simulates the mechanical behavior of the rocks, including deformation, faulting, and fracturing. This approach covers complex interplays between these geological processes to optimize the generation of predictive models. Finally, Seismic calibration is used as a tool for validation, ensuring that the models are consistent with field seismic data and ultimately, minimizing uncertainty in interpretation.

In this presentation, we will share successful case studies demonstrating the ability of process-based modeling workflow to generate low-uncertainty and optimized models of complex reservoirs and geological formations. We will also discuss the benefits and limitations of this approach, and provide insights into possible applications and future developments, highlighting its potential to become a game-changer in the field of geological modeling.