AAPG
3rd Edition
AAPG Decision Based Integrated Reservoir Modeling GTW
24-26 November 2025 | Al-Khobar, Saudi Arabia

3D Reservoir Modeling: Advances, Developments and Ongoing Challenges

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Abstract

Quantitative reservoir modeling has shown significant development due to the full integration of different disciplines, supported by advances in characterization, descriptive geology, rock physics, seismic interpretation, inversion, dynamic simulation, and the gradual use of artificial intelligence and deep learning. Indeed, a huge ensemble of data types collected since the 1930s constitutes a robust source of application for data mining, which opens a large room for improvement in prediction and, moreover, automation.

Historically, geostatistical modeling, supported by geocellular grid-cell design, has struggled to solve complex geometries. However, gridless or unstructured grid modeling has enhanced the results, and point-based modeling accommodates and preserves prior data, mitigating scaling effects.

On the other hand, discrete property modeling, such as depositional environments (facies), is supported by pixel or object-based approaches and is heavily influenced by conceptual models and cognitive geology. A second approach to high-resolution facies simulation through time and space is stratigraphic process-based forward modeling. Indeed, the application enhances the comprehension of depositional environment distribution, guiding 3D petrophysical modeling.

In all cases, the use of 3D seismic attributes (deterministic, stochastic) to improve the prediction and accuracy of lateral distribution in reservoir simulation and hydrocarbon estimation is crucial.

The integration of multi-data sources for modeling classically uses conditional simulation with non-stationary algorithms based on spatial statistical interpolation methods. The main challenge is the hybrid approach, which is data-driven, using both 'Machine Learning' (ML) and 'Geostatistics' to improve prediction quality and performance through non-parametric multi-regressions and embedded algorithms.

Data-driven characterization from 1D (well level) and 2D (trends) are inputs for spatial distribution and prediction, along with their associated uncertainties. The use of deep learning methods to capture and map inter-well lateral heterogeneities in 3D dimension is a significant step-change in exploring the frontiers of spatial distribution. The challenge is to produce the best-in-class prediction scenarios to image reservoir connectivity. Indeed, seismic quality (from acquisition to processing) is key to enhancing ‘engineering surrogate 3D modeling' history matching (physics and thermodynamics) and predictions.