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

Next-Gen Geological Modeling Driven by Machine Learning

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Abstract

This paper introduces Next-Gen Geological Modeling, a knowledge-driven machine learning solution designed to enhance the geological modeling process. The objective is to demonstrate how integrating geological understanding with advanced machine learning techniques can support more efficient and geologically consistent subsurface interpretation, reservoir characterization, and property modeling. The focus is on guided machine learning, not replacing geoscientists, but empowering them through intelligent automation.

The Next-Gen Geological Modeling workflow is structured into three major components, each leveraging machine learning while being anchored in geological knowledge.

The first stage focuses on seismic interpretation using convolutional neural networks. Manually interpreted seismic lines serve as training data, allowing the model to detect and predict horizons that form the structural framework.

The second stage applies AutoML techniques for reservoir characterization. Elastic and petrophysical well logs, along with synthetic AVO attributes, are used to train models that generate property volumes from angle stacks.

The final stage involves property modeling using EMBER, a unique algorithm that blends the predictive capabilities of random forests with the spatial continuity of kriging. EMBER ensures that the modeled properties honor geological trends and maintain realism.

Applying machine learning across the entire modeling process led to a 75% reduction in total time compared to conventional manual workflows. However, the benefits go beyond time savings. The machine learning outputs were benchmarked against traditional expert-driven models and showed strong consistency in structural interpretation, facies architecture, and property distributions.

The seismic interpretation using CNNs delivered continuous and geologically sound horizons. AutoML-based reservoir characterization effectively captured heterogeneities with minimal manual input. EMBER successfully propagated petrophysical properties consistent with well data and depositional patterns. By embedding geological knowledge into each step, Next-Gen Geological Modeling produced models that are not only computationally efficient but also geologically robust and interpretable. These results demonstrate the value of guided machine learning in delivering faster, more reliable, and more scalable geological models.

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This paper presents a complete machine learning framework that uniquely integrates geoscientific knowledge throughout the geological modeling workflow. Unlike traditional black-box approaches, Next-Gen Geological Modeling emphasizes transparency and geological control, offering a practical and scalable methodology that improves modeling efficiency and consistency.