Integrating Petrophysics, Seismic Attributes, and Machine Learning for Shale Facies Identification and Prediction

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Abstract

3D seismic is routinely used to interpret depositional geomorphologies to develop an understanding of basin evolution and facies distributions within sedimentary basins. Advances in technical computing, and the recent in-house development of user-guided machine-learning program allows interpreters to scan and classify nearly 300 textural attributes in 3D seismic. With appropriate training, the program can improve interpretability by revealing 3D seismic attribute trends that have geologic significance (e.g. reservoir/non-reservoir facies, seismic morphologies indicative of channels, sediment waves, etc.). We were able to identify diverse shale types in 3D seismic, and the results are being used to update or better inform basin models, earth models, and hydrocarbon seal analyses. Six wells used in this study showed significant shale property scatter (e.g. variations in bulk properties, clay mineralogy, and resistivity anisotropy) between bounds that encompass most of the data, indicating shale property diversity within and between the wells not accounted for by normal compaction. Regional compaction trends created from the bounds characterized endpoint shale types (referred to as “Hard” and “Soft”) and were used in a compositional analysis for volume fractions of brine, hydrocarbon, sand and the two shale types. The ratio of soft to total shale was transformed to a “shale softness index” (S) and each depth frame classified as Hard (S0.75). Each shale class corresponds to a limited range of bulk, elastic, mineralogic, and textural properties.Three shale and one sand classification were used to train a Random Forest classifier. Results

indicate that 80% of the 3D predictions are correct at well locations (based on a 5-fold cross validation). In a nearby channelized system, results clearly separate channel from levee deposits. Observations showed hard shales associated with sands within the channel system, intermediate density shales on the adjacent levee and distal to the channel, and soft shales distal to the channel. The significance of this distribution may be related to either compaction, diagenesis, depositional environment, or a combination of each. This study highlights the value of integrating machine learning techniques with traditional interpretive methods to improve subsurface understanding and illustrates how the digital transformation occurring in our industry can lead to future opportunities.

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