Integrating Seismic Stratigraphy and Forward Stratigraphic Modeling for Prediction of Source Rocks and Tight Carbonate Facies: A Case Study from the Callovian-Oxfordian of the Eastern Saudi Arabia

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ABSTRACT

The Jurassic Callovian-Oxfordian Tuwaiq Mountain and Hanifa formations contain world-class hydrocarbon source rocks and carbonate reservoir rocks in Saudi Arabia. A regional stratigraphic framework of these formations has been constructed by integrating well logs, the sedimentology of core/drill cuttings, well-log electrofacies, and 3-D seismic interpretations. Seismic sequence stratigraphic analysis and forward stratigraphic modeling played an important role in further constraining this integrated sequence stratigraphic model.

The workflow for seismic sequence stratigraphic analysis includes 3-D seismic data interpretations, conditioning and filtering 3-D seismic volumes, interactive interrogating seismicfacies and calibrating well-log electrofacies and core data, and transforming the chronostratigraphic seismic events into the Wheeler domain for sequence stratigraphic interpretations. The forward stratigraphic model was built by inputting interpreted key structural depth grids, gross depositional environment (GDE) maps, lithofacies, well log data of selected key wells, and paleoenvironmental parameters such as paleobathymetry, subsidence/sedimentary supplies, and environmental considerations (e.g. wind directions and water depth). The results from this integrated approach revealed great details regarding hiatuses, maximum flooding surfaces, and spatial distribution of source rocks, reservoirs, and seals through time. In particular, the forward stratigraphic modeling results have provided additional insights for prediction of grainstone shoaling complexes, and source rock deposition and distribution within the Tuwaiq Mountain and Hanifa sequences.

The integrated model highlighted the areas where carbonate muds accumulated in protected low-energy settings such as lagoon, distal (off shelf-margin), and the deeper water settings. The relatively shallower water on the carbonate outer ramp is characterized by source rocks that are generally thin due to deposition in shallow fluctuating environments, except where subsidence rates are sufficient to limit exposure and maintain water depths. This sequence stratigraphic model has highlighted a variety of potential exploration concepts that include stratigraphic traps and unconventional resources in the Jurassic Callovian-Oxfordian Tuwaiq Mountain and Hanifa formations.