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3D Forward Stratigraphic Modeling in Reservoir Quality Prediction – Arab-D Reservoir, Ghawar Field, Saudi Arabia

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ABSTRACT

Carbonate reservoirs are characterized by significant heterogeneity at the regional to inter-well scale. Reservoir quality predictions (RQP) based on geostatistical and object-based modeling approaches, contain additional uncertainties in carbonates compared to siliciclastic reservoirs. Process-based, forward stratigraphic modeling (FSM) offers high potential for improved RQP with reduced risk in exploration and improved recovery in production. FSM tools and workflows have been used for RQP in the Arab-D reservoir (Lower Jurassic) in the Ghawar field. Data quality and coverage are exceptional with wells spaced at short distances. While effective porosities and permeabilities are generally high, marked lateral and vertical heterogeneities occur in this homoclinal carbonate ramp setting. They are related both to depositional facies and diagenetic overprint, e.g., dolomitization.

FSM for RQP in the Arab-D has been performed at a regional scale (max. 270x180 km, min. cell size 1000 m, min. time step 5 ka). Models are calibrated to 11 key wells and detailed depth/thickness grids from several hundred wells. The model has been tested by comparing virtual wells generated from the FSM to real-world wells not included in the input database. Both Navier-Stokes/Lagrangian and diffusion-based approaches have been applied.

Over reservoir thicknesses of 1-3 m, FSM correctly predicts (textural) porosities with errors of ±3 pu. Modelled depositional facies, e.g., skeletal-oolitic grainstone/rudstones and stromatoporoid packstone/grainstone/boundstones with high porosities, closely match core and log data. Vertical stacking patterns, e.g., parasequence sets and high- frequency sequences at the scale of 5-10 m resolution, are predicted according to the actual subsurface data. In shallow subtidal to peritidal reservoir-prone settings, thickness uncertainties range between ±4 and ±10%. In more open marine settings (outer ramp to basin), uncertainties are higher and may reach up to ±28%. Input data and processes in these settings still require optimization.
Current FSM studies focus on the field to inter-well scale, based on a rigorous sequence stratigraphic framework.

They reach the resolution of individual flow units (parasequences, shallowing/deepening-upward cycles). FSM may be coupled with other modeling approaches, e.g., reactive transport modeling for diagenesis and surfaced-based modeling for fluid flow.