Hierarchical Reservoir Modeling Using Process-Based Models as Digital Analogs

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Reservoirs often contain multi-scale heterogeneities that result from the hierarchical nature of sedimentary deposition. For example, shale drapes are often present at parasequence scale and bed set scale, acting as multi-scale flow barriers. Understanding the characteristics of these multi-scale heterogeneities and capturing their distribution appropriately in reservoir models is essential for better reservoir performance prediction. However, understanding the characteristics of multi-scale heterogeneities is difficult in practice because of the limited 3D quantitative data available from outcrops and natural analogs. In this work, we used process-based models as reservoir analogs. These models simulate the fundamental geologic processes and produce realistic 3D numerical representation of the reservoir architecture. Therefore, the results are ideal for collecting quantitative information that is linked to the hierarchy of deposition.

Using the results of process-based models, we have developed a workflow for hierarchic modeling of deep-water distributary systems. In this workflow, the first step is to generate a process-based “analog” model. The second step is to perform stratigraphic hierarchy interpretation. The interpretation results are then analyzed to derive depositional rules and statistics of geometries and stacking patterns at different hierarchical levels. In the last step, we use the results of this analysis and object-based modeling techniques to sequentially simulate depositional bodies that are bounded by surfaces. We start by modeling higher level, larger hierarchic features and then use them to constrain the distribution of lower level, smaller hierarchical features. As shale drapes are often associated with the hierarchical surfaces, the drapes can be placed along them using rules to serve as flow barriers or baffles. The final model results preserve the stacking patterns observed from the process-based model and capture the multi-scale heterogeneities that are controlled by the hierarchy and distribution of shales.