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Modeling Deep-Water Lobe Systems Using Process-Derived Concepts and NURBS Surfaces

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ABSTRACT

Deep-water turbidite lobe complexes form many important hydrocarbon reservoirs and contain hierarchically arranged thin and laterally extensive sandstone beds, often separated by fine-grained sediments such as hemipelagites. Geological modeling of turbidite lobe complexes is challenging: the thickness of individual lobes or lobe complexes are often below seismic resolution; well data may be sparse; and during initial field development no dynamic flow data exist that could used to constrain reservoir geometries. Numerous outcrop and subsurface studies have shown the complex architecture of deepwater lobe complexes arising from the simultaneous interaction of multiple depositional processes that control the distribution of key heterogeneities. However, conventional geostatistical methods such as object-based or pixel-based methods do not reproduce complex spatial structures or honour sedimentological concepts. As a result key reservoir architecture impacting fluid flow is often not captured in resulting models. A numerical algorithm for modeling deep-water lobe complexes integrating simple sedimentological concepts such as compensational stacking using a small number of input parameters is presented. The resulting models contain a framework of hierarchically arranged parametric surfaces represented using Non-uniform rational basis splines (NURBS). NURBS surfaces efficiently represent complex geometries using a small number of control points, allowing multiple lengthscales of heterogeneity to be represented because no predefined mesh is present during the geological modeling stage. Data from a Paleocene deep-water reservoir provides a context in which to validate the numerical algorithm. The reservoir comprises three sand-rich stacked, laterally extensive turbidite lobe complexes each separated by hemipelagic shales. The algorithm is used to simulate NURBS surfaces representing genetically related lobes and distributary channels within each turbidite lobe complex. The model is then discretized for flow simulation using a fully unstructured mesh to preserve the geometries of the NURBS surfaces. Resulting flow simulation results demonstrate the importance of capturing stacking patterns of turbidite lobes, as the juxtaposition of fine-grained lateral fringe facies and coarse-grained lobe-axis facies creates barriers or baffles to flow that may significantly impact hydrocarbon recovery.