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My Geology is Too Complex for My Grid: Grid-Free Geological Modeling Using NURBS Surfaces

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ABSTRACT

Building spatially realistic representations of geologic heterogeneity in reservoir models is a challenging task that is limited by the inflexibility of predefined pillar or cornerpoint grids. Rock types with diverse petrophysical characteristics are ‘averaged’ within grid cells of arbitrary size and shape, and the continuity and connectivity of baffles, barriers or high-permeability zones is often lost. Because the same areal grid resolution is needed everywhere in the model, large features are over-resolved and small features are under-resolved or omitted. Moreover, common structural configurations including intersecting faults or overhanging horizons cannot be represented on pillar grids, and inclined surfaces need to be stair-stepped. We present a surface-based modelling workflow using grid-free surfaces that allows efficient creation of geologic models without the limitations of predefined grids. Surface-based reservoir modelling uses a boundary representation approach. All heterogeneity of interest (structural, stratigraphic, sedimentologic, diagenetic) is modelled by its bounding surfaces, independent of any grid. Smooth surfaces are modelled across scales using a parametric NURBS description. These surfaces are efficient to generate and manipulate, and allow fast creation of multiple realizations of geometrically realistic reservoir models that contain detail at appropriate scales. Surfaces are explicitly constructed by (1) extruding a cross section along a plan-view trajectory, or (2) using geostatistical models. Both approaches seamlessly integrate with commonly available information such as geologic descriptions from cross sections and map views in outcrop or seismic data, or sill, range and anisotropy of variogram models. We demonstrate this NURBS surface-based approach using a coastal-plain and overlying wave-dominated shoreface succession, analogous to an upper Brent Group reservoir, North Sea (e.g. SPE10 benchmark reservoir model). Geometric data from literature, such as clinoform orientation, dip and length, clinothem facies proportions, cementation distribution and channelised sandbody depth, width and sinuosity, is sampled stochastically to generate surfaces. These surfaces are then combined into a reservoir model that preserves realistic geometries. The resulting models can be used directly for flow simulation on adaptive tetrahedral grids that preserve input geometry without the need for upscaling.