Strategies for Modeling Depositional Heterogeneity of Carbonate Ramps Using Outcrop Analogs and Multiple Point Statistics

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Outcrop exposures offer continuity, correlation, and resolution of geological data well beyond that of the subsurface, and serve as ‘idealized’ analogs for reservoirs. In this study, measured sections, photomosaic mapping, DGPS, and LIDAR data were collected along a 38 km dip exposure of Lower Jurassic carbonate ramp strata in the High Atlas of Morocco, and converted into a static model using multiple point statistics (MPS). The goal was to generate new modeling strategies through simulation of ramp depositional heterogeneity during both transgressive (TST) and highstand (HST) conditions, and for each of the facies belts observed (inner, middle, outer, and basinal ramp settings).

The MPS approach uses combinations of hard data constraints (i.e. well data) and soft geologic concepts (i.e. depositional models) to populate 3D grid space. Outcrop LIDAR and GPS data were integral for the model stratigraphic framework and representation of complex stratal patterns. Soft constraints entailed Training Images and a Facies Probability Cube, which together capture juxtaposition relationships and spatial proportions and likelihoods of the facies belts while honoring the hard measured section and traced outcrop surface data. Using this approach, ramp depositional heterogeneity was successfully simulated within the sequence stratigraphic architecture, including stratigraphic partitioning of facies belts, ramp progradation and retrogradation, and changes in facies belt width.

This outcrop-based modeling effort provides strategies that can be incorporated into subsurface modeling workflows. For example, only two systems tract-specific (TST and HST) Training Images were required to capture stratigraphic facies belt partitioning. This enabled simulation of muddier, peloid-dominated settings in the TST and grainier, ooid-dominated settings in the HST for all mapped sequences. Another learning involved high degrees of facies belt interfingerizing in the Training Images to replicate facies belt contraction, expansion, and migration while preserving juxtaposition rules. This study also addresses the effects of 1) data configuration (i.e. well spacing), 2) facies delineation schemes (i.e. rock types versus cycle types), and 3) modeling targets on the preservation of geological heterogeneity that impacts subsurface flow and reservoir quality distribution.
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