Scale Dependent Variations in Fracture Network Properties and Implications for Reservoir Characterization: A Fractured Carbonate Analog Study, Northwest Montana.

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Abstract

Fractured carbonate multilayers pose significant challenges to effective reservoir characterization and production, particularly in zones of structural complexity. The geometric properties of connected fracture networks may significantly impact fluid flow pathways in the subsurface, but can be difficult to predict in these settings, given the limitations on availability or resolution of subsurface data. Excellent exposure of fractured Mississippian carbonates at Swift Anticline, a reservoir-scale structure, in NW Montana make this site a suitable analogue to multi-layer carbonate reservoirs in contractional settings. Field-based measurements, 3D photogrammetric reconstruction techniques and interpretation of aerial imagery provide a detailed multi-scale assessment of the variable controls on fracture intensity and orientations. Fracture orientations at the site are complex and variable, with six discrete fracture sets identified. Only two sets, oriented approximately parallel and perpendicular to the axial trace of the anticline, show evidence of a systematic increase in intensity with proximity to the fold hinge. We find that structural control on fracture intensity is subordinate to lithological control in that grainstone and packstone lithologies exhibit lower fracture intensities than fine-grained, mud-supported units in multiple structural positions across the anticline. Comparison of different observation scales and resolutions suggests that large-scale, low resolution data provide a better representation of

structural controls on fracture occurrence, while small-scale, high-resolution data highlight the influence of lithology. Based on these results, we suggest that reservoir modelling strategies should focus on both downscaling from lower-resolution data and upscaling from isolated, high-resolution sample sites. This multi-scale approach will likely represent the most effective method for characterizing fractured carbonate reservoirs and predicting permeability pathways in structures of this type.