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Jeffrey Chapin1, Kurt Sternlof1, David Pollard1, Louis Durlofsky2 (1) Stanford University, Stanford, CA
(2) Department of Petroleum Engineering, Stanford, CA

Permeability Effects of Systematic Deformation Band Arrays in Sandstone

Effective permeability tensors for sandstones containing deformation bands (DBs) can be calculated using analytical techniques combined with finite difference and finite element numerical methods based on homogenization theory. Our approach allows for the discrete and realistic representation of any characteristic DB array, and provides a rigorous means of upscaling permeability effects to the reservoir and aquifer scale. A range of scalable bulk permeability tensors can be calculated for any given repetitive pattern of DBs as a function of band spacing, thickness and permeability relative to matrix.

We apply this integrated technique to characteristic DB patterns exposed in the Aztec Sandstone of the Valley of Fire State Park, Nevada. This Early Jurassic aeolian sandstone is considered a stratigraphic/depositional equivalent to the widespread Navajo Sandstone, and provides an excellent exhumed analog for many subsurface reservoirs and aquifers. The characteristic DB patterns exposed occur on length scales from 1 to 100+ meters, with band thicknesses from 1 to 15 millimeters and band spacings from 1mm to 2 m.

Our results show that such DB patterns can reduce effective bulk permeability by more than 2 orders of magnitude, while introducing an equivalent permeability anisotropy. The scale of these permeability effects are similar to those induced by shale lenses within sandstone, suggesting that the aggregate influence of DBs can equal that imposed by large-scale depositional heterogeneities. Thus, we suggest that understanding the nature, distribution and permeability effects of characteristic DB patterns is vital to optimizing resource recovery in sandstone reservoirs and aquifers.