

Formation and Extension of Localized Compaction in Porous Sandstones

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Narrow, roughly planar zones of localized porosity loss have been observed in porous sandstones both in the field and in the laboratory. In the laboratory the bands form perpendicular to the maximum compressive stress and are inferred to do so in the field. Although this mode of localization has been recognized only recently in porous rocks, it is common in a variety of other porous materials, e.g., cellular solids and metal foams. The significance of these compaction bands in sandstones is that both laboratory and field studies have shown that bands reduce the permeability by one to several orders of magnitude, and they form barriers to fluid flow. Consequently, their presence in subsurface formations would affect applications involving fluid injection or withdrawal, including sequestration of CO₂ to mitigate adverse effects on the climate.

This talk will summarize laboratory and field observations of compaction bands and discuss theoretical results for their formation and extension. Theoretical results for band formation based on localization theory are roughly in accord with laboratory observations although detailed quantitative comparison is limited by the simplicity of the models and available data. Field data indicate that the midpoint width of the band scales as the square root of the band half-length L . This dependence is consistent with that of a very thin elliptical inclusion subjected to uniform compressive displacement w over the central portion of the band. If it is assumed that propagation of the band requires a critical value of energy released per unit area of advance, then w is proportional to the square root of L . The decrease of energy release rate (proportional to the square of the stress intensity factor at the tip of the band) with band length in this model suggests that the bands form with an energy release rate above the critical value and then grow unstably (dynamically) until the energy release rate falls to the critical value.

Micro-computed tomography images of a sandstone core from the field have unprecedented views of three dimensional microstructural features. Upscaling methods indicate that a permeability reduction of an order of magnitude, less than suggested previously.