

Fracture growth processes in sandstone inferred by textural investigations on crack-seal fracture cements

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Opening-mode fractures are ubiquitous structures in sedimentary rocks even in slightly deformed and flat-lying sequences. Opening-mode fractures in sandstone are often partially or completely cemented in deep reservoirs (>1 km depth). Such fractures in sandstones develop by progressive opening over a long period of time. The history of the fracture opening can be recorded in crack-seal textures of quartz cement bridges, where each crack-seal increment represents a stage of incremental fracture opening. We can distinguish several mechanisms by which opening-mode fractures can form. Fractures may widen in aperture at the same time as they lengthen by tip propagation. Alternatively, fractures may propagate to a certain length followed by an increase in aperture without further propagation. This second process can be envisioned for fractures with high ratios of aperture to length, common in deep gas sandstone reservoirs.

To test for these different mechanisms of fracture growth, we will utilize several methods in examining partially cemented fractures in sandstones from outcrops and cores of different basins (e.g.: E. Texas Basin, NW Scotland, and Utah). Thin sections will be examined under polarized light microscope, SEM, and SEM-cathodoluminescence imaging to reconstruct quartz cement bridges in partially cemented fractures from cross-cutting relationships of crack-seal textures. The reconstruction of cement bridges determines the relative timing of different crack-seal increments. Moreover, we will compare crack-seal textures for cement bridges near the tip of fractures and bridges near the center of fractures. More crack-seal increments in the center of fractures compared to the tip would be consistent with widening of fractures while lengthening. An equal number of crack-seal increments in both locations, with thinner increments near the tips, will indicate that fractures widen in aperture without lengthening. Understanding the relationships between fracture propagation and fracture aperture growth in various structural and diagenetic settings may enable us to predict fracture length and flow properties in reservoirs that are relevant to energy resources and CO₂ sequestration.

Keywords: fractures, crack-seal texture, sandstone, quartz bridges, fractured reservoirs