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Chemical-mechanical interactions during natural fracture growth in tight gas and oil reservoirs: Implications for flow during reservoir charge and production

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Natural fractures in tight sandstone and shale reservoirs are characterized by partial to complete cementation. In all tight-gas sandstone reservoirs and suitable outcrop reservoir analogs, fractures frequently contain crack-seal quartz and carbonate cement that formed during incremental fracture opening. These synkinematic cements may be followed by blocky postkinematic cement occluding any residual fracture porosity. Fluid inclusion microthermometry combined with Raman analyses demonstrate that synkinematic cement formed under conditions close to maximum burial and incipient exhumation under elevated pore fluid pressures and over time spans of 10-50 m.y.. Fracture opening rates, integrated over the kinematic fracture aperture, are on the order of 10 microm/m.y. Based on the textural evidence of synkinematic cement growth, in combination with kinetic models of quartz cementation, we infer that these rates are comparable to rates of dissolution-precipitation reactions in the host rock, and of mass transfer between host rock and fracture. It is thus suggested that dissolution-precipitation creep is a dominant deformation mechanism allowing accommodation of permanent fracture strain under these deep-burial, diagenetically reactive conditions.

Synkinematic mineral reactions in the host rock and precipitation of fracture lining cement guarantee that partially cemented natural fractures remain propped open and thus conductive under production conditions. However, cement linings and bridges can inhibit flow between micro-porous host rock and residual fracture porosity resulting in flow barriers. Complex pore geometry in partially cemented fractures may impede multiphase fracture flow and production. In shale, the interface between host rock and fracture cement is frequently mechanically weak potentially allowing fracture reactivation during well completion. Such artificially reactivated fractures may thus increase flow of production fluids even in formation containing otherwise sealed natural fractures.