Mineral paragenesis and microtextures in naturally sealed shale fractures

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Mudstones act as geologic seals, as well as sources and hosts of hydrocarbons in many sedimentary basins. Fluid migration is commonly facilitated by natural fractures whose development and evolution are not well understood. Cemented fractures in a core sample from the Permian Wolfcamp Formation were studied to elucidate the complex mineral paragenesis resulting from past fluid migration in fractures and along interfaces. We focused on a large, multi-generation dolomite-filled fracture and a thinner, bedding-parallel calcite-filled vein that intersects the larger dolomite fracture at a high angle. Combined µXCT, QEMSCAN® and BSE imagery reveal spatial relationships among matrix rock surfaces, fracture-filling minerals, pores, and organic matter (OM) in the mudrock. These coupled techniques reveal a complex architecture that includes different generations of dolomite, calcite, and quartz in the fractures. The earliest-stage dolomite contains inclusions of barium-rich carbonate and barite. The next generation inward is a mottled zone with small pores and inclusions associated with patchy intergrowths of Fe-dolomite and much less porous calcite. Particles of rock matrix phases (illitic clay, quartz, and albite) and OM are distributed within this mottled dolomite. The final generation of dolomite displays oscillatory zoning of Fe. A subset of these late dolomite crystals terminate into large pore spaces (vugs) while others are infilled by youngest, central, inclusion-free calcite crystals. Late-stage quartz plugs some central regions of the vein. XCT image analysis for quantification of 3D volumes of the different mineralized layers in the large fracture suggests that 62% is early-filling dolomite, 33% is the mottled dolomite, 0.5% is quartz (not present in the thin sections) and 4.5% is pore space.

Homogenization temperatures measured on aqueous fluid inclusions present in dolomite crystals lining the fracture walls indicate they precipitated at temperatures greater than 94-105 °C. Oil occurrence in specific vein layers as well as in the matrix adjacent to the veins suggests that generation and expulsion of oil by indigenous OM may have fractured the rock matrix.