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Structural-Diagenetic Controls on Fracture Opening in Tight Gas Sandstone Reservoirs, Alberta Foothills

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In tight gas reservoirs, understanding the characteristics, orientation and distribution of natural open fractures, and how these relate to the structural and stratigraphic setting are important for exploration and production. Outcrops provide the opportunity to sample fracture characteristics that would otherwise be unknown due to the limitations of sampling by cores and well logs. However, fractures in exhumed outcrops may not be representative of fractures in the reservoir because of differences in burial and exhumation history. Appropriate outcrop analogs of producing reservoirs with comparable geologic history, structural setting, fracture networks, and diagenetic attributes are desirable but rare. The Jurassic to Lower Cretaceous Nikanassin Formation from the Alberta Foothills produces gas at commercial rates where it contains a network of open fractures. Fractures from outcrops have the same diagenetic attributes as those observed in cores <100 km away, thus offering an ideal opportunity to 1) evaluate the distribution and characteristics of opening mode fractures relative to fold cores, hinges and limbs, 2) compare the distribution and attributes of fractures in outcrop vs. core samples, 3) estimate the timing of fracture formation relative to the evolution of the fold-and-thrust belt, and 4) estimate the degradation of fracture porosity due to postkinematic cementation. Cathodoluminescence images of cemented fractures in both outcrop and core samples reveal several generations of quartz and ankerite cement that is synkinematic and postkinematic relative to fracture opening. Crack-seal textures in synkinematic quartz are ubiquitous, and well-developed cement bridges abundant. Fracture porosity may be preserved in fractures wider than ~100 microns. 1-D scanlines in outcrop and core samples indicate fractures are most abundant within small parasitic folds within larger, tight, mesoscopic folds. Fracture intensity is lower away from parasitic folds; intensity progressively decreases from the faulted cores of mesoscopic folds to their forelimbs, with lowest intensities within relatively undeformed backlimb strata. Fracture apertures locally increase adjacent to reverse faults without an overall increase in fracture frequency. Fluid inclusion analyses of crack-seal quartz cement indicate both aqueous and methane-rich inclusions are present. Homogenization temperatures of two-phase inclusions indicate synkinematic fracture cement precipitation and fracture opening under conditions at or near maximum burial of 190-210°C in core samples, and 120-160°C in outcrop samples. In comparison with the fracture evolution in other, less deformed tight-gas sandstone reservoirs such as the Piceance and East Texas basins where fracture opening is primarily controlled by gas generation, gas charge, and pore fluid pressure, these results suggest a strong control of regional tectonic processes on fracture generation. In conjunction with timing and rate of gas charge, rates of fracture cement growth, and stratigraphic-lithological controls, these processes determine the overall distribution of open fractures in these reservoirs.