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Natural sealed fractures from the Montney-Doig unconventional reservoirs tied to burial and tectonic history of the Western Canada foreland basin

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Characterizing the factors controlling the occurrence of natural fractures in fine-grained deposits like mudstones is key to better understand the evolution of porosity and permeability in these tight rocks. This understanding can provide additional constraints to calibrate basin and reservoir models for the exploration and production of unconventional resources.

A multidisciplinary approach (including sedimentology, fracture diagenesis and fluid inclusion microthermometry) has been applied for the first time to natural mineralized fractures (veins) hosted by the Lower-Middle Triassic Montney-Doig unconventional resource play of the Western Canadian Sedimentary Basin. The aim was to define the factors controlling the occurrence of natural fractures in relation with the host rock properties as well as with the geological evolution of the Canadian Cordillera fold-and-thrust-belt and the associated foreland basin.

Forty-five core samples (2100-2500m in depth) were collected from two wells from an unconventional field in British Columbia. These sediments present variable mineralogy and organic content (TOC of 1.2 to 3.7wt% measured with the Rock-Eval 6 Shale Play protocol) and were deposited in shoreface to offshore environments.

Three generations of mineralized fractures were identified. The first generation of vertical fractures is cemented by a calcite precipitated at about 110°C from basinal brines and which carries oil and aqueous inclusions recording the migration which occurred in the Cretaceous (~100Ma). The second generation of horizontal fractures is cemented by calcite that carries mono-phase liquid $CH4 \pm CO_2$ inclusions, indicating that they formed after gas generation, probably at higher temperatures. The third generation of vertical fractures shows petrographic evidence for post-dating the second generation and contains monophase liquid $CH4 \pm CO_2$ inclusions.

The cathodoluminescence response and the oxygen and carbon isotopic signature (δ18O and δ13C) are very similar for all the studied calcite cements, irrespective of the fracture orientation and core provenance, suggesting calcite parent fluids in equilibrium with the host rock. This suggests that the Montney-Doig formations behaved like a closed system through time, and possibly acted as the source rocks of the unconventional system, at least in this part of the basin.

Host rock facies and matrix diagenesis partially controlled the occurrence of the fractures. Indeed, vertical veins are more abundant in the coarser facies (coarse siltstone and very fine sandstone) and in hemipelagic facies (calcispheric dolosiltstones) which have undergone early cementation, whereas the horizontal veins are rather localized in very fine facies (clay and silt).

The three identified generations of fractures were integrated to the burial history of the Montney-Doig formations and discussed within the broader context of the basin geodynamic evolution. The vertical fractures (first generation) possibly opened during the Late Cretaceous when vertical movements of the foreland were limited and rapid sedimentation of the Colorado Group occurred. The horizontal fractures (second generation) possibly opened close to maximum burial (Early Paleogene) as a result of overpressures induced by CH4 generation which would have lowered the main vertical stress, together with compressive horizontal stress. The vertical fractures (third generation) possibly opened during the uplift of the basin (Late Paleogene) as a result of the diminished far-field horizontal stress.