



CSPG ROCK ANALYSIS WORKSHOP

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Lithological controls on hydrocarbon storage and transport properties of the Montney Formation: An integrated core analysis approach

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Summary

This work presents results from a laboratory study investigating pore network characteristics, matrix permeability and dynamic rock mechanical properties (Young's Modulus, Poisson's Ratio) of selected intervals within the Montney Formation (Western Canada). The primary objectives are to 1) compare different laboratory-based methodologies for determination of porosity and matrix permeability; 2) characterize the pore network attributes (porosity, pore size distribution (PSD), dominant pore throat size, specific surface area) and matrix permeability of the selected target intervals; and 3) analyze the effects of different controlling factors (anisotropy, effective stress, bitumen saturation) on matrix permeability and dynamic rock mechanical properties obtained from ultrasonic tests.

Eight selected pairs of core plugs, drilled vertically and horizontally, are analyzed in this study. These core plugs are obtained from a vertical interval of 15 m within the fine-grained intervals of the Upper Montney Formation in British Columbia (Canada). The experimental techniques used for characterization include: bitumen reflectance (BR_o); Rock-Eval pyrolysis; helium pycnometry; Archimedes, caliper and 3D laser scanner analyses; low-pressure gas (N₂) adsorption; pulse-decay; and crushed-rock gas (N₂, He) permeability measurements. Ultrasonic experiments are performed on selected core plug samples under the same triaxial stress conditions as used for pulse-decay permeability measurements. Unique to this study, stress-dependent unpropped/propped fracture permeability/conductivity and elastic properties are further determined, allowing for a comparison of the same properties for intact core plug samples.

Excluding one of the samples (a laminated vertical core plug): 1) the slip-corrected pulse-decay gas (N₂) permeability values (measured at effective stress of 15.8 MPa) and apparent crushed-rock gas (He) permeability values generally increase with increasing porosity (4.2–8.1%), ranging from $1.4 \cdot 10^{-5}$ to $8.6 \cdot 10^{-4}$ md; and 2) the slip-corrected pulse-decay (N₂) permeability values ($1.2 \cdot 10^{-4}$ – $8.6 \cdot 10^{-4}$ md) are consistently higher than apparent crushed-rock (He) permeability values ($1.4 \cdot 10^{-5}$ – $1 \cdot 10^{-4}$ md). Pulse-decay (N₂) permeability values measured parallel to bedding (horizontal core plugs) are consistently between 10% and 25 times higher than those measured perpendicular to bedding (vertical core plugs). Based on a single pair of laminated core plugs



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analyzed in this study, the degree of permeability anisotropy (ratio between parallel and perpendicular permeability values) appears to be significantly higher for the laminated core plugs (up to 25 times) than bioturbated core plugs (up to 3.5 times). Compared to pulse-decay (N_2) permeability values, there is a minimal discrepancy (considering the maximum experimental error margin) between the crushed-rock gas permeability values that were measured on pairs of horizontal/vertical core plugs after crushing/sieving. In a gross sense, slip-corrected pulse-decay (N_2) permeability values decrease with increasing bitumen saturation. The derived dynamic rock mechanical properties (such as Young's modulus), for intact core plug samples are in excellent agreement with log-derived values. Because of the difference in scales for core- and log-based measurements, this agreement suggests that reservoir heterogeneities affecting acoustic wave propagation (and derived rock mechanical properties) occur at the sub-core plug scale for the target reservoir interval.

Experimental observations further indicate that propped fracture permeability/conductivity can be significantly higher than unpropped fracture (up to three orders of magnitude) and matrix (up to seven orders of magnitude) permeability under similar effective stress conditions for the Montney Formation. Unpropped fracture permeability values decrease up to 95% with increasing effective stress (685-6640 psi), reaching to a limiting "residual" value much higher (up to three orders of magnitude) than matrix permeability at similar experimental conditions. The stress dependency of shear wave splitting was found to be much larger for the propped fracture sample than for the unpropped fracture sample, suggesting that time-lapse seismic may be used to distinguish fracture types.

Through application of an integrated multidisciplinary approach, this study provides a better understanding of the coupled geomechanical/petrophysical phenomena by performing systematic fluid flow and ultrasonic tests on intact/fractured core plug samples under controlled stress conditions. The findings of this study could be beneficial to the operators for identifying controls on hydrocarbon storage and transport properties of the Montney Formation.

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