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Petrophysics, Geomechanics and Rock Composition in the Montney Formation

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Summary

The Triassic Montney Formation of the Western Sedimentary Canadian Basin, a clastic sequence dominated by siltstone, has been recognized as a major gas resources in Alberta and British Columbia, and has seen increasing amounts of condensate and liquids production in recent years.

Developing an understanding of relationships between rock composition and the physical properties of the rock is of outmost importance. Petrophysical properties such as porosity and permeability and geomechanical properties such as brittleness depend on rock fabric, mineralogy and diagenetic processes, which in turn depend on sediment source, depositional environment, and the pressure and thermal history of the basin.

Extensive study of the mineralogical composition, the organic material content and the paragenesis was performed on the Montney Formation together with facies analysis. Datasets include mineralogical analyses of core and cuttings samples via QEMSCAN and XRD, whole rock geochemical analyses of cores and cuttings, petrographic analysis of thin sections with optical and cathodoluminescence microscope, SEM imaging and core logging. The diagenetic history of the Montney Formation includes pore-occluding and porosity-enhancing events. Pore-occluding events identified are cements precipitation (quartz, feldspar, pyrite, clay minerals, calcite and several generations of dolomite) and mineral replacement (dolomite replaces silicate grains, and gypsum replaces carbonates). Pore-enhancing events include dissolution of several phases (feldspar, quartz and carbonate bioclaststic grains).

Several facies were identified by core logging, ranging from tidal flats to off shore facies and deep water turbidites. Facies determined by cores logging and diagenetic trends identified by thin section study of selected wells in the deep, middle and shallow parts of the basin were incorporated with mineralogical

data and well-logs into GAMLS software (Geologic Analysis via Maximum Likelihood System) to create a fine tuned lithological model of the Montney.

The lithological model served as the basis to our petrophysical analysis, which included mercury injection porosimetry, matrix (crushed rock) and plug pulse decay permeability measurement, constant flow permeability tests and SEM imaging for pore system characterization. This large petrophysical dataset was aimed at developing a model explaining vertical and horizontal porosity and permeability trends across the basin. Porosity data obtained by mercury porosimetry analysis on samples from selected wells ranges between 2 and 4.4% and averages at 2.85%, while porosity estimated by neutron well log (calibrated to sandstone) is estimated at a much wider range of 2-26% with values as high as 50% in the shallow part of the basin. These results indicate that much of the porosity present in the rock is within the nano-pores scale and is not in fact effective. Permeability values varies significantly in the Montney (10E-5 to 5 md) but comparison between datasets is difficult since many different methods were used to obtain those values.

Well log-based calculations of Young's Modulus and Poison's Ratio were calibrated to rock samples to obtain the brittleness of the formation, thus inferring its reaction to hydraulic fracturing. Brittleness indices, calculated from mineralogical composition, average 0.69 and vary less in deeper Montney wells, suggesting that these rocks have more consistent mineralogical composition and diagenetic characteristics. Most samples have moderate to high Young's modulus (>5 GPa) and Low Poisson's ratio (<0.25), which place them in the brittle region suitable for hydraulic fracturing. Changes in the vertical profiles of Young's modulus and Poisson's ratio can be correlated with facies transition and lithological variations, providing the opportunity to identify sweet spots with higher porosity and matrix permeability values and potentially good response to hydraulic fracturing.