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Geochemical and petrophysical characteristics of Horn River shale, Middle and Upper Devonian, Northeastern British Columbia, Canada

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The Evie, Otter Park and Muskwa members exhibit a range of organic and inorganic compositions that is stratigraphically controlled. In other shale formations, porosity development has been associated with kerogen cracking, suggesting that reservoir quality should be stratigraphically constrained. We test for those relationships in a large data set from the Middle and Upper Devonian Horn River shale were assessed with a variety of techniques to understand controls on petrophysical properties. Samples were examined by ICP-MS, helium porosimetry, pulse decay permeability analysis, SEM imaging of ion milled samples, nitrogen adsorption measurements and mercury injection analysis, and the results were compared to rock composition.

Five distinct shale lithofacies were identified by hand-core and thin section analyses: massive mudstones, pyritic mudstones, laminated mudstones, bioturbated mudstones and carbonates. The Evie member is carbonate-rich, primarily comprising massive mudstones, pyritic mudstones and carbonates. The Otter Park member is clay-rich, mainly consisting of laminated mudstones and bioturbated mudstones. The Muskwa Formations is quartz-rich, primarily containing massive mudstones and pyritic mudstones. The Evie has moderate organic matter concentration. The Otter Park is characterized by the lowest organic matter enrichment, while the Muskwa has the highest TOC content.

Porosity ranges from 2.4 to 10.8% and is slightly elevated in the Evie and Muskwa. A positive correlation is observed between porosity, organic matter abundance and quartz content, indicating that organic matter content is probably a primary factor controlling porosity development. A similar correlation between TOC and quartz indicates the latter is mainly biogenic in origin. Weak negative correlations are observed between porosity and the carbonate and clay content. SEM images suggest that several kinds of sites are provided for porosity development, including organic matter, pyrite framboids, clay platelets, quartz rims, carbonate grains and microfractures.

Results from nitrogen adsorption and mercury injection analysis suggest that pore size distribution includes micropores, mesopores and macropores, ranging from 1 nm to 1000 nm. Pores more than 10 nm dominate in terms of volume. Permeability ranges from 3.4 to 33 nanodarcy. Sea level fluctuation has direct impacts on geochemical composition and indirect influence on the petrophysical propreties. Evie, Otter Park and Muskwa members are assigned to HST, TST, and LST, respectively. Shale successions deposited during rising sea level stage (Evie and Muskwa formation) have higher porosity than intervals deposited during falling sea level stage (Otter Park formation), possibly because rising sea level rising is more favorable for organic matter accumulation.