A NEARLY COMPLETE CHARACTERIZATION OF PERMEABILITY TO HYDROCARBON GAS AND LIQUID FOR UNCONVENTIONAL RESERVOIRS: A CHALLENGE TO CONVENTIONAL THINKING


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ABSTRACT

In recent years interests in the North America oil/gas industry have shifted to and focused on tight/shale liquid-rich gas/oil reservoirs because of the low price of natural gas. It is evident that, beside gas permeability, permeability to hydrocarbon liquids must be understood to properly evaluate liquid production potentials. Previous studies have used gas to determine the intrinsically “true permeability” with the assumption that the “true permeability” corrected from gas permeability is equivalent to the liquid permeability for shale or tight reservoirs with microporous fabric. The microporous fabric with pores or pore-throats in the nanometer size range causes multiple co-existing gas transport mechanisms (continuum/viscous flow, slip flow, transitional and Knudsen diffusion). Several studies have shown that the conventional Klinkenberg correction to gas permeability is no longer appropriate for microporous medium, implying that the permeability to hydrocarbon liquid is likely also different from the gas-based “true permeability”. We envision that for unconventional rocks with nano-scale pores or pore-throats, the intrinsically “true permeability” from gas does not exist alone anymore because the permeability becomes a parameter that measures both the effectiveness of pore-network connectivity and the strong interaction between the specific fluid and the pore structure.

In this study, the gas-based “true permeability” of multiple samples of the Montney Formation from the Western Canada Sedimentary Basin were measured with different gases (including helium and argon) using different techniques. Permeability to hydrocarbon liquid (decane) was also tested on duplicate samples. The results show that liquid permeability is significantly lower than the gas permeability, even with Klinkenberg effect corrections. Gas and oil porosity, pore structure and lithology of the samples were also tested using pycnometry, high-pressure mercury-injection porosimetry, scanning electron microscopy, and x-ray diffraction. Integration of the data provides a comprehensive characterization of the permeability and porosity of the samples and sheds insights into our understanding of gas and liquid permeability of unconventional rocks. The implications of the results, the importance of appropriately designed laboratory programs for permeability testing and proper utilization of measured permeability data to evaluate the unconventional gas and oil production potentials are discussed.

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