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Stress-Dependence of Porosity and Permeability of Tight rocks of the Montney Formation: New Insights from Holistic Interpretations of MICP Data

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Summary

Unconventional tight and shale reservoirs undergo significant changes in in-situ stresses during their production life span from stimulation to depletion. Changing in-situ stresses can greatly affect well performance of unconventional reservoirs due to the strong stress-dependence of the low porosity and permeability. Therefore, it is important to quantify the stress-dependence of porosity and permeability to effectively evaluate and exploit unconventional reservoirs. Porosity of tight rock is rarely measured under confined stress condition and the stress-dependence is poorly understood. Stress-dependence of low permeability tight rock is tested with direct permeability measurements of core samples under different confining stresses which simulates the varying stress conditions during the production lifecycle. However, misleading data is often produced due to a lack of sample integrity and consistent testing conditions. High pressure mercury injection capillary pressure (MICP) data are commonly acquired to characterize the pore-throat size distribution of tight rocks. MICP data is not severely affected by a lack of sample integrity as is the case for permeability measurement on cores and core plugs. However, MICP data for tight and shale samples require careful corrections and interpretations to obtain meaningful porosity, pore-throat size distribution and permeability. Numerous studies have considered this very subject, yet it is still common to see that MICP data is either over-corrected or under-corrected and hence misinterpreted. Moreover, few studies have focused on quantifying the stress-dependence of porosity and permeability based on MICP data. Here we apply a holistic method to consistently and rigorously correct and interpret MICP data acquired from the Montney Formation in Alberta and used to derive porosity and permeability under ambient and stressed conditions. Bulk modulus or compressibility of dozens of samples from multiple Montney wells are also derived from MICP data and the results show remarkable consistency when compared to values determined directly by triaxial compression tests. The stress-dependence of porosity and permeability of the Montney samples is further studied based on a poro-elastic model that includes different flow regimes (viscous and slip flow and Knudsen diffusion) and MICP-derived properties and the effects on production are highlighted. Overall, the consistency and similarity between the MICP-derived parameters and the direct laboratory measurements suggest that the presented approach can be applied to obtain insightful information on rock properties (especially stress-dependence of porosity and permeability) from MICP data for better evaluating tight and shale reservoirs.