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Fast and Robust Measurement of the Key Organic-Rich Shale Petrophysical Characteristics

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Abstract

Quantification of the key shale petrophysical properties is challenging. Shales contain extremely small microspores which disrupt the application of classic fluid flow theory. Moreover, these microspores alongside the organic material in the shales kerogen have a significant adsorption capacity. This microstructure of the shale renders conventional techniques for measuring shale permeability impractical. The unsteady state techniques have been extensively used to estimate permeability of the shale samples. However, the measured values often suffer from the non-uniqueness problems which are the result of the non-uniform experimental protocols and interpretation methods. Another significant limitation of these techniques is inability to perform the measurements under the stress conditions.

This article presents the results of measurements on several Marcellus Shale samples porosity, permeability, formation compressibility, and sorption characteristics under reservoir stress conditions using a fast, accurate and repeatable near steady-state technique. The experimental results indicate that stress has irreversible and non-linear impact on the shale permeability, but reversible and linear impact on the porosity. This could be attributed to gas flow through micro-fractures, which dominate the permeability but do not contribute to porosity significantly. The non-linear permeability variation with respect to stress is contributed to different fracture and matrix responses to the stress. The fractures closure pressure can be determined by the application of the Walsh theory. In addition, the reliable values for the absolute permeability can only be obtained by the application of the gas double-slippage corrections.

Nitrogen low temperature adsorption/desorption results for Marcellus Shale samples suggest multi-layer adsorption and slit-like pores. This can provide an explanation for high productivity of the over-pressured Marcellus Shale reservoirs. The permeability measurements results exhibit hysteresis for adsorption and desorption cycles. The adsorption can result in the pore size and permeability reduction.