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The Stress-dependence of Poroelasticity in Low-permeability Rocks

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Abstract Text:

Fluid transport through the matrix of low-permeability rocks is often affected by the gas slippage phenomenon and stress conditions (i.e., magnitude, direction) combined. Poroelasticity, which describes the interaction between fluid flow and rock mechanical properties, is among the most elusive properties to accurately assess in the laboratory for tight rocks. The primary objectives of this work are to 1) compare different laboratory-based methodologies (permeability-derived vs. ultra-sonic-derived) for evaluating Biot coefficients, an important poroelasticity parameter in tight rocks, and 2) investigate its stress sensitivity and anisotropic behavior. None of these objectives has been previously addressed for low-permeability rocks in the literature

To address these objectives, apparent gas (N₂) permeability and ultrasonic velocity (P and S-wave) measurements were performed simultaneously over a wide range of confining (1000-5000 psia) and pore (200-3500 psia) pressures during multiple loading and unloading cycles. Two types of low-porosity, low-permeability rock samples (tight siltstone and organic/clay-rich shales) were studied. A series of recently-developed evaluation techniques were applied to determine 1) Biot coefficients, 2) permeability modulus, and 3) gas slippage factors as a function of stress under replicated "in-situ" stress conditions.

The Biot coefficients, evaluated using different techniques, were consistently lower than 1, ranging between 0.47 and 0.89. The Biot coefficients derived from permeability testing were consistently (up to ~25%) higher than those derived from ultrasonic velocity testing. The observed discrepancy is attributed to the primary controls on fluid flow and ultrasonic wave transfer in tight rocks - permeability is affected by the transport pore in the direction of the flow while ultrasonic velocity is impacted by the entire pore system. The estimated Biot coefficients were also higher during unloading cycles (versus loading cycles) and when measured parallel to bedding.

This study provides a first-time comparison between permeability-derived and ultrasonic-velocity-derived Biot coefficients in tight rocks. In addition, the stress-dependence behavior of

the Biot coefficient was documented for the first time for low-permeability rocks.

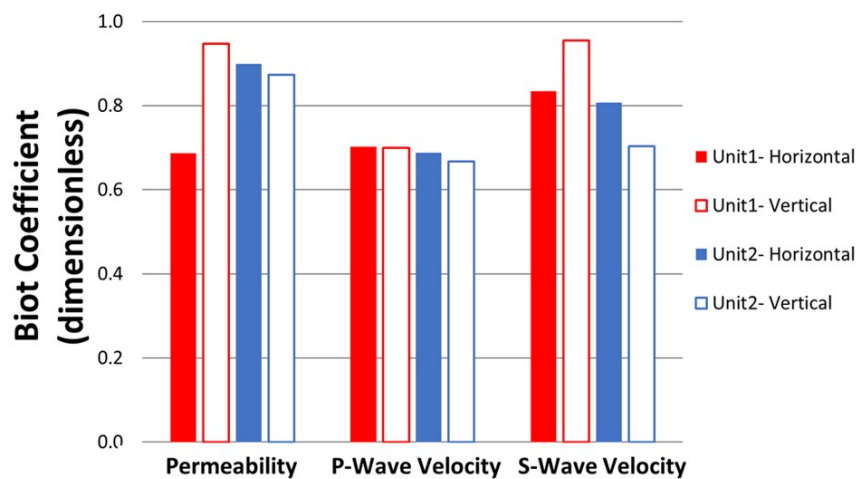


Fig1: Comparison of Biot coefficients derived using 1) permeability (as a function of stress), 2) (Ultrasonic) P-wave velocities, and 3) (Ultrasonic) S-wave velocities for vertically- and horizontally-oriented Montney tight siltstone core plug samples.

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