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Experimental Investigation of Gas Slip Flow in Partially Water-Saturated Tight Sandstones

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Unconventional tight gas sandstone reservoirs have unique petrophysical properties, and established concepts of two-phase (gas/water) flow and relative permeability are not readily applicable. One of the issues addressed by several workers (Rose, 1948; Fulton, 1951; Estes, 1956; Rushing, 2003; Li and Horne, 2004), is the magnitude of the Klinkenberg slip-flow effect in two-phase (gas/water) systems. While there is some agreement that slip flow may enhance permeability at low mean pressures, the influence of water saturation on gas slippage and effective permeability is still disputed.
Our goal was to assess the effects of saturation and slip-flow on effective permeability measurements in tight gas sandstones and develop a non-steady state permeability measuring technique. Two different types of permeability measurements were performed in a triaxial flow cell originally designed for low-permeable (nano darcy range) claystones.
The methods were tested on a sample set, consisting of core plugs from Permian (Rotliegend) and Triassic (Buntsandstein) tight gas reservoir intervals. The absolute, Klinkenberg-corrected gas permeability of the set ranges from 10-7 D to 10-5 D.
Two types of experiments were performed. The first is a non-steady state adaptation of the steady state experiments by Li and Horne (2004) and Rushing (2003) to assess gas slip factor. In the second set of experiments the effects of saturation and capillary pressure on the effective permeability were tested while the Klinkenberg effect was eliminated by maintaining a constant mean pressure. Permeability coefficients were then related to saturation data measured separately in a standard porous disc apparatus. In addition, several standard petrophysical characterization methods and thin section analyses were conducted for pore system analysis and related to the permeability data. The sensitivity of the methods to variations in (mean) pressure and saturation as well as possible sources for error will be addressed.

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