Comparitive Study of Relative Permeability and Residual Saturation Estimates of Kerogen and Shale Samples

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ABSTRACT

Understanding of relative permeability and residual saturations is helpful in improving the interpretation of production performance of shale reservoirs. In absence of accurate direct measurements of these two properties, we estimated the relative permeability and residual saturations from the adsorption-desorption isotherm measurements on 80 organic-rich shale samples and 7 kerogen samples extracted from Bakken, Wolfcamp, and Woodford formations. These included native and cleaned samples, treated with methanol-toluene mixture to remove bitumen and soluble dead hydrocarbons. These measurements were interpreted to obtain pore size distribution (PSD) using modified Barrett-Joyner-Halenda (BJH) method. Bimodal fractal PSD model was used to estimate percolation parameters (coordination number, percolation cluster length and percolation threshold) and fractal dimension. Thereafter, relative permeability and residual saturations were estimated for the samples using percolation theory, effective medium theory and critical path analysis.

Kerogen samples exhibit larger pore volume fractions for pore widths > 80 nm, whereas the native shale samples exhibit nearly equal pore volume fractions above and below the pore width of 80 nm. Fractal dimension, which indicates the pore network complexity, for both shale and kerogen samples increased from 2.3 to 2.9 with the increase in kerogen maturity. Kerogen and native shale samples show an increase in residual water saturation estimates with maturity. For the kerogen samples, the irreducible water saturation estimates increase from 17% to 30% with an increase in kerogen maturity. Both wetting and non-wetting phase relative permeability decreased by nearly 60% in the water saturation range of 30% to 40% with an increase in kerogen maturity in kerogen samples. Cleaning of native shale samples with toluene-methanol mixture to remove soluble hydrocarbons and bitumen showed an increase in hydrocarbon relative permeability and decrease in aqueous phase relative permeability, which are analogous to the relative permeability curves estimated for kerogen samples.