New Predictive Model for Relative Permeability of Deformable Gas Hydrate-Bearing Sediments

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Global energy demand is expected to grow significantly as the world population and the standard of living increase in the coming decades. As a potential source of energy, gas hydrate, which is a crystalline compound of gas-water mixture formed in stable of high pressure and low temperature, has been intensively investigated in the past few decades. In this work, a new analytical model is derived to study the effect of hydrate saturation on stress-dependent relative permeability behavior of hydrate-bearing sediments. The proposed relative permeability model solves the steady-state Navier-Stokes equations for gas-water two-phase flow in porous media with hydrates. It considers water saturation, hydrate saturation, viscosity ratio and hydrate-growth pattern, and is adequately validated with the experimental results in existing literatures. The model demonstrates that gas-water relative permeability in wall coating hydrates (WC hydrates) is larger than that in pore filling hydrates (PF hydrates). For WC hydrates, water phase relative permeability monotonically decreases as gas saturation increases. However, for PF hydrates, water phase relative permeability firstly increases and then decreases with the increase of gas saturation, which can be explained by the “lubricative” effect of the gas phase that exists between the water phase and hydrates. This work constitutes a comprehensive investigation of stress-dependent relative permeability in deformable hydrate-bearing sediments, which is a key issue for sustainable gas production. It not only provides theoretical foundations for quantifying relative permeability in hydrate-bearing sediments, but also can be used to estimate pore-scale parameters and rock lithology of gas hydrate-bearing sediments using inverse modeling.