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The paper was published in the proceedings of XVI Pan-American Conference on Soil Mechanics and Geotechnical Engineering (XVI PCSMGE) and was edited by Dr. Norma Patricia López Acosta, Eduardo Martínez Hernández and Alejandra L. Espinosa Santiago. The conference was held in Cancun, Mexico, on November 17-20, 2019.

Impacts of Hydrate on Core-Scale Permeability in Sediments

Sheng DAI^{a,1}

^a*School of Civil and Environmental Engineering, Georgia Institute of Technology*

Abstract. Permeability is a critical parameter describing flows of methane gas and water through hydrate-bearing sediments. It is also one of the most critical parameters to estimate gas production rate, which determines whether expensive deepwater drilling to produce gas from hydrate deposit is economically feasible. However, studies on permeability in hydrate-bearing sediments are limited, in part due to experimental difficulties and the phenomena per se is complex and scale dependent. This presentation discusses the basic physical processes involved in mixed fluids transport in sediments, the impacts of hydrate formation and dissociation on mixed fluids flow, and the challenges and potential solutions to enhanced understanding of the core-scale permeability in hydrate-bearing sediments.

Keywords. Permeability, pore habit, tortuosity, capillarity, relative permeability.

1. Extended Abstract.

Permeability is a measure of the ability of sediments to allow fluids (gas or liquid) to pass through it. It is a fundamental physical property of the porous medium, although different pore fluids may pass through the same porous medium at different velocity (i.e., conductivity), affected by fluid viscosity and pressure gradient.

Hydrate formation in sediments decreases the overall pore volume and changes the pore space connectivity and tortuosity, and thus alters the sediment permeability. Typically, the permeability in hydrate-bearing sediments is called the effective permeability k_{hyd} , to be distinguished from the intrinsic permeability k_{int} that refers to the permeability of host sediments without hydrate. A majority of experimental, numerical, and analytical studies if not all so far are inherently looking into how the effective permeability k_{hyd} decreases with increasing hydrate saturations S_h , i.e., the permeability reduction curve. The permeability reduction curve has been experimentally measured using various natural soils and designed porous microfluidic chips, numerically simulated using pore network modeling and Lattice Boltzmann method, and analytically formulated based on capillary tube flow, fractal, and percolation theories.

When gas and water coexist in sediments, for instance during hydrate dissociation, the flow process becomes more complicated, as the gas and the water will compete for the pore space and the developed water-gas capillarity alters the overall flow pattern in the sediment cores. The mixed fluids flow at this condition is described using relative permeability. The relative permeability to water k_{r_w} is the permeability of water at

¹ Sheng Dai, Geosystems Engineering, Georgia Institute of Technology, 790 Atlantic Dr NW, Atlanta, GA 30332 USA; E-mail: sheng.dai@ce.gatech.edu

different water saturations (i.e., unsaturated condition) normalized by the permeability measured when the sediments is fully saturated by water. In a similar way, the relative gas permeability $k_{r,g}$ is defined. Relative permeability to both water and gas are normalized values, ranging from zero to one. Three basic parameters are needed to describe relative permeability: a shape factor m in the van Genuchten model (or λ in Brooks-Corey model), residual water saturation S_{rw} , and residual gas saturation S_{rg} . Two- and three-dimensional pore network model simulations have been conducted to probe how these parameters vary at different hydrate saturations. These results have not yet been validated experimentally or theoretically.

The following properties are essential to evaluate the mixed fluids transport in hydrate-bearing sediments, yet still very little is known: (1) permeability anisotropy, (2) discrepancies in measured permeability of collocated cores using different methods, (3) hydrate saturation dependent relative permeability, (4) relative permeability in cores subjected to isotropic depressurization versus a pressure gradient, and (5) upscaling techniques from core-scale measurements to reservoir-scale applications. Recent advances in laboratory and numerical studies that may potentially shed light to these processes will also be discussed [1-4].

References

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