Analysing the Effects of Inhomogeneity on the Permeability of Porous Media Containing Methane Hydrates

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Abstract

The permeability of porous media containing gas hydrates is of crucial importance in predicting the fluid flow behavior and gas production capacity during the exploitation of gas hydrate resource. Gas hydrates are generally found to be unevenly distributed in the natural samples, the inhomogeneity of which could have significant impacts on the permeability properties. Most of the permeability measured in a laboratory-synthesized hydrate sediment is based on the Darcy law or its derivatives, which can only provide an overall characteristic of the non-uniform multiphase system. The effects of the local inhomogeneity on the permeability are still largely unclear. The pore network model (PNM) [*Blunt*, 2001; *Dong and Blunt*, 2009], which considers the 3D distribution of each component in a multi-phase system, has recently been widely applied in the study of permeability simulation [*Dai and Seol*, 2014; *Mahabadi et al.*, 2016]. Benefiting from the input of the reconstructed pore structure, the influence of the porosity, particle size, pore throat ratio, coordination number, shape factor and pore throat orientation on the permeability can now be investigated [*An et al.*, 2016; *Ghanizadeh et al.*, 2015; *Ma et al.*, 2014]. Very few studies are found to focus on the effects of local inhomogeneity of the hydrate-bearing sediment on the permeability behavior. Here we extend our previous studies to investigate the impacts of heterogeneous distribution of gas hydrates on the permeability of the porous media; special interest is placed on the hydrate formation factor and flow direction. The PNM study combined with CT observation is expected to provide some implications for understanding the significant role of inhomogeneous hydrate distribution in the gas production behavior from natural sediments.

Different grains including dolomite (case 1), quartz (case 2) and feldspar (case 3) are used to study the effect of irregular porous media on the permeability property. The gas/water relative permeability in the three hydrate-bearing sands are presented in Fig. 1. Overall, with the increase of water saturations, the water relative permeability increases, with that of gas gradually decreasing. Yet clear differences of flow behaviour in the three cases can be seen. At water saturations lower than 40%, the relative permeability of water do not differ so much, with case 2 and 3 almost overlapping. But the relative permeability of gas shows a strong dependence on the pore parameters. To extrapolate to large scale field test from marine hydrate sediments, the rather high water saturation would have a crucial impacts on the gas production, even in highly-permeable sediments; water flow would govern the permeation, which is unexpected in the gas production.

The distribution of gas hydrates could be very inhomogeneous after water fully or partly transformed. On account of this, the permeability property of different locations in the hydrate-bearing sands would also yield significant differences. To investigate the effects of inhomogeneous hydrate formation on the permeability, we locally segment the dolomite sands into 12 parts, and select 5 of them to simulate. As expected, the porosity and pore/throat radii are smaller at where the hydrates concentrate on. The large amout local formation of hydrates would hinder the fluid permeation, and likely result in snap off phenomenon. It is indicated that though the porostiy is close, the microstructures of pores and throats would likely differ resulting from the random and complicated hydrate formation; some pores may not have sufficient throats connected to them, limiting the fluid flow. Thus, in terms of hydrate-bearing sands, a high porosity may not exactly lead to a better permeation of fluid; the microstructures of hydrate in pores and the connectivity of surrounding pores could also play a crucial role.

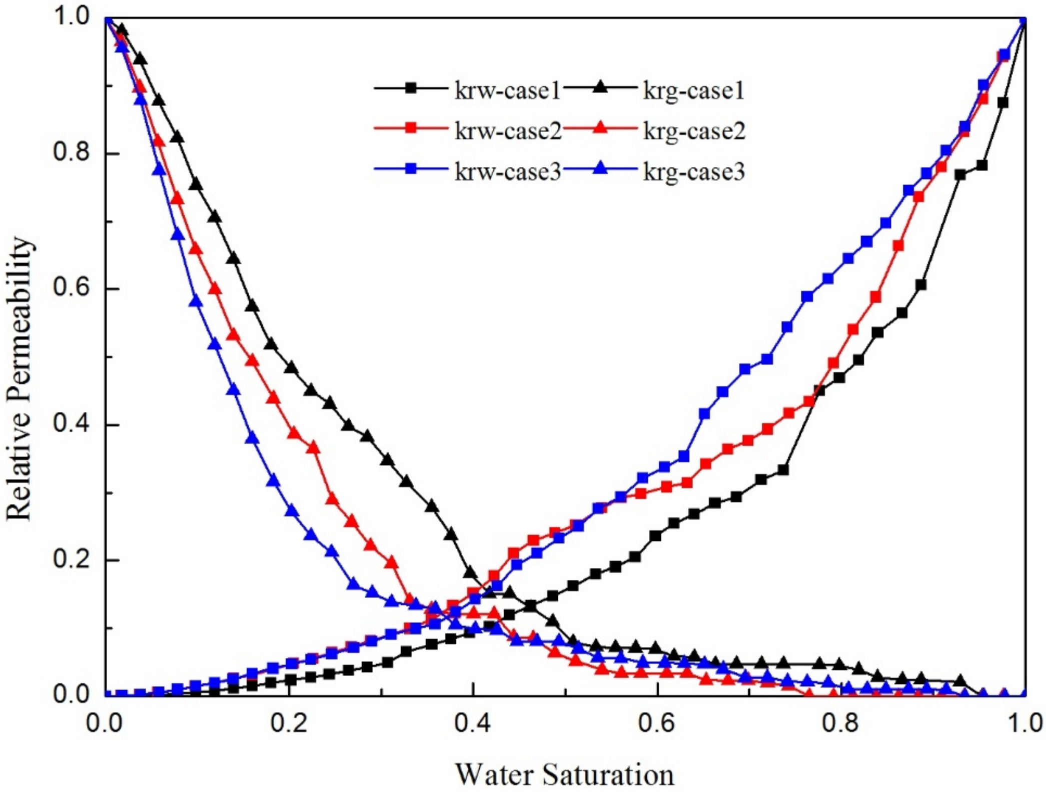

Fig.1 : The gas/water two-phase relative permeability in different sands containing gas hydrates

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