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Apparent Permeability for Gas Transport in Nanopores of Organic Shale Reservoirs Including Multiple Effects

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Abstract: Gas transport in nano-scale channels has been of high complexity. The extra properties of shale gas reservoirs make it even more complicated. Therefore, accurate modeling of the apparent permeability of gas transport in shale gas reservoirs is urgently needed. In this work, we developed apparent permeability models for real gas transport in both nano-capillary tube and nanopores which incorporate different mechanisms including gas adsorption, stress dependence, non-Darcy flow, and surface diffusion. In particular, both monolayer and multi-layer adsorptions were included using a unified equation. The models were verified using the experimental data of gas transport in nano-capillary tube and nanopores. After that, we used the models to study the behaviors of different mechanisms of apparent permeabilities focusing on their contributions to the total apparent permeability and their sensitivity to several important parameters. We investigated the variations of apparent permeabilities with different mechanisms for gas transport under four different cases, which are, in nano-capillary tubes or nanopores, and with monolayer or multi-layer adsorptions, respectively. The results indicated that, under most real shale-gas-reservoir conditions, the corrected permeability due to gas adsorption and the non-Darcy flow permeability are dominant in the apparent permeability, while the surface diffusion permeability caused by adsorbed gas can be largely overlooked. In addition, for the cases with relatively larger sizes of nano-capillary tubes or nanopores, we observe a smaller ratio of non-Darcy flow permeability over the corrected permeability due to gas adsorption and a smaller contribution of surface diffusion as well. However, if we artificially increase the diffusion coefficient, the contribution of surface diffusion to the total apparent permeability can rapidly increase. The findings are crucial for evaluating the contribution of surface diffusion.

Keywords: apparent permeability; gas transport; modeling; nanopores; shale gas reservoir

Introduction

Shale gas has received great attention and has been playing an increasingly important role around the world. Shale gas with huge reserves and extensive distribution is becoming more and more important to the global natural gas supply in years to come. However, the features of shale gas reservoirs, such as gas adsorption/desorption, non-Darcy flow, stress dependence, and surface diffusion of adsorbed layer, make it very difficult to clearly understand the apparent permeability of gas transport.

Methane in organic shale gas formation is stored as free gas and adsorbed gas (Jenkina et al. 2008). The high contents of organic matter or clay minerals and the large surface area of nanopores induce the content of adsorbed gas up to 20%-80% (Curtis 2002; Wu et al. 2014).