Predicting Transport through Heterogeneous Pore Matrices: Analytical vs. Stochastic Approaches

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With increasing global energy demands, unconventional formations, such as shale rocks, are becoming an important source of natural gas. Extensive efforts focus on understanding the complex behavior of fluids (including their transport in the sub-surface) to maximize natural gas yields. Shale rocks are mudstones made up of organic and inorganic constituents of varying pore sizes (1-500 nm). With cutting-edge imaging technologies, detailed structural and chemical description of shale rocks can be obtained at different length scales. However, predicting fluid permeability remains challenging. Experimental measurements supply answers, but at elevated costs of time and resources. To complement these, computer simulations are widely available, at various length scales. However, they employ significant approximations, and a reliable methodology to estimate permeability in heterogeneous pore networks remains elusive. We compare here permeability predictions obtained (a) by implementing deterministic methods; (b) direct numerical simulations; and (c) one stochastic approach, using a kinetic Monte Carlo algorithm. We discuss the effects resulting from pore size distribution, the impact of micro- and macropores, and the effects of anisotropy (induced or naturally occurring) on the predicted matrix permeability. When possible, comparison against experimental datasets are provided as guiding principles for selecting the appropriate predictive method.