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Effect of capillary pressure and geomechanics on multiphase fluid flow in rocks

Denis Anuprienko[1,2], Viktoriya Yarushina[3], and Yury Podladchikov[4,5,6]
[1]Nuclear Safety Institute, Russian Academy of Sciences, Moscow, Russian Federation (denis-anuprienko@yandex.ru)
[2]Marchuk Institute of Numerical Mathematics, Russian Academy of Sciences, Moscow, Russian Federation
[3]Institute for Energy Technology, NO-2007 Kjeller, Norway
[4]Institute of Earth Sciences, University of Lausanne, 1015 Lausanne, Switzerland
[5]Swiss Geocomputing Centre, University of Lausanne, 1015 Lausanne, Switzerland
[6]Faculty of Mechanics and Mathematics, Lomonosov Moscow State University, Moscow, 119899, Russian Federation

Understanding interactions between rock and fluids is important for many applications including CO_2 storage in the subsurface. Today significant effort is aimed at research on CO_2 flow through low-permeable shale formations. In some experiments, CO_2 is injected in a shale sample at a constant rate, and the upstream pressure exhibits rise until a certain moment followed by a decline, representing the so called breakthrough phenomenon. After the breakthrough, downstream flux significantly rises. This behavior was thought to be the result of fracture occurence or mechanical effects.

Here, we present a 3D numerical model of flow through experiments in shale. Our model accounts for poroelastic compaction/decompaction of shale, its time-dependent permeability, and two-phase flow, the fluid phases being CO_2 and air. The model also accounts for a capillary entry pressure threshold observed in experiments. The key feature of the model are saturation-based relative permeabilities which result in sharp overall permeability increases as the CO_2 moves through the shale sample. The model is implemented for 3D calculations with the finite volume method. Our results show that CO_2 breakthrough is a natural outcome of two-phase fluid flow dynamics and does not need a fracture to exhibit pressure behavior observed in experiments.