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PORE SCALE MODELING OF TWO-PHASE FLOW

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High-resolution, three-dimensional, X-ray microtomography images of multiphase porous media systems have become widely available over the past decade. At the same time, several methods have been developed to both analyze the pore space and calculate macroscopic flow properties. Absolute and relative permeability are perhaps the most fundamental pore-scale properties since they are required as input into larger-scale reservoir simulations (and are the basis for any modeling of more complex/coupled phenomena). The objective of this paper is to validate image-based permeability and formation factor estimation.

Theoretical convergence estimates and validation of numerical approaches for Navier-Stokes flow to date remain impractical to model natural porous formations. We first compare lattice-Boltzmann and finite-difference based codes for simulation of single-phase flow in realistic samples independently developed by our respective research groups. We also assess numerical errors due to discretization and biases due to sample size and location.

We obtain quasi-static drainage and imbibition fluid configurations using the level set method based quasi-static algorithm. This algorithm is geometrically robust with respect to the (image based) pore-space complexity and properly describes detailed fluid configurations, including residual fluids. Fluid configurations compare well to available experiments (drainage in a dolomite sample and spontaneous imbibition in a Fontainebleau sandstone). We then estimate permeability using single-phase flow simulators in each of the fluid phases. Even though the estimated two-phase relative permeability does not explicitly incorporate inter-phase exchange of momentum, its computational complexity is substantially lower than with explicit two-phase flow simulations. We finally use the fluid configurations to compute

formation factor (resistivity index) and compare/assess random walk algorithms used by the research groups.

The combination of experimental validation and cross-validation of different numerical approaches for estimation of properties is an important step toward more predictive and reliable modeling.