Combining Pore-scale Simulation Capabilities with NETL's Geoimaging Lab Facilities to Develop Digital Rock Technologies for Geologic Carbon Sequestration and Oil & Gas Applications

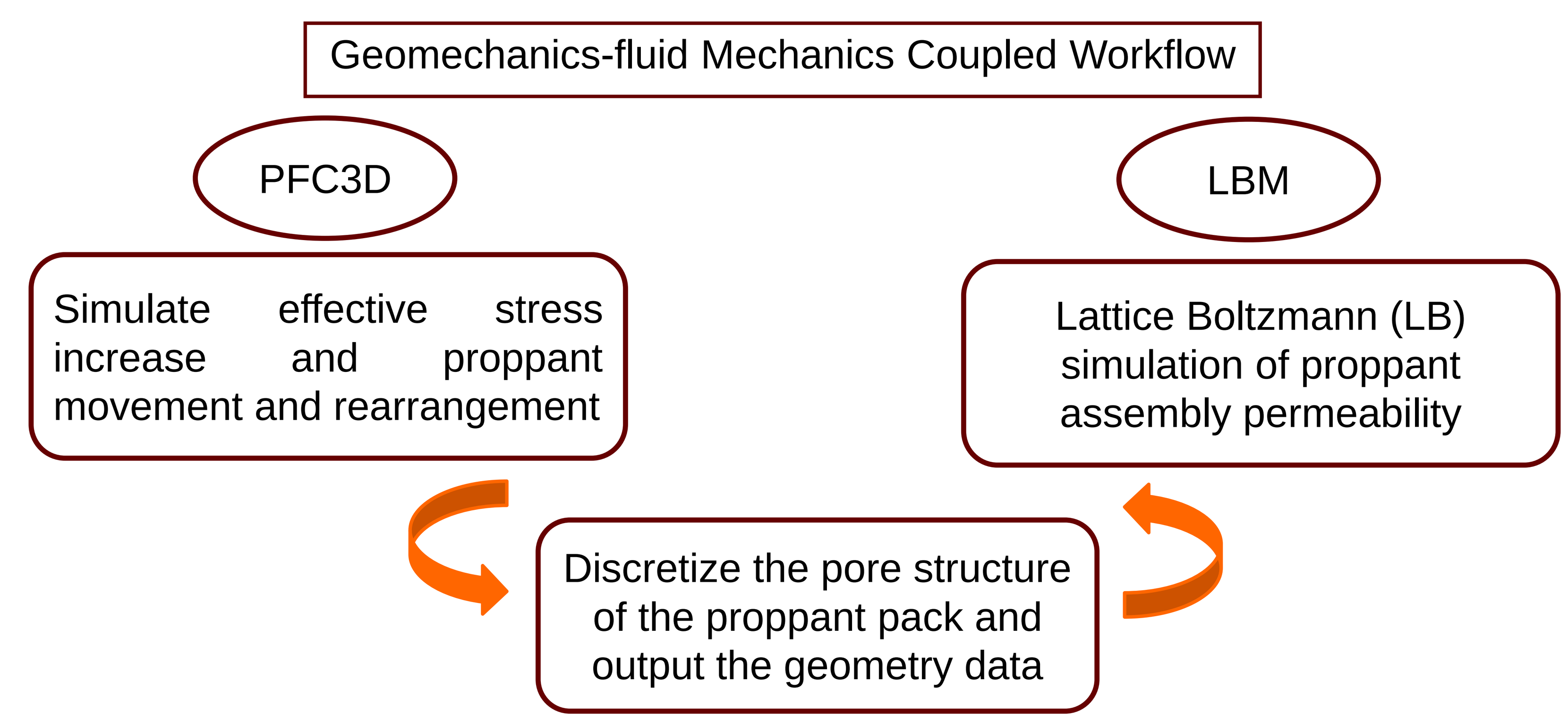
Ming Fan[1], James McClure[2], Dustin Crandall[3], Laura Dalton[3], Karl Jarvis[3], and Cheng Chen[1]

[1] Department of Mining and Minerals Engineering, Virginia Tech, Blacksburg, VA ; [2] Advanced Research Computing, Virginia Tech, Blacksburg, VA; [3] National Energy Technology Laboratory, Morgantown, West Virginia

Abstract

X-ray computed tomography (CT) scanning has the advantage of visualizing *in situ* pore structure and fluid distribution within the pore space without opening the porous medium destructively. Image data from CT scanning can be used as boundary conditions in a pore-scale lattice Boltzmann (LB) simulator to simulate single- and multiphase flows within the pore space. The Geoimaging Lab at National Energy Technology Laboratory's Research & Innovation Center hosts three CT scanners having different resolution capabilities. Pore-scale LB simulation capabilities, enhanced by CPU/GPU parallel computing technologies, have been developed to fully utilize rock image data from the Geoimaging Lab. Two projects are presented in this poster. The first study investigated the role of proppant compaction and proppant size heterogeneity on the relative permeability of a propped fracture. Simulation results showed that relative permeability of the non- wetting fluid phase was more sensitive to the change of effective stress; non-monotonic change in relative permeability can occur because of nonlinear development of pore structure and connectivity. High-performance LB simulations were conducted on the Titan supercomputer and Virginia Tech's Cascades supercomputing cluster; thus, many more rock samples can be analyzed given the same processing time. The second was a study focused on the role Capillary number (Ca) and contact angle have on the multiphase flow properties within a sandstone reservoir. Simulation results showed that both Ca number and contact angle significantly influence the relative permeability curves, which regulate multiphase flow during geologic CO2 injection at the macroscopic scale.

Overview of Numerical Workflow



Results

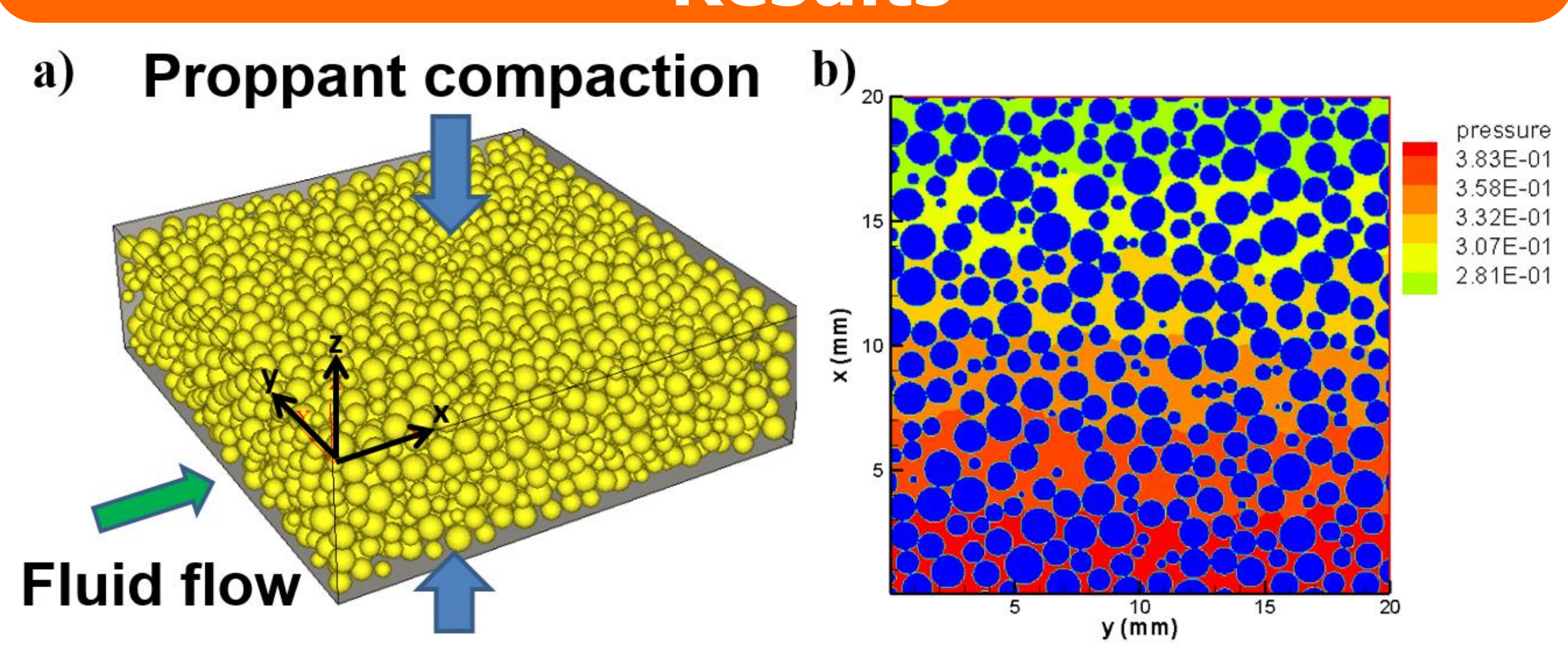


Fig. 1 a) PFC-simulated 16/30-mesh-size proppant assembly of 30 mm × 30 mm × 8 mm under effective stress of 10 psi, and b) corresponding LB-simulated pressure distribution within the pore space.

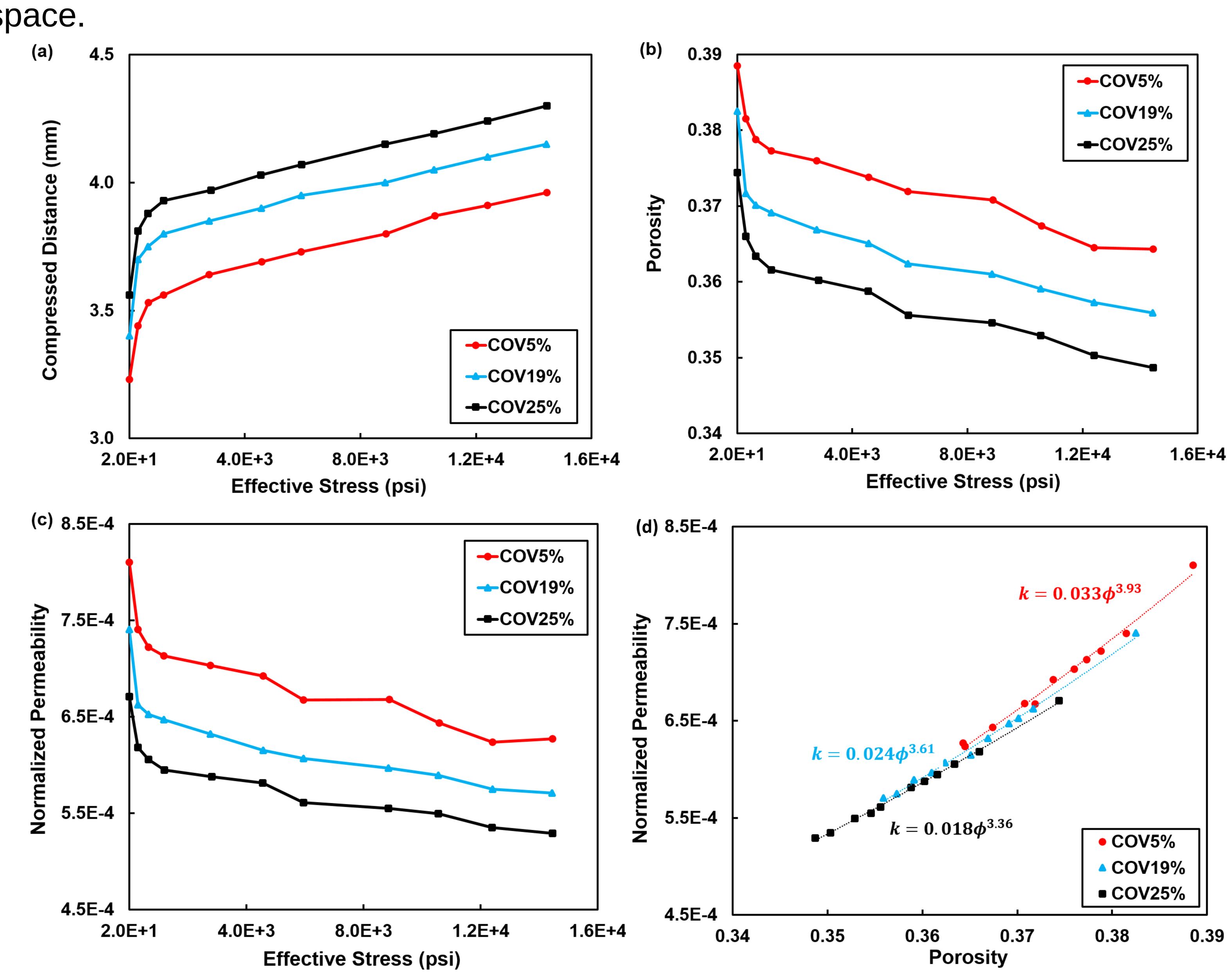


Fig. 2 a) Compressed distance, b) porosity, and c) normalized permeability as functions of effective stress, d) normalized permeabilities as functions of porosity.

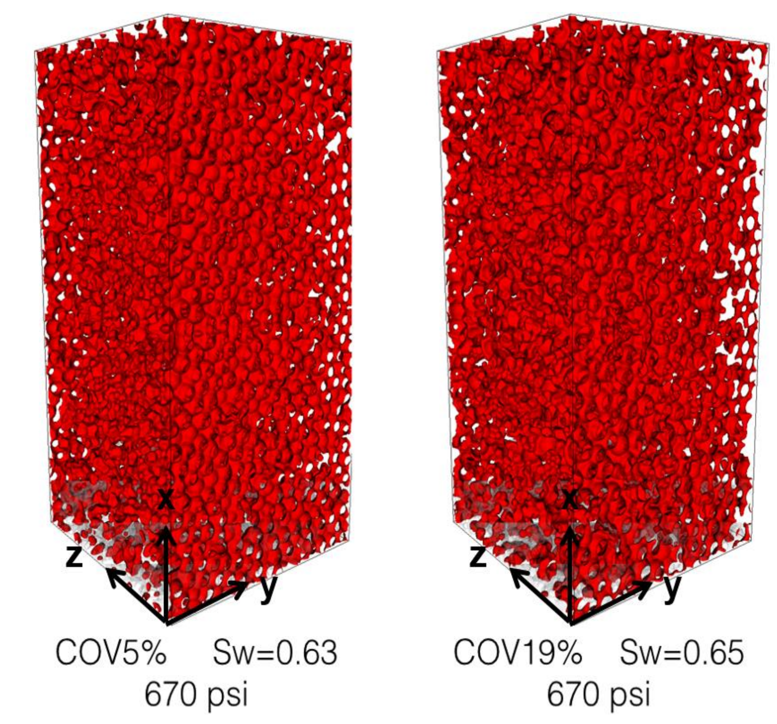


Figure 3. Oil phase distributions in steady-state two phase flow observed for diameter COVs of a) 5%, and b) 19%, respectively.

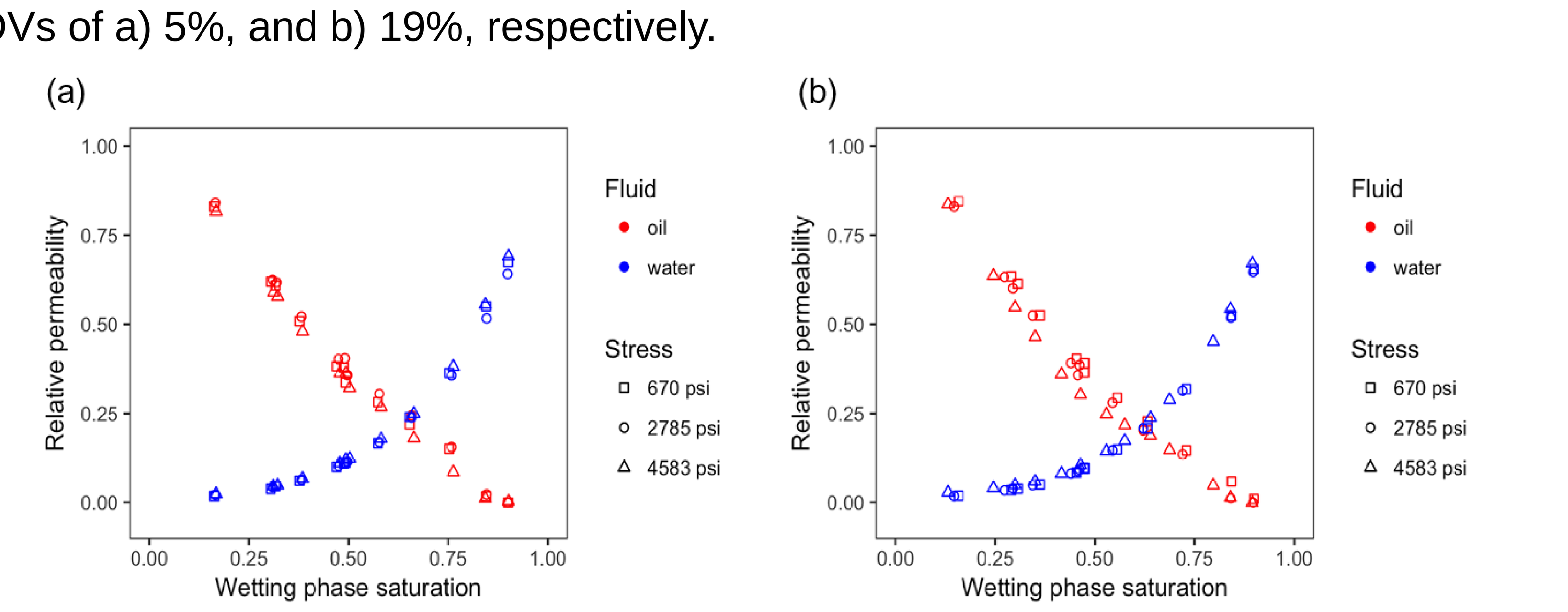


Figure 4. Relative permeability curves determined from pore-scale multiphase LB simulations for the geometries having a) 5% diameter COV; and b) 19% diameter COV.

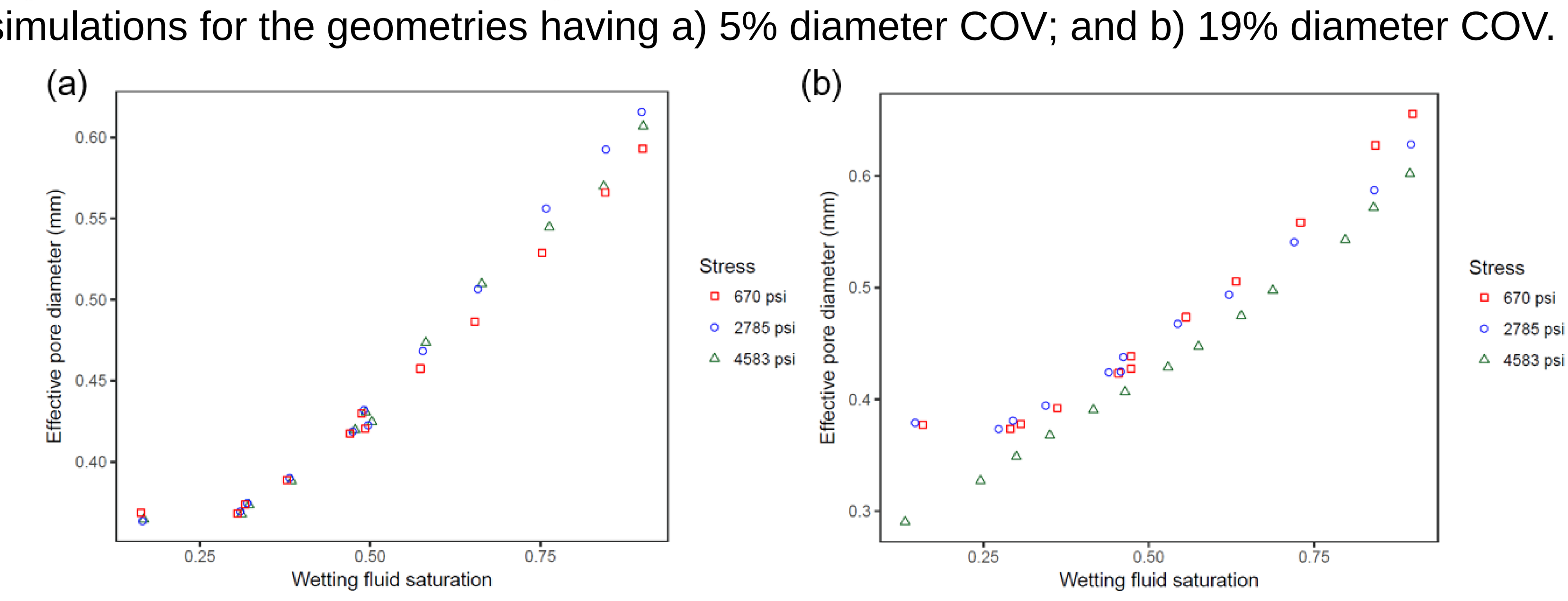


Figure 5. Effective pore diameters for the geometries having a) 5% diameter COV; and b) 19% diameter COV.

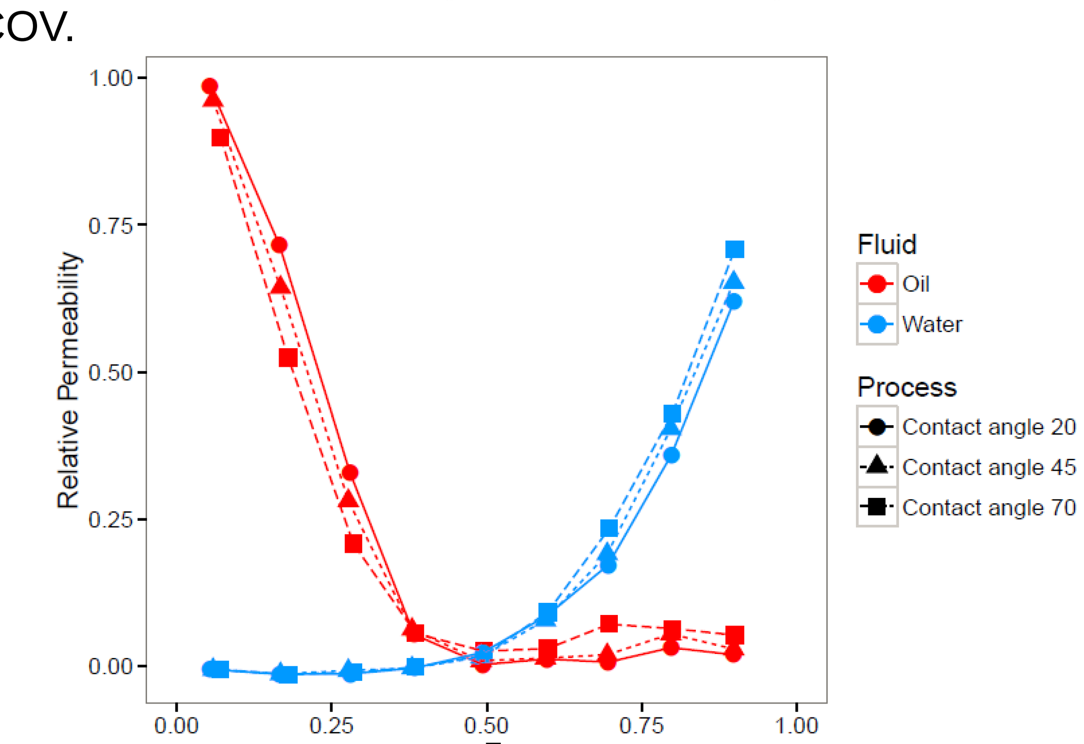


Figure 6. Relative permeability curves determined from pore-scale multiphase LB simulations within a sandstone reservoir for three contact angles 20 °, 45 °, and 70 °.

Conclusions

- Under the same effective stress, a proppant pack with a smaller diameter COV had higher porosity and permeability and smaller fracture width reduction.
- The relative permeability of oil phase was more sensitive to changes in geometry and stress, compared to the wetting phase.
- Relative permeability changes non-monotonically: when effective stress increased continuously, oil relatively permeability increased first and then decreased.
- Both Ca number and contact angle significantly influence the relative permeability curves.

Acknowledgements

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