Impact of Surface Roughness and Contact Line Dynamics on CO_2 Migration

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Alec Kucala[1], Mario Martinez[1], Yifeng Wang[1]

[1]Sandia National Laboratories

Controlling Emergence

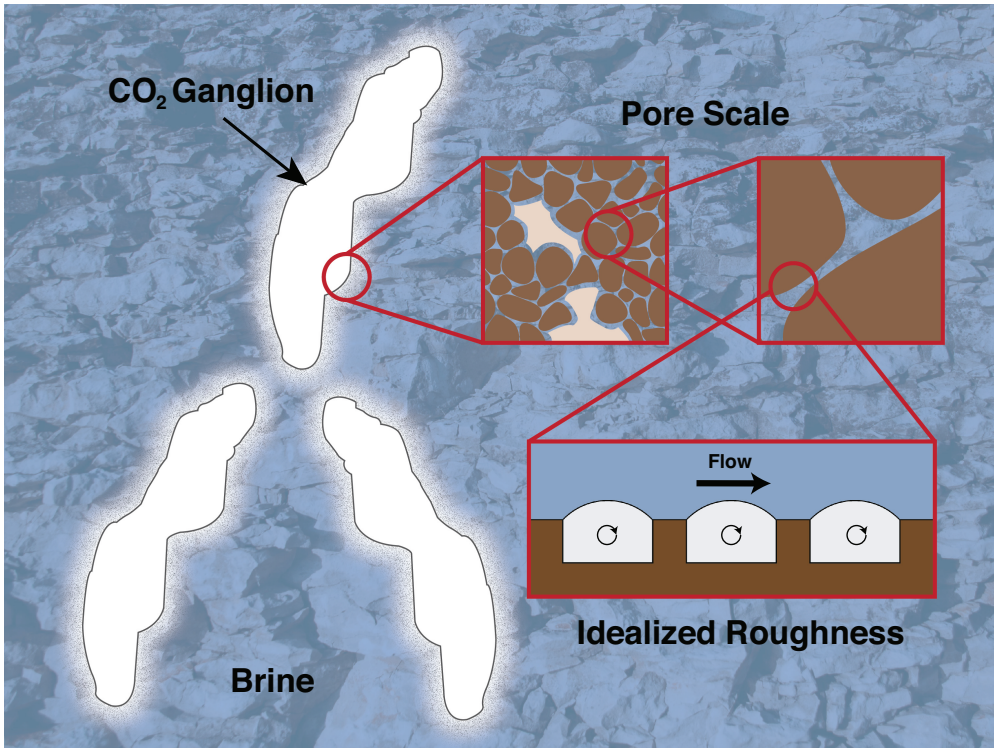
The complicated two-phase flow physics in subsurface reservoirs must be modeled to determine preferential flow paths of CO_2 in residual brines, thus predicting and possibly controlling emergent behavior of these systems.

We investigate the influence of surface roughness an flow slip along the two-phase immiscible interface, where residual brine or CO_2 can be trapped in roughness pores and alter the permeability characteristics of the reservoir.

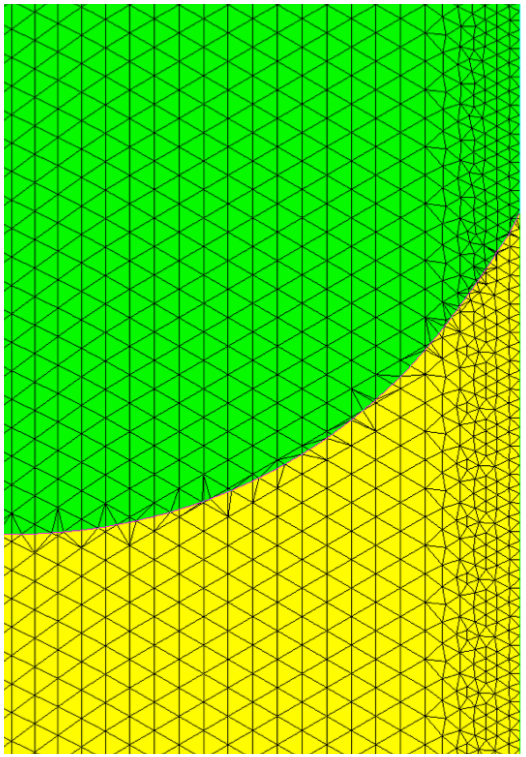
Contact line dynamics also play an important role in the propagation of interface fronts in complicated pore networks during imbibition and drainage processes. Accurate representation of these moving contact line problems is imperative to understanding and predicting emergent behavior in GCS.

Objectives and Methods

- **Use computational fluid dynamics to simulate immiscible two-phase flow**
  - Flow slip in rough pores
  - Moving contact line of immiscible interface

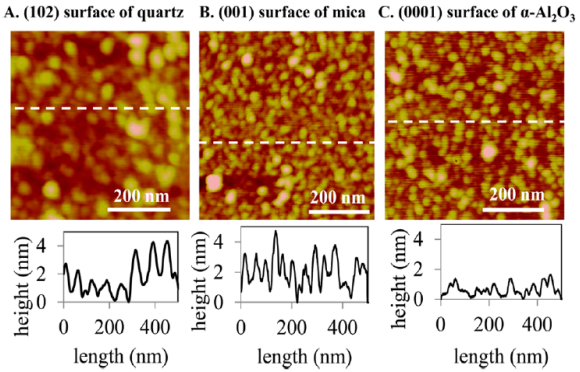


Flow slip in rough pores

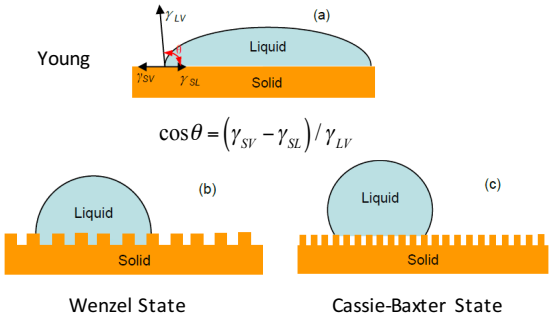


Contact line dynamics

Results – Flow Slip Through Rough Pores

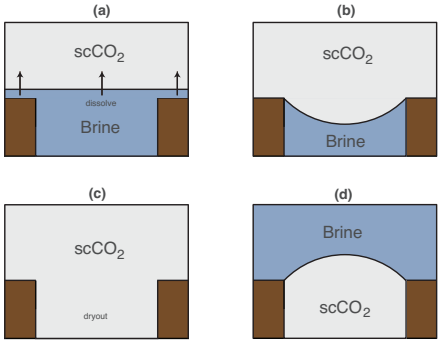


Pore Roughness (Hu et al., 2013)

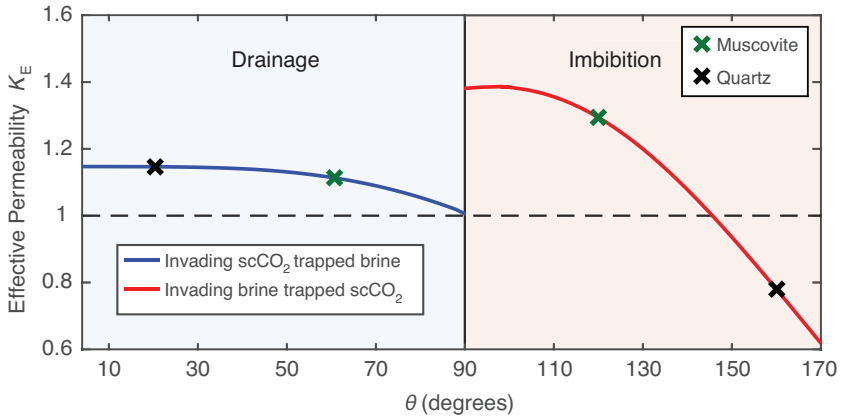


$$\cos\theta = \left(\gamma_{SV} - \gamma_{SL}\right)/\gamma_{LV}$$

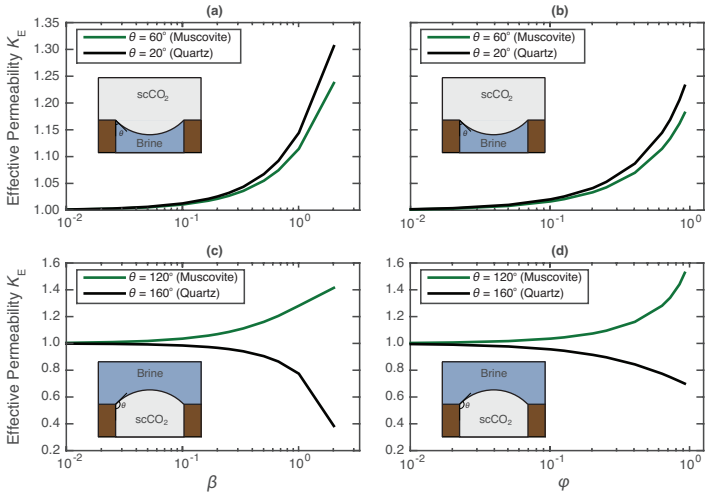
Hydrophobicity introduces slip



Possible flow configurations in CO_2-brine system



Permeability can be enhanced or diminished with respect to surface wettability

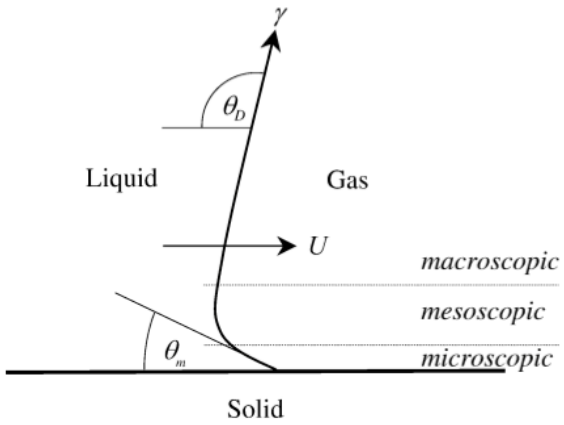


Permeability is enhanced or diminished with increasing roughness

- Kucala, A., Martinez, M. J., Wang, Y. and Noble, D. R.., (2016). "Effect of surface roughness and wetting angle on geologic CO_2 sequestration", *Water Resources Research* (in review).
- Kucala, A., Wang, Y., and Martinez, M. J., "Impact of mineral grain surface roughness on CO_2 ganglion dynamics", *8th International Conference on Porous Media & Annual Meeting,* Cincinnati, Ohio, May 9-12, 2016.

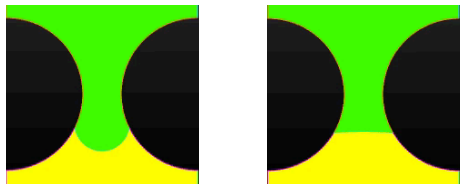
Results – Moving Contact Lines

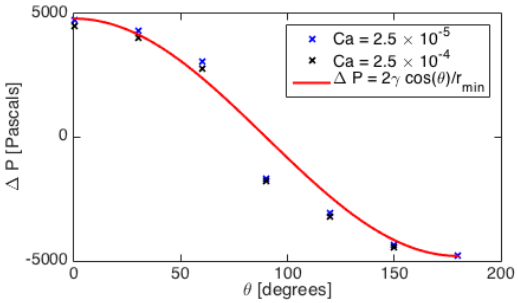
Hydrodynamic models (Blake, 2006)



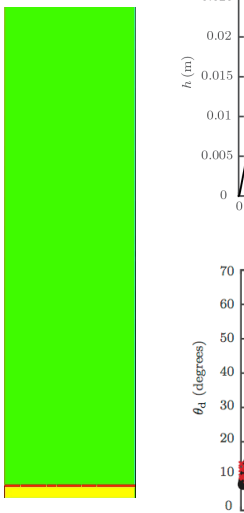
Capillary Pressure Curve

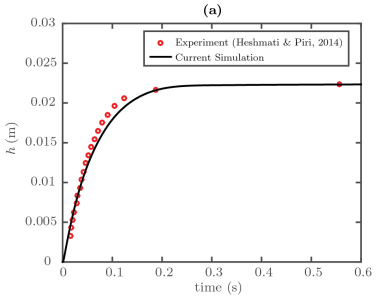
$\theta = 30°$ $\theta = 150°$

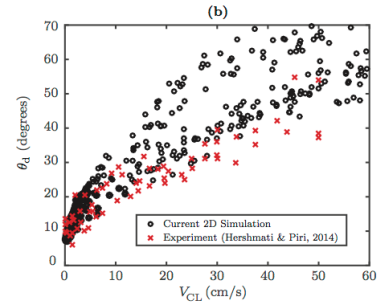




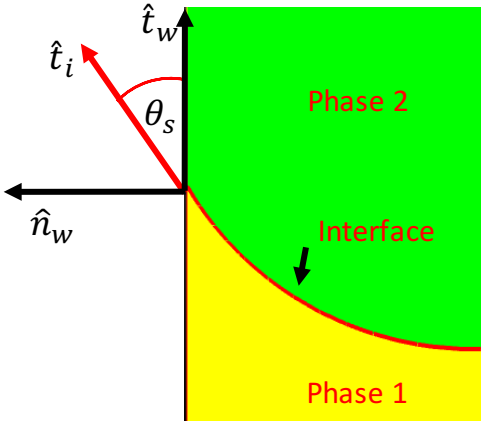
Capillary Rise







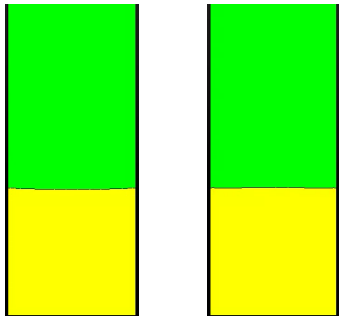
Our recently developed model



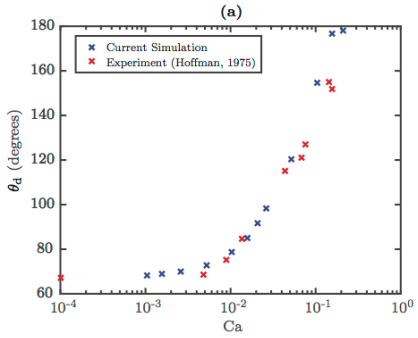
Capillary Injection

Ca = 5.2e-3 (low)

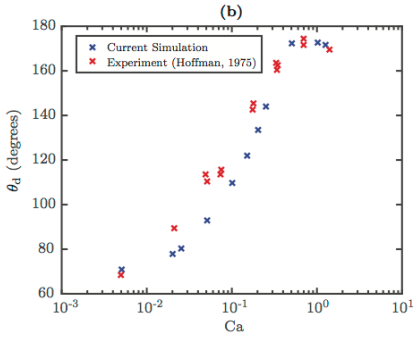
Ca = 4.4e-2 (high)



Sancitizer 405 ($\theta_s = 67°$)

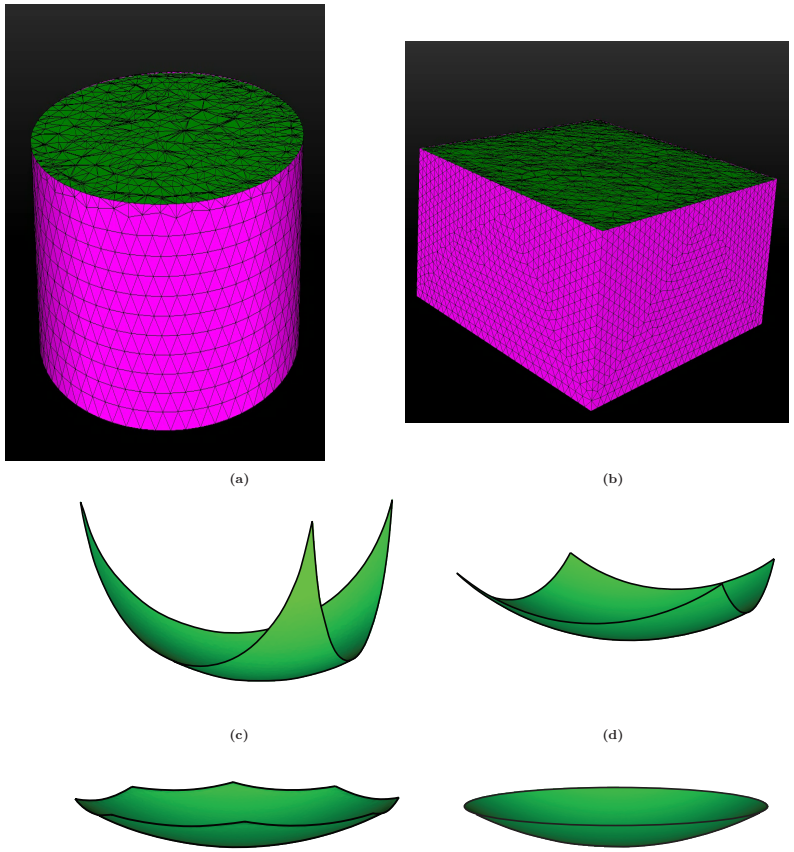


Amdex 760 ($\theta_s = 69°$)



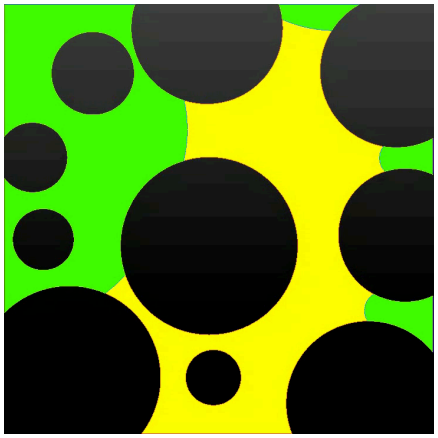
Results – Moving Contact Lines

3D Interface Shapes

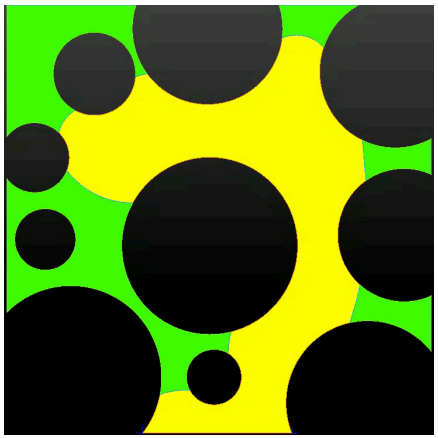


Flow Through a Pore Network

Imbibition



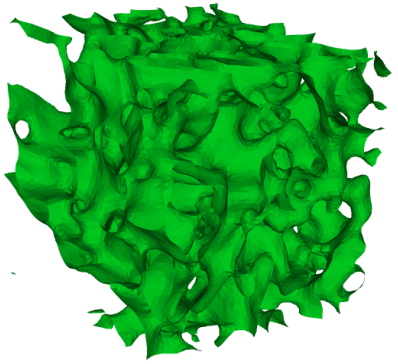
Drainage



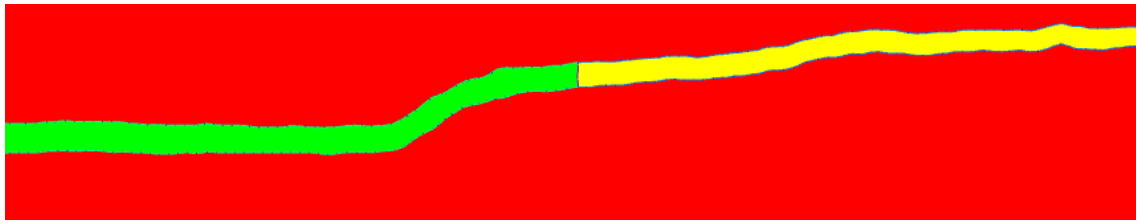
- Kucala, A., Noble, D.R., and Martinez, M. J., "Pore-scale modeling of moving contact line problems in immiscible two-phase flow", *AGU Fall Meeting,* San Francisco, California, Dec. 12-16, 2016.
- Noble, D. R.., Kucala, A., and Martinez, M. J., (2016). "Modeling of moving contact line problems using the conformal decomposition finite element method", (in preparation).

Planned Manuscripts and Future Work

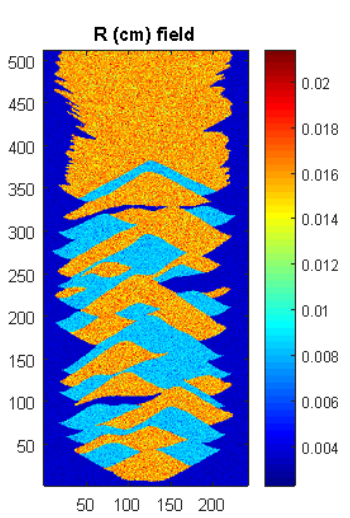
- **Moving contact line problems**
  - Run full 3D simulations in geometry of Boise sandstone CT scans (collaboration with David DiCarlo's group at UT)
  - Simulate two-phase flow through fracture with external stresses
- **Macroscale Darcy flows**
  - Model sandbox experiments from Bob Glass (circ 2001)
    - Compare IP model results
  - Model sandbox experiments of Prasanna

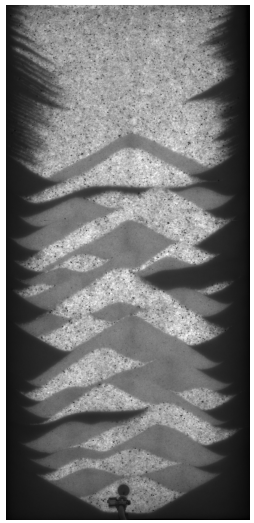


3D micro CT scan of sandstone sample



2D multiphase simulation of flow through a fracture





Compare results with experimental data