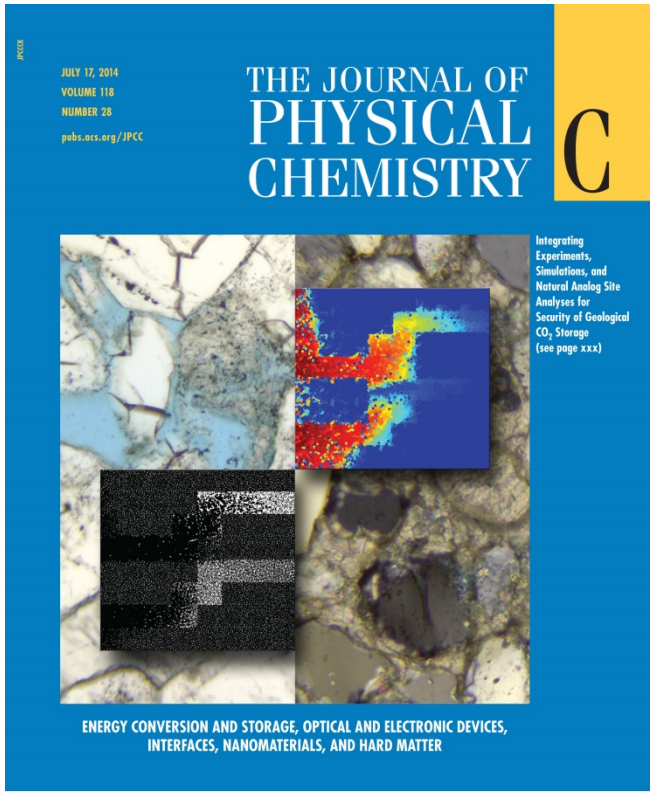
Chemical and Hydrodynamic Mechanisms for Long-Term Geological Carbon Storage



Photomicrographs (background) of unaltered (left) and altered (right) sandstone in the vicinity of a natural CO_2 seepage conduit at Little Grand Wash fault in Utah, USA. Overset images show cementation (left) and normalized concentration (right) fields of pore network modeling developed with an aim to capture emergent behavior resulting from coupling of convection and reaction at the pore-scale.

Scientific Achievement

The integration of pore-scale experiments, molecular dynamics simulations, pore-scale simulations, and the study of natural analog sites has provided useful insight in the efficacy of capillary, solubility, dissolution, and mineral trapping for geological CO_2 storage (GCS).

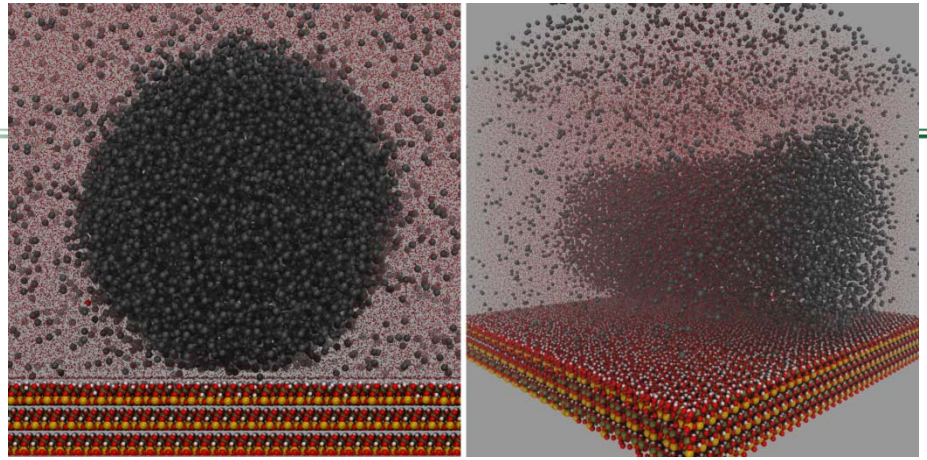
Significance and Impact

A scientific understanding of multiscale, multiphysics processes are needed to ensure safe and economically feasible GCS.

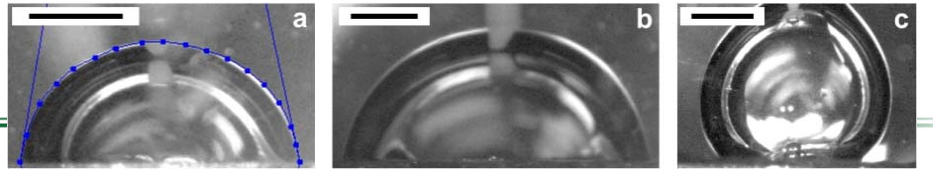
Research Details

- **Nanoscale distribution of wetting and nonwetting phases can differ significantly for different mineral surfaces, impacting macroscopic contact angle measurements**
- **Indication of strongly hydrophilic media offer significant potential for supercritical CO_2 residual capillary trapping**
- **Nanoparticles, with appropriate surface chemistry, could enable an increase in the overall efficiency of large-scale CO_2 storage**
- **Realistic pore configurations, flow and transport physics, and geochemistry are needed to enhance our fundamental mechanistic explanations of how calcite precipitation alters flow paths by pore plugging to match the Little Grand Wash fault observations**

Altman, S.J., et al., 2014. Chemical and Hydrodynamic Mechanisms for Long-Term Geological Carbon Storage. Journal of Physical Chemistry C 118, 15103-15113.

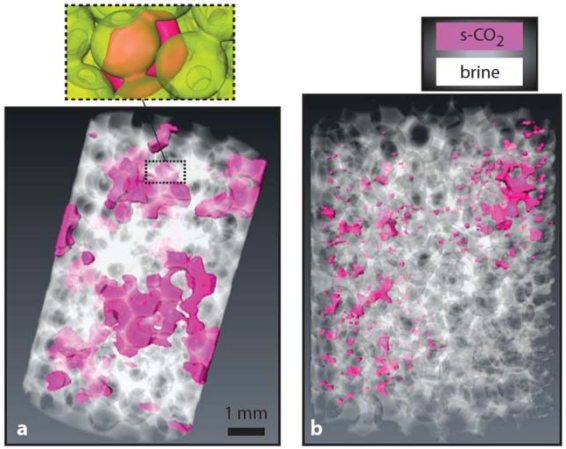


Snapshot of an infinitely long CO_2 "droplet" on the gibbsite surface of kaolinite in the presence of water containing dissolved CO_2



Contact angle measurement of supercritical CO_2 at 333 K and 13.7 MPa (scale bar ~ 1 mm). (a) Silica glass substrate in deionized water, (b) muscovite substrate in deionized water, and (c) muscovite substrate in $CaCl_2$ aqueous solution.

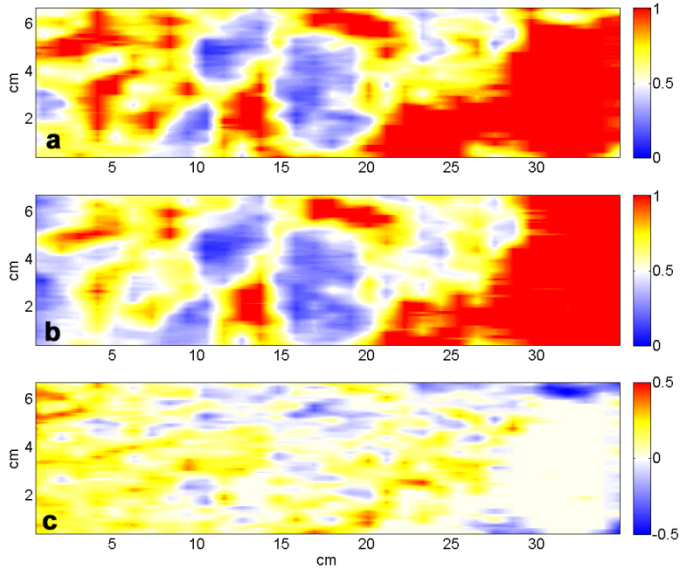
Nanoscale distribution of wetting and nonwetting phases can differ significantly for different mineral surfaces, impacting macroscopic contact angle measurements.



HRXCT images of residually trapped supercritical CO_2 in (a) hydrophilic glass and (b) hydrophobic Teflon beads.

Hydrophobicity of substrate impacts degree of residual trapping (greater trapping with hydrophilic surfaces)

Surface-treated nanoparticles mitigate coalescence of snapped-off droplets of CO_2, controlling wettability and improving storage efficiency



(a) Side view of the brine saturation distribution after injecting 0.25 pore volumes of CO_2 into a brine-saturated Boise sandstone core. (b) Side view of brine saturation distribution after injecting 0.25 pore volumes of CO_2 into a brine (containing 5 wt % nanoparticles)-saturated Boise sandstone . (c) Point-by-point CO_2 saturation difference of the (a) control case and (b) nanoparticle case. Higher CO_2 saturation in the control case is illustrated by cold color and higher CO_2 saturation in the nanoparticle case is red.

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