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Multiphase flow and reactive transport at pore to continuum scales: Application to a natural analogue for leakage

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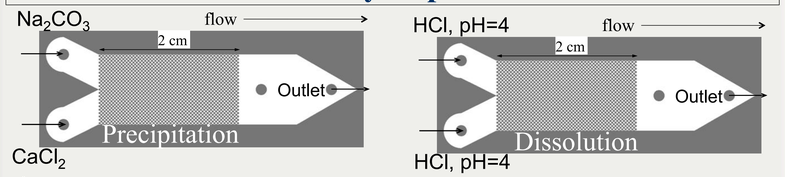
We combine laboratory micro-scale and rock core-scale experimental and modeling efforts to examine:

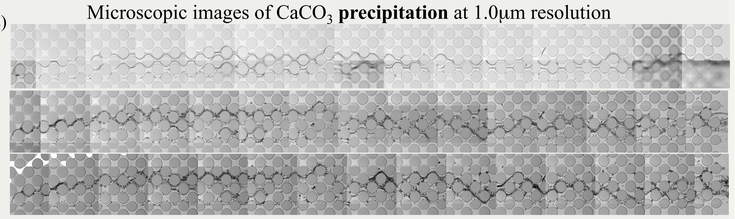
- How does $scCO_2$ interact with brines and mineral surfaces? [**multiphase flow**]
- What are the relevant physics of dissolved CO_2 transport? [**reactive transport and rock-fluid interactions**]
- How can pore scale processes be synthesized and upscaled into more powerful continuum models? [**upscaling**]
- How can observed leakage at local scales like the Crystal Geyser be used to improve the predictive models? [**model development**]

Pore Scale Modeling of Reactive Transport

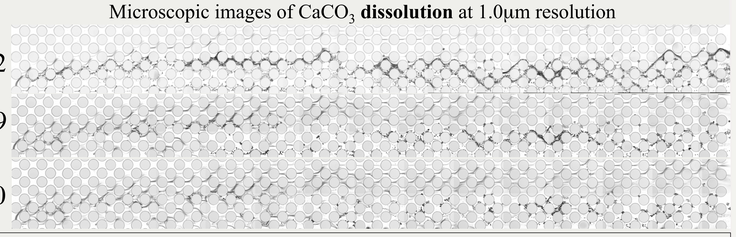
Laboratory Experiments



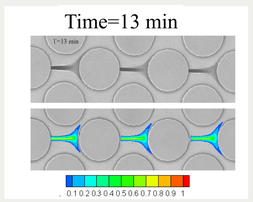
Microscopic images of $CaCO_3$ **precipitation** at 1.0μm resolution

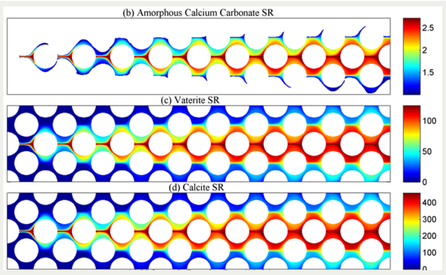


Microscopic images of $CaCO_3$ **dissolution** at 1.0μm resolution



Simulations



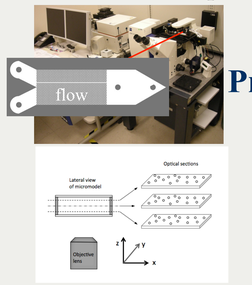


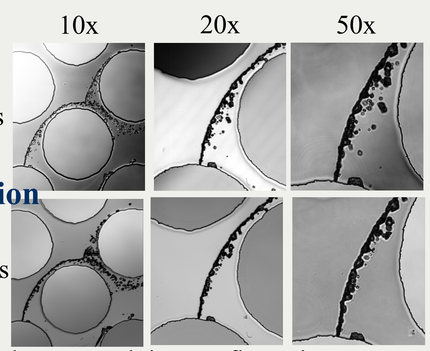
- Simulations capture precipitation observed in the micromodel

Characterizing structural evolution in pores

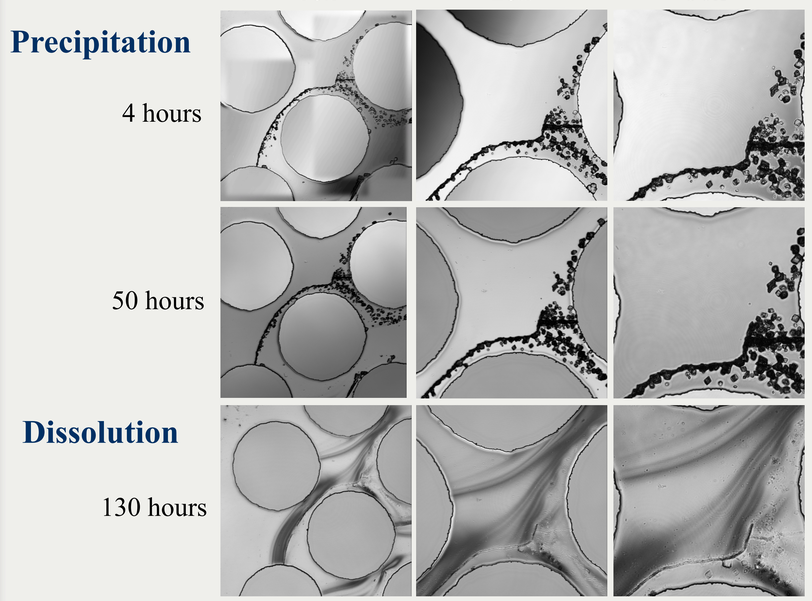
Laboratory Experiments

3D images of $CaCO_3$ in individual pores using laser scanning confocal microscope





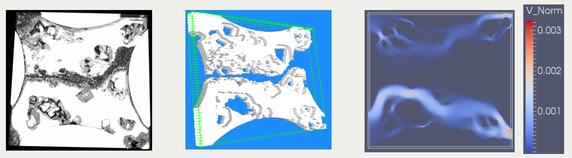
- We observe evolving configurations
- with non-uniform geometries over depth



Simulations

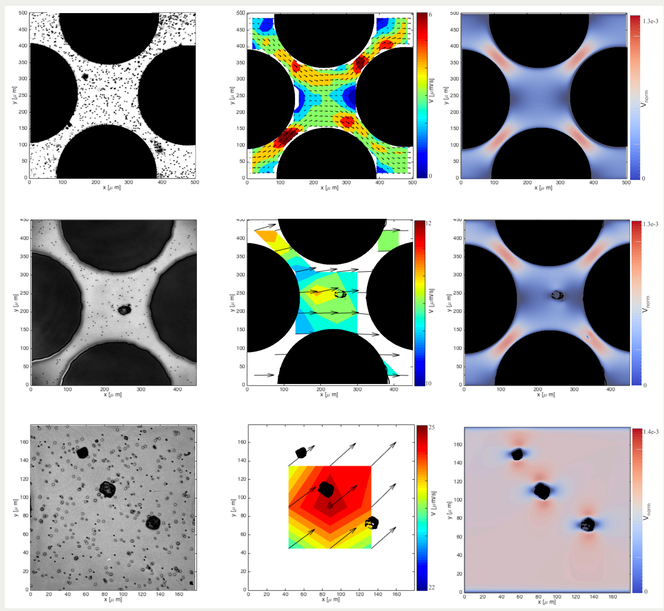
Simulated flow in individual pores

3D pore structure from confocal microscope → Mesh generated from structure image → Simulated flow in pore using Lattice-Boltzmann method



Characterizing 3D flow effects in pores

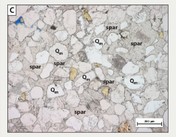
Particle Images | Measured 2D Velocity Field | Simulated 3D Velocity Field



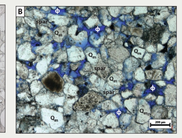
- We observe 3D flow effects in lab and simulations with relatively simple structural configurations

Natural Analogue for Carbonate Sealing of CO_2 Leakage Pathways

Crystal Geyser, Utah

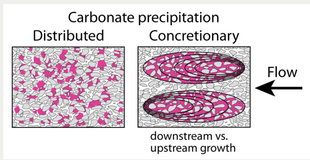


Inside fault zone: Porosity completely filled with calcite spar



Outside fault zone: High porosity and absence of calcite cement

Conceptual model of cementation



Flowrate
Mineral type
Chemistry
(e.g., pH & CO_2 content)

- Reaction rate models for precipitation and dissolution will be developed as a function of system parameters using pore scale model and microfluidic cell experiments based on field observations at the Crystal Geyser natural analogue
- Models developed from pore scale modeling will be used for mortar hybrid modeling of more realistic environmental conditions at larger scales

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