Application of a pore-scale reactive transport model to a natural analog for reaction-induced pore alterations

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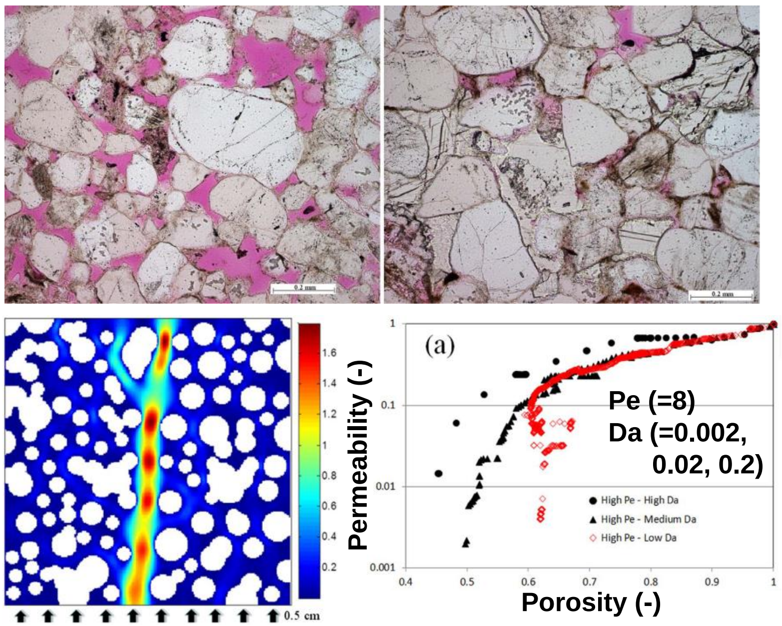

Top: Cementation increase in sandstones at the Crystal geyser field site from left (near fault) to right (far from fault)
Bottom: Velocity field (cm/min) in a porous medium with a high permeable conduit (left) and normalized permeability and normalized porosity evolution with Pe (8) and Da (0.002,0.02,0.2) numbers (right)

Yoon, H., Major, J., Dewers, T., Eichhuble, P. (2017, in press), Application of a pore-scale reactive transport model to a natural analog for reaction-induced pore alterations, Journal of Petroleum Science and Engineering, http://dx.doi.org/10.1016/j.petrol.2017.01.002

Scientific Achievement: **Carbonate cementation significantly increases caprock sealing capacity in fault-controlled CO_2 leakage conduits**

Significance and Impact: **Pore scale reactive transport modeling can reveal the significant impact of hydrological and chemical characteristics on cementation patterns and prediction of fault zone cementation patterns/fault sealing**

Research Details

- Pore-scale reactive transport model qualitatively captures cement precipitation and pore clogging patterns in CO_2 leakage conduits mimicking the Little Grand Wash fault at the Crystal geyser site, Utah
- Pore-scale simulations with representative pore structures can reveal (1) the significance of structural and chemical control of fluid migration and cementation and (2) permeability and porosity relationships for various flow and reaction regimes

Work was performed in the geoscience division at Sandia National Laboratories in collaboration with the Bureau of Economic Geology at the University of Texas at Austin as part of the Center for Frontiers of Subsurface Energy Security (CFSES) (100% CFSES funded)

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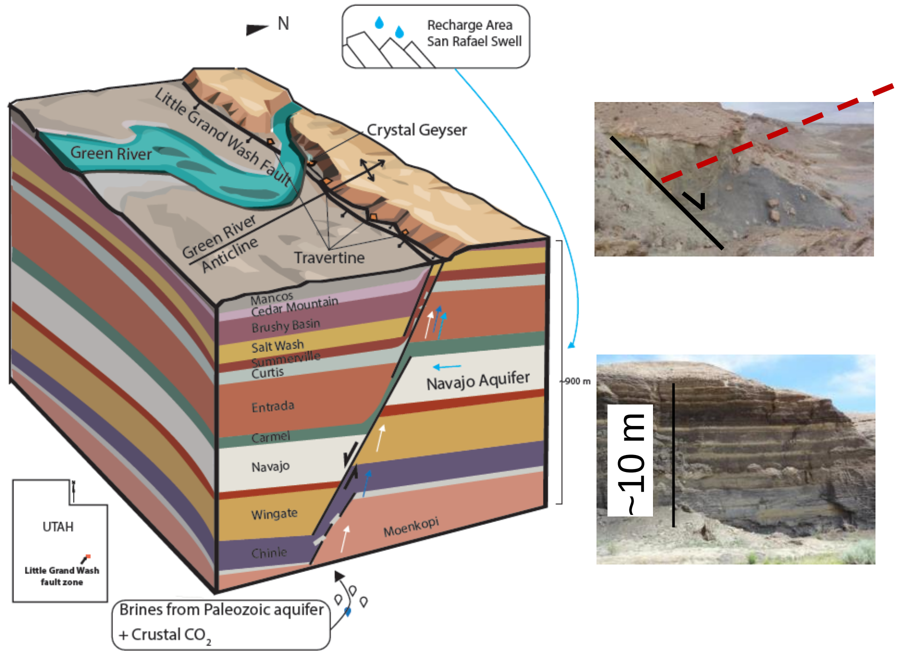
Little Grand Wash Fault, Crystal Geyser, Utah

► Observations along the surface exposure of the Grand Wash fault indicate alteration zones of 10-50 m width with spacing on the order of 100 m

► Locations of conduits controlled by fault-segment intersections and/or topography

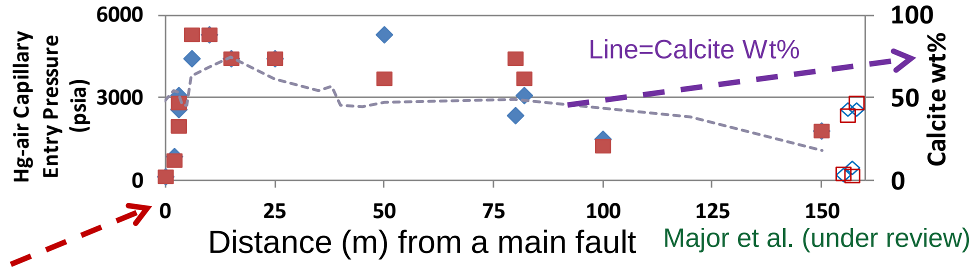
► Sandstone permeability reduced by 3 to 4 orders of magnitude in alteration zones by carbonate cementation



Crystal geyser natural analog site. Schematic of conceptual model of CO_2 leakage along normal faults (left). (Right) Pictures of chemical alteration in Mancos shale hanging wall and thin cementation layers within stratigraphic layers

Mancos Shale Transect

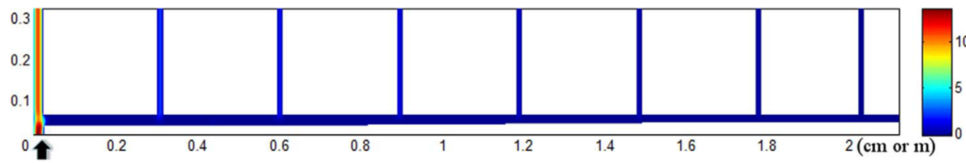
Pc vs. distance from fault (CO_2 alteration intensity)



Major et al. (under review)

► Calcite content is very high near the main fault, peak at ~15 m, remains high by ~100m (background at ~150 m)

► Capillary entry pressure is proportional to the degree of cementation



► Simple 2D pore and fracture networks for modeling

► Flow and chemical conditions based on the literature

► Peclet and Damkohler numbers vary over 2-3 orders

► Calcite cementation and dissolution is considered

► For upscaling of pore-scale modeling results, porosity-permeability relationships are constructed for porous model and two different scales (2 cm vs. 2m) for fracture network

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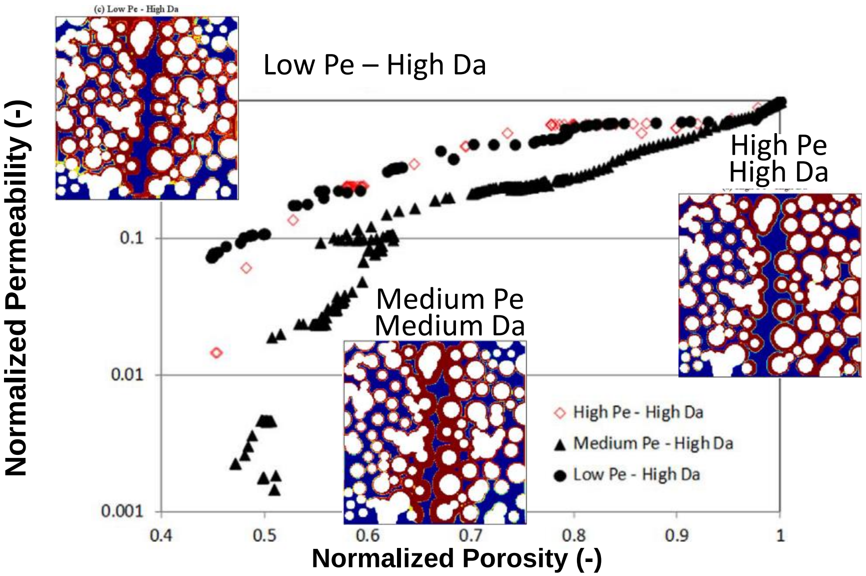
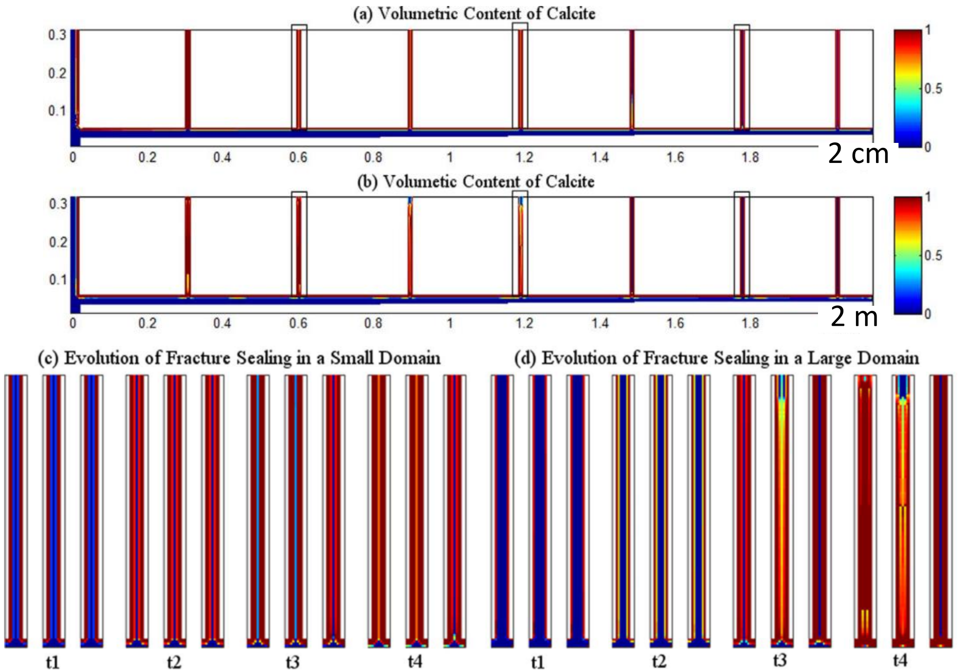
Pore Scale Reactive Transport Modeling Results

Cementation in a Porous Medium



- ► Multiple responses with varying Pe and Da numbers (total 9 cases)
  - cementation changes pores: dynamic flow & reaction paths
- ► Cementation patterns vary near fracture & within porous medium
  - medium Pe-Da has relatively uniform cementation
- ► Porosity-permeability does not follow a power-law for all cases
  - need to test in a full 3D domain

Cementation in a Fracture Network



- ► Relatively uniform cementation patterns over time
  - high Pe/medium Da case in porous medium can be used to explain
- ► Cementation patterns are similar at both 2 cm and 2 m scales
  - given a fracture network, flow & reaction regimes can be scalable

Key Implications

► Fault sealing by cementation is critical to the study of faulted reservoirs and caprocks as this process selectively acts on high permeability sections of a fault (fault-zone permeability reduction and fluid transport potential change)

► Perm-porosity & porosity-reactive surface area constructed from pore-scale simulations can be used in a continuum scale model that may account for large-scale phenomena mimicking lateral migration of surface CO_2 seeps