2023 ARMA Future Leader Webinar Series

Every Two Weeks on Fridays 9-10 AM MT

9th lecture: July 14, 2023

Please reach out to shahrzad.roshankhah@utah.edu to get the Zoom meeting information.

Speaker: Brandon Schwartz

(in collaboration with Anne Menefee)

Title & Abstract:

Geomechanical Considerations when Determining the Value of Mineralization during Geologic Carbon Sequestration

Mineralization during geologic carbon sequestration is typically viewed as the most stable form of long term storage. Projects show significant precipitation within 10-50 years of CO_2 injection in ultra-mafic rocks, and such results have led to a "premium" being charged for mineralization at sites such as Carbfix. Anecdotally, rapid mineralization has been opined to have its drawbacks, including lost injectivity before scheduled injection is complete; however, this is not observed in the field. In this talk, we will first present a model that quantifies the value of mineralization relative to saline aquifer storage with dissolution trapping. We explore three mineralization rates reflective of rapid pilot scale mineralization, field scale mineralization rates with carbonated brine injection, and field scale rates with bulk CO_2 injection. Model inputs are selected by comparing leakage risk in a sedimentary reservoir versus a reactive reservoir with active mineralization occurring. Leakage risk is prescribed to determine the impact of mineralization on potential a) tax credit forfeiture (at $85/ton for amine separation, $180/ton for direct air capture (DAC)), b) adjustment to the levelized cost of CCS, and c) remediation activities once a leak is detected. Other considerations include d) the upfront cost savings for reduced trust fund requirements (i.e., a reservoir with 100% mineralization before the start of the PISC period has fewer requirements for upfront trust deposits), as well as e) added costs of carbonated brine injection. Our results show that for realistic leakage scenarios (0% to 5% of total injected volume), mineralizing the CO_2 has a value between -$0.80/ton to $12/ton.

Having established a monetary value to pursue mineralization, we then turn our attention to the geomechanical response of a reservoir undergoing mineralization within pores and fractures. Geologic media typically have a bimodal pore size distribution (PSD), with pore diameters on the order of nanometers to micrometers. We model mineralization rates as a function of pore diameter and find that smaller pores may fill with precipitates at a faster rate than macropores due to the pore's solid surface area (which donate cations) relative to the volume of fluid in the pore. The concentration of reactants donated from the solid relative to concentration of anions in solution is captured by the ratio SA/PV. Smaller pores also begin to transition flow regimes to slower velocities, as captured by the Péclet number and Damköhler numbers (Pe, Da_I, Da_{II}). As a result, permeability loss may be negligible in geologic media with bimodally distributed pores, which is consistent with field observations. Lastly, we consider the alteration in mechanical properties with calcite coating internal pore boundaries. We find that stress-dependent permeability loss decreases as pore boundaries transition to stiffer mineral

components (calcite). The increase in pore stiffness corresponds to an increase in bulk mechanical strength. Finally, we consider the impact of calcite coating on two-phase flow typically found in carbon sequestration; and suggest that wettability, contact angle, and relative permeability begin to collapse towards curves for calcite given a particular PSD. Our models show that under the right circumstances, mineralization may enjoy several benefits over saline aquifer storage in sedimentary reservoirs, including lower risk of leakage, negligible loss of permeability, and increased mechanical strength.

Biography:

Dr. Brandon Schwartz is currently an Assistant Research Professor in the Department of Energy and Mineral Engineering at Penn State University with expertise in the areas of experimental geomechanics and dynamic rock physics modeling. His research focuses on how internal pore structure and rock fabric influences transport and mechanical property evolution during thermal, mechanical, hydrologic, and chemical processes in porous and fractured geologic media. His interests are in characterizing the deformation-driven impacts of fluid injection, flow, and storage on rock and fluid properties with application to carbon sequestration, induced seismicity, nuclear waste disposal, unconventional reservoirs, and hydrogen storage in underground salt caverns. His work contributes to multiscale characterization of fundamental processes that govern emerging energy and environmental applications.