CO_2 storage in fractured basalt: Coupling experimental analyses with reactive transport modeling

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Fractured basalt reservoirs hold promise as CO_2 storage repositories, as the trapping of injected CO_2 as stable carbonate precipitates could provide long-term secure CO_2 storage. However, the evolution of fracture microstructure and permeability after CO_2 injection will control the viability of these reservoirs for geologic CO_2 sequestration activities.

Here, we apply reactive transport modeling to simulate and extend experimental investigations of these processes. A series of CO_2-water core flooding experiments examined two different basalts, a serpentinized and a flood basalt, exposed to flow of CO_2-acidified water under representative geologic storage conditions. Dissolution was more pronounced for both rocks when exposed to higher salinity water representative of typical reservoir fluids, but variation in temperature from 45°C-100°C was found to have less of an impact on dissolution rates.

A predictive modeling framework was developed to evaluate the role of mineral spatial distribution in controlling fracture permeability evolution by linking high-resolution imaging techniques with reactive transport modeling. Backscattered electron imaging and energy dispersive spectroscopy are used to identify specific mineral phases within X-ray computed tomography (XCT) data of the basalt cores. Mineral segmentation data from the processed XCT scans serves as input for two-dimensional reactive transport simulations designed to investigate the flow of CO_2-saturated water through fractured basalt. The reactive transport code CrunchFlow is used to follow the evolution of reactive mineral phases and solution composition along fracture pathways. Effluent chemistry data from the core flooding experiments complement simulation results. Reactive transport modeling coupled with experimental validation allows us to extend our work to greater spatial and temporal scales than can be achieved in lab. This approach offers insight into the implications of mineral distribution, heterogeneities, and reactivity on the long-term security and viability of CO_2 sequestration in basalt formations.