Hydrologic and geochemical responses to CO_2 injection in basalts based on flow-through experiments

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Basalt-CO_2 experiments have increased our ability to predict geochemical responses within mafic rocks during geologic CO_2 sequestration, but the lack of flow-through experiments prevents the use of coupled hydrologic-geochemical models to predict evolution of permeability and porosity, critical parameters for assessing storage feasibility. We present results of three flow-through experiments during which we employed X-ray Computed Tomography (CT). We injected CO_2-saturated water into an intact core of glassy basaltic tuff from the Snake River Plain (Φ: 34%) at reservoir conditions (90 bar, 50°C) at 5.5 ml/min for ~3.5 hours. Before and after the CO_2 injection, we performed tracer tests using a solution of NaI (~100,000 ppm) to analyze changes in flow path distribution. During the tracer tests, CT scans were taken every 2.5 minutes, and outlet fluid was sampled at the same intervals, enabling interpretation of the tracer breakthrough curve by imaging and geochemical analysis. Increase in aqueous solute concentrations after CO_2 injection implied dissolution. However, CT-derived core-averaged porosity values decreased, which is inconsistent with geochemical observations and implies porosity underestimation due to incomplete drying of the core before CT scanning. Porosity determination by thin section analysis and by mass balance confirms instead an overall porosity increase of 0.5-2%. During CO_2-saturated flow, permeability decreased from ~4.9×10^{-12} m^2 to 1.18 $\times 10^{-12}$ m^2, but no secondary precipitates were identified in the reacted core. We hypothesize that fine-grained shards of glass, mobilized via the dissolution of microporous glassy cement, clogged pore throats and resulted in decreased permeability. Imaging of tracer distribution in the core shows changes in flow path spatial heterogeneity and the appearance of "dead-end pores," areas with longer fluid-residence times. In summary, we show that geochemical evidence is essential for confirming CT interpretations, and that basalt-CO_2 interactions result in significant modifications of transport properties.