Geochemical-isotopic systematics, geothermometry, and THMC models of the Newberry Volcano Enhanced Geothermal System

ERIC L. SONNENTHAL[1], TRENTON CLADOUHOS[2], SHAUN T. BROWN[1], JOHN N. CHRISTENSEN[1], J. TORQUIL SMITH[1], NICOLAS F. SPYCHER[1], MARK E. CONRAD[1], B. MACK KENNEDY[1], LI YANG[1] AND PATRICK F. DOBSON[1]

[1]Lawrence Berkeley National Lab, elsonnenthal@lbl.gov
[2]AltaRock Energy, tcladouhos@altarockenergy.com.

Development of an Enhanced Geothermal System (EGS) requires stimulating fractures within a large volume of low permeability rock. EGS evaluation is done primarily by separate analyses of injectivity, temperatures, tracer returns, microseismicity, geochemical data, and reservoir modeling. Despite widespread use of isotopes for geothermal systems, few have been integrated rigorously into coupled thermal-hydrological-chemical-mechanical (THMC) models. At Newberry Volcano (Oregon, USA) about 10 million liters of groundwater was injected in 2014 over a 3-week period into volcanic/intrusive rock to a depth of over 3000m. Initial temperatures of 220-330°C in the open borehole were lowered by ~150°C, at flow rates of ~7-8 kg/s. To evaluate the spatial extent of permeability changes associated with shear/tensile failure, fracture porosity, surface area, and aperture, combined with THMC modeling, we collected water and gas samples during a post-injection flowback and measured aqueous and gas geochemistry, Ca, Sr, O, H, and He isotopes. Multicomponent geothermometry using GeoT, empirical, and sulfate-water isotope geothermometers yielded water-rock interaction temperatures of 230-250°C, indicating reactions with feldspars, pyrite, quartz, calcite, and Fe-Mg silicates in fractures outside the borehole. Although injected groundwater has a Sr isotopic ratio close to the mean value in surface basalts, flowback waters show shifts toward more radiogenic pre-Newberry Miocene-Pliocene tuffs. Ca isotopic ratios show effects of calcite dissolution and precipitation. He R/Ra values in gas over 8, as well as increased Cl concentrations in flowback water, indicate mixing of injected groundwater with small amounts of magmatic-geothermal fluid. THMC models of the injection include mineral-water-gas isotopic systems using a thermodynamic-kinetic solid-solution approach developed for the TOUGHREACT code. Simulations show calcite precipitation adjacent to the wellbore, and dissolution in fractures away from the wellbore, consistent with the observed isotopic changes, providing independent constraints on fracture property evolution.