Predictive Modeling of Fracture Generation and Fluid Circulation and Comparisons to Observations for a Meso-Scale Enhanced Geothermal System Experiment – EGS Collab Project

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Abstract

The United States Department of Energy, Geothermal Technologies Office (GTO) is funding a collaborative investigation of enhanced geothermal systems (EGS) processes at the meso-scale. This study, referred to as the EGS Collab project, is a unique opportunity for scientists and engineers to investigate the creation of fracture networks and circulation of fluids across those networks under in-situ stress conditions. The EGS Collab project is envisioned to comprise three experiments and the site for the first experiment is on the 4850 Level (feet below surface) in phyllite of the Precambrian Poorman formation, at the Sanford Underground Research Facility, located at the former Homestake Gold Mine, in Lead, South Dakota. Principal objectives of the project are to develop a number of intermediate-scale field sites and to conduct well-controlled in situ experiments focused on rock fracture behavior and permeability enhancement. Data generated during these experiments will be compared against predictions of a suite of computer codes specifically designed to solve problems involving coupled thermal, hydrological, geomechanical, and geochemical processes. Comparisons between experimental and numerical simulation results will provide code developers with direction for improvements and verification of process models, build confidence in the suite of available numerical tools, and ultimately identify critical future development needs for the geothermal modeling community. Moreover, conducting thorough comparisons of models, modelling approaches, measurement approaches and measured data, via the EGS Collab project, will serve to identify techniques that are most likely to succeed at the Frontier Observatory for Research in Geothermal Energy (FORGE), the GTO's flagship EGS research effort. As noted, outcomes from the EGS Collab project experiments will serve as benchmarks for computer code verification, but numerical simulation additionally plays an essential role in designing these meso-scale experiments.

This paper describes specific numerical simulations executed to direct the design of experiments for creating fracture networks between two boreholes and the circulating fluids and tracers across the generated fracture network. Numerical simulations were additionally executed to forecast specific experimental outcomes, such as how the injection pressure changed with fracture propagation, arrival curves for conservative tracers, and pressure drop across the fracture network as a function of production hole pressure. Experiment 1 of EGS

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Collab is designed to investigate the generation of two hydraulic fractures from notched sections of the injection borehole and then fluid circulation between sub-horizontal injection and production boreholes in each fracture individually and collectively, including the circulation of chilled water. Whereas the mine drift allows for accurate and close placement of monitoring instrumentation to the developed fractures, active ventilation in the drift cooled the rock mass within the experimental volume. Numerical simulations were executed to predict seismic events and magnitudes during stimulation, initial fracture orientations for smooth horizontal boreholes, pressure requirements for fracture initiation from notched boreholes, fracture propagation during stimulation between the injection and production boreholes, tracer travel times between the injection and production boreholes, and produced fluid temperatures with chilled water injections, and pressure limits on fluid circulation to avoid fracture growth.