Analysis of flow and pressure data for the estimation of fracture generation and propagation – first model results from coupled hydromechanical experiments in COSC-1 borehole in deep crystalline rock, Åre, Sweden

Farzad Basirat^1, Chin-Fu Tsang^1,2, Alexandru Tatomir^1, Yves Guglielmi^2, Patrick Dobson^2, Paul Cook^2, Chris Juhlin^1, and Auli Niemi^1

^1Uppsala University, Earth Science, Uppsala, Sweden
^2Lawrence Berkeley National Laboratory, USA

Characterization of the coupled hydro-mechanical properties of rock fractures has become an increasingly important field of geosciences research, relevant for a number of key applications. Examples include analysis of enhanced geothermal systems, hydraulic fracturing operations, CO₂ geological storage, nuclear waste disposal and mining operations. A newly developed technology that allows conducting advanced experimentation of the coupled HM processes in the field is the step-rate injection method for fracture in-situ properties (SIMFIP) by Guglielmi et al. (2014). The SIMFIP method is unique in that it measures simultaneously the time evolution of flow rate, pressure and 3D deformation of a packed off borehole interval.

During June 2019 a field campaign was carried out in Åre, Sweden, where the SIMFIP was applied in the COSC-1 scientific borehole to estimate the fracturing and fracture propagation behavior during hydraulic stimulation in some previously well-characterized rock sections. Three intervals were investigated: an unfractured section (intact rock) at 485.2 m depth, a non-conductive steeply dipping fracture at 515.1 m depth, and a section with a gently dipping hydraulically conductive fracture at 504.5 m depth (Niemi et al., in prep.).

As a first step for analyzing the results, this work aims to develop a simple hydrologic model for the interpretation of the collected pressure and flow data during different stages of the experiments. Modeling has been used to estimate the key parameters of the induced and propagated fractures such as the length, aperture and geometry, based on the pressure response during the water injection and abstraction steps. A numerical model based on COMSOL Multiphysics combining the fluid flow within the fracture and rock domains was developed and the permeability of fractures was defined by the well-known cubic law function of the local fracture aperture. The initial low injection-pressure data for the test interval without any fracture were used to find the parameters of the packed off borehole interval. Consequently, these parameters were used in the analysis of the case with a conducting fracture, as well as the case with a non-conducting fracture. Models in agreement with the observed pressures and injection flow rates could be defined for all the three cases, allowing parameters to be estimated for the length and
aperture of the induced fractures in each case.


Niemi, Auli, Yves Guglielmi, Patrick Dobson, Paul Cook, Chris Juhlin, Chin-Fu Tsang, Benoit Dessirier, Alexandru Tatamir, Henning Lorenz, Farzad Basirat, Bjarne Almqvist, Emil Lundberg and Jan-Erik Rosberg 'Coupled hydro-mechanical experiments on fractures in deep crystalline rock at COSC-1 – Field test procedures and first results'. Manuscript under preparation, to be submitted to Hydrogeology Journal.