Transient hydraulic tomography for characterizing hydraulic properties and connectivity of the major fractures

Klepikova Maria V., ETH Zurich, Geological Institute, Zurich, Switzerland
Mohammadreza Jalali, ETH Zurich, Geological Institute, Zurich, Switzerland
Bernard Brixel, ETH Zurich, Geological Institute, Zurich, Switzerland
Florian Amann, RWTH Aachen, Aachen, Germany

Key words: inverse modelling, fractured media, DFN, hydraulic tomography

The accurate characterization of the hydraulic properties, and connectivity of major fracture zones is essential to model flow, solute, heat and fluid pressure propagation in fractured media. In this study the spatial variability of transmissivity and storativity of a fracture network was investigated through field and numerical hydraulic tomography experiments. Several injection tests were performed at the Grimsel Test Site (GTS) in Switzerland as part of a pre-stimulation characterization survey in the framework of the In-situ Stimulation and Circulation (ISC) experiment [1]. The GTS is located in crystalline rock referred to as Aar Granite and Grimsel Granodiorite, characterized by the average transmissivity of the intact rock in the order of 10^{-13} m^2/s. The rock mass is intersected by the S3 shear zone, target zone for the hydraulic stimulation injections, consisting of a fracture zone bound by two metabasic dikes on either side, and the transmissivity ranging from 10^{-12} to 10^{-6} m^2/s.

Cross-hole injection tests were conducted in a tomographic configuration, with pressure responses monitored at five observation intervals located within the S3 shear zone at various depths in two different boreholes at the site. A simplified discrete fracture network approach is developed to estimate log-transformed transmissivity (T) and log-transformed storativity (S) values of hydraulically active fractures between the pumping and observation wells by inverting the pressure responses, under the hypothesis that T and S are independent functions. We identified several transmissive fractures and their connectivity without considering fracture geometry (length, orientation, dip) with most calibrated responses capturing well the observed transient pressure behaviors. Moreover, we demonstrate that assuming that both storativity and transmissivity are heterogeneous within the shear zone, more consistent fit of observed pressure measurements is obtained. Hence, the proposed tomography approach appears to be a promising approach for characterizing connectivity patterns and hydraulic properties of the main flow paths in fractured rock.

References

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