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High-resolution cross-borehole thermal tracer testing in granite: preliminary field results

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Understanding how heat is transported, stored and exchanged across fractured media is becoming increasingly relevant in our society, as manifested from the growing popularity of modern technologies relying on the subsurface to either source or store heat. One good example is the utilization of heat from deep hydrothermal or petrothermal systems to generate electricity for base load power generation, a technology also known as deep geothermal energy (DGE). While very attractive in principle, the number of geothermal fields producing economical levels of electricity to this day is still very limited – largely due to the difficulty of either locating deep reservoirs that are both sufficiently hot and permeable or, in the absence of the latter, creating them.

In this context, the Swiss Competence Center for Energy Research - Supply of Electricity (SCCER - SoE) is carrying out an in situ stimulation and circulation (ISC) experiment at the Grimsel Test Site (GTS), an underground rock lab located in the Aar massif, in the Swiss Alps. The circulation experiment planned for the post-stimulation phase represents one of the key components of this experimental research program, and the outcome of this test is expected to ultimately provide key insights in the factors controlling the performance of enhanced geothermal reservoirs. Therefore, to support the design of this experiment, short-term thermal tracer tests (TTT) were conducted with the objective to (i) assess the feasibility of conducting TTTs in a relatively intact granite (where fluid flow is controlled by a limited number of discrete fractures); (ii) determine optimal experimental setups; and to ultimately (iii) monitor thermal breakthroughs at high spatial and temporal resolution, providing insights on heat transport and complementing the characterization of hydrogeological conditions carried out through conventional means (e.g. hydraulic and/or solute tracer tests).

Presented herein are the results of a 10-day thermal tracer test conducted by continuously injecting water at 40°C (ambient groundwater temperatures average around 12-13 °C) across a discrete fractured zone, isolated with packers. Monitoring was achieved using a combination of discrete temperature sensors (PT1000) and FO DTS (Silixa XT system) deployed along a network of both packed-off and open boreholes situated approx. 6-20 m apart from the injection zone. Thermal breakthrough was observed in multiple boreholes, as early as 6-7 hours following the injection of hot water. The rate of increase in temperatures was observed to significantly diminish over time, allowing water in the fracture carrying the majority of heat to reach a temperature of 17°C at the closest observation location. Furthermore, temperature declined along the fracture length. These data allowed us identifying the precise location of conductive fractures, thereby improving our understanding of the connectivity structure of our experimental rock volume. In addition, these results provide significant insights on heat transport and the efficiency of heat-exchange between fractures and the surrounding rock mass at Grimsel.