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Hydro-thermal experiments and simulations within a granitic fracture

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The porous medium that we consider is a fracture with impermeable walls that have a complex topography. Our study aims at addressing the heat and mass transport which occurs during the injection of cold water into a fracture, initially filled with warm water and embedded in a warm rock. The characterization of such transfers is relevant to, for instance, hydrothermal circulations occurring at depth, or use of temperature measurements as a tracer of flow pathways. The fluid-rock interface separates exclusively-diffusive from advecto-diffusive processes where the water flows, and the heat diffusion is different in the water and rock. We look at the shape of the isotherm lines (in two dimensions) or surfaces (in three dimensions – 3D) through time, until steady state is reached. We have both numerical and experimental approaches.

The numerical simulations are done with a coupled lattice Boltzmann method that solves both the complete Navier-Stokes and advection-diffusion equations in 3D. The experimental setup has been developed in order to adjust the scaling of our simulations and further investigate the complexity of the hydro-thermal exchange. In this setup, an infrared camera and thermistors are used to monitor the temperature in space and time. Water is injected through a partly natural rough fracture: the bottom part is a granitic bloc with a rough wall, and the top part is a flat layer which is transparent in the infrared range. The surface of the granitic bloc has been digitized using a photogrammetry software (MicMac, developed by the French Institut Géographique National). This digitized surface is then transformed into a 3D mask showing void spaces and rock (digitized porous medium), and is used for the 3D hydro-thermal simulations.

We will first present a numerical simulation where the geometry of the fracture consists of flat parallel walls perturbed by a single cavity. Then we will present experimental observations of the temperature done using a granitic rock surface, and we will compare these observations with numerical simulations. The isotherms show sharp variations at the fluid-rock interface, and they evolve in a complex way through time: some areas cool down and reheat alternatively several times.