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Characterization of shallow geothermal efficiency in fractured media through thermal tracer tests and numerical modeling

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Geothermal energy is a renewable energy source particularly attractive due to associated low greenhouse gas emission rates. Crystalline rocks are in general considered of poor interest for geothermal applications at shallow depths (< 100m), because of the low permeability of the medium. In some cases, fractures may enhance permeability, but thermal energy storage at these shallow depths is still remaining very challenging because of the low storativity of the medium. Within this framework, the purpose of this study is to test the possibility of efficient thermal energy storage in shallow fractured rocks. For doing so, several heat tracer tests have been carried on in a single well between two connected fractures. We completed this experimental work with numerical modeling of thermal transport in fractures embedded in an impermeable conductive matrix.

The thermal tracer tests were achieved in a crystalline rock aquifer at the experimental site of Ploemeur (H+ observatory network). The experimental setup consists in injecting hot water in a fracture isolated by a double straddle packer in the borehole while pumping and monitoring the temperature in a fracture crossing the same borehole at greater elevation. Several tracer tests were achieved at different pumping and injection rates. This experimental set up allowed to estimate temperature breakthrough for different tracer test durations and hydraulic configurations from fully convergent to perfect dipole tracer tests. Thanks to those tests and numerical modeling of heat transport in fractures, we demonstrate that temperature recovery is highly dependent on flow rate and streamlines shape. Thus, thermal storage rate is inversely proportional to flow and is maximized in perfect dipole configuration. These thermal tracer tests and numerical modeling allow to define the most efficient configuration for optimizing shallow geothermal storage in fractured rock.