Induced Fault Reactivation and Hydraulic Diffusivity Enhancement: Insights from Pressure Diffusion Inversion in Laboratory Injection Tests

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Understanding how the permeability of a fault evolves during injection induced fault reactivation process is of great interest. The interactions between fluids and faults can be complex, as the confining pressure, effective stress and shear slip can affect the hydro-mechanical properties of the fault. The relationship between induced slip (reactivation) front and fluid front requires a better understanding of what controls hydraulic diffusivity as well.

In this study, we investigate shear induced fluid flow and permeability enhancement during fracture shearing. We used a series of laboratory injection reactivation tests on saw cut Andesite rock sample, under triaxial conditions, at different confining pressures (30, 60 and 95 MPa). The sample was connected to two pressure sensors, at two opposite locations of the fault, and equipped by strain gauges along strike.

We thus propose a numerical method, in the context of deterministic and probabilistic inversion approaches, that allows to estimate the temporal evolution of the effective hydraulic diffusivity (and its associated uncertainties) of an experimental fault throughout an injection test, using the pressure history at two points on the fault.

The numerical method was able to reproduce the experimental data for a wide time range of the different experiments. The hydraulic diffusivity was found to largely depend on the confining pressure and to increase (by one order of magnitude) throughout the injection experiment with the reduction of the mean effective stress acting along the fault plane. As well, the shear slip was observed to have an effect on the hydraulic diffusivity evolution. Instantaneous short term diffusivity enhancement accompanied slip events with large slip velocities, while long term increases accompanied slow slip events.