Inferring permeability enhancement during fault slip reactivation triggered by laboratory-scaled injection experiments.

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Typically, earthquakes that occur during geothermal exploitation or any other fluid-injection activity (hydraulic fracturing, CO_2 waste disposals…) are attributed to the reactivation of rapid slip along critical faults prompted by an escalation in pore pressure leading to a concomitant drop of effective normal stress. Rutter E and Hackston A. **[1]** - as well as many other recent in-situ and laboratory studies - pointed out unambiguously that application of fluid pressure to a weak plane via a hydraulic fracture provoke seismogenic offloading. Despite that, the fundamental physics governing the reactivation of fault slippage induced by fluid injection remains elusive. In order to advance our knowledge, it is imperative to have a good grasp on how the fluid permeate into the fault plane. Thus, we need to infer the evolution of the fault permeability during injection experiments, a task that is equivalent to establishing **Eq. 1.**, which represents the focal point of this PhD project.

Eq. 1. $k(x,y,t)=f(p,\sigma_e,\delta)$,

where k is the permeability (m^2), f is the model to be inferred, p is the pore pressure (MPa), σ_e is the effective normal stress (MPa) and δ is the cumulative slip (stable and instable) along the fault (m), and x, y and t are the independent variables representing space and time.

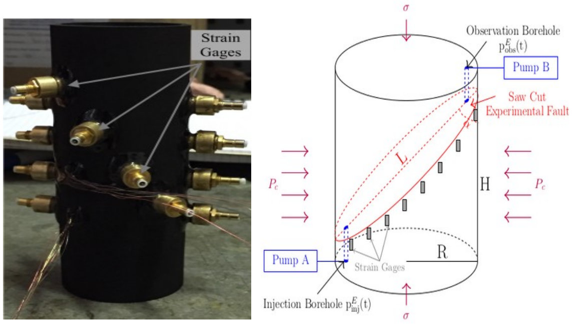

Fig. 1. Experimental setup. **[2]**

Measurements of pore pressure, stress, strain and fault slip were carried on a rock sample in the laboratory. The experimental setup in **Fig. 1.** showcases a frontal perspective of a cylindrical rock sample. The experimental setup in question was employed within Michelle Almakari's **[2]** doctoral research, which serves as a preleminary investigation to my own ongoing Ph.D. project. The purpose of this experiment is to explore the reactivation of a fault - illustrated here by a solitary 2D saw-cut fracture - induced by fluid injection. The left-hand side displays the jacketed cylindrical specimen. The right-hand side displays a sketch of the cylindrical rock sample, which will be loaded into the triaxial press. The specimen will be subjected to an axial stress denoted by σ (MPa) and a confining pressure represented by P_c (MPa). The height of the cylinder designated as H (m), and its radius as R (m). Additionally, the fault length is represented by L (m) and its dip angle by α. Pump A, connected to the injection borehole, measures the injected pressure P^E_{inj} (t) (MPa) at the injection borehole. Whilst, Pump B is connected to the observation borehole, which measures the observed pressure P^E_{obs} (t) (MPa). A prerequisite for determining the permeability distribution across the 2D fault is to have a multitude of observation boreholes scattered along the fault. The setup also features eight strain gages uniformly dispersed along one side of the cylinder, running parallel to the fault strike, recording the deformation of the sample. The experimental data obtained from this setup will be confronted to the predictions of a hydro-mechanical numerical model using finite element method, which I will devise during my doctoral research. To achieve this, I will employ deterministic (gradient-based method) and Bayesian (Markov Chain Monte Carlo (MCMC) methods) inversion approaches.

References:

[1] Rutter E, Hackston A. 2017, On the effective stress law for rock-on-rock frictional sliding, and fault slip triggered by means of fluid injection. Phil. Trans. R. Soc. A 375: 20160001.

[2] M. Almakari , H. Chauris, F. Passelègue , P. Dublanchet, A. Gesret. 2019, Fault's hydraulic diffusivity enhancement during injection induced fault reactivation: application of pore pressure diffusion inversions to laboratory injection experiments. Geophys. J. Int. (2020) 223, 2117–2132.