Fault slip reactivation by fluid injections : aseismic slip and induced seismicity in rate-and-state fault models

P. Dublanchet, MINES ParisTech, PSL Research University, Centre de Gosciences, Fontainebleau
R.C. Viesca, Tufts University, Medford, MA 02155
M. Almakari, MINES ParisTech, PSL Research University, Centre de Gosciences, Fontainebleau

Key words: hydromechanical model, induced seismicity, aseismic slip

Many observations indicate that seismicity could be triggered by fluid operations at depth [4]. This induced activity could be interpreted as the reactivation of rapid slip on preexisting faults. Recent studies have furthermore shown that such operations also trigger a significant amount of slow aseismic slip [2, 1, 6, 8, 3]. This process could partly explain the discrepancy between injected energy and radiated energy sometimes observed during fluid injection in a rock medium [5, 3]. This propagating aseismic slip in turn loads remote seismogenic asperities on the fault, which results in a complex pattern of seismic and aseismic events [7, 1].

Understanding the mechanics of fault slip reactivation by fluids is thus of primarily importance to better assess the induced seismicity hazard, and to evaluate the possibility of using microseismicity to monitor fluid flow and damage at depth.

Here, we consider a fault model consisting in a planar interface between elastic solids, where slip is resisted by Dieterich-Ruina friction (figure 1). We present numerical and theoretical results about the slip events generated by a local fluid injection on such a fault. We first consider oversimplified models such as a fault with homogeneous frictional properties, where friction evolves faster than fluid diffusion. For this end-member case, we demonstrate the existence of a range of self similar solutions for slip rate of the form $V = t^{-\alpha} f(x/t^{\beta})$, where α and β depend on the injection history and the elastic configuration respectively. These solutions allow to identify the mechanical parameters controlling the evolution of slow slip in response to a localized pressure increase. We next present results about the slip reactivation in more complex situations such as faults with heterogeneous friction generating seismicity and aseismic slip, and characterized by a non negligible fluid flow. It appears that the injection history, in particular the pressure rate is a critical parameter controlling the amount of seismicity, and the magnitude of the earthquakes.

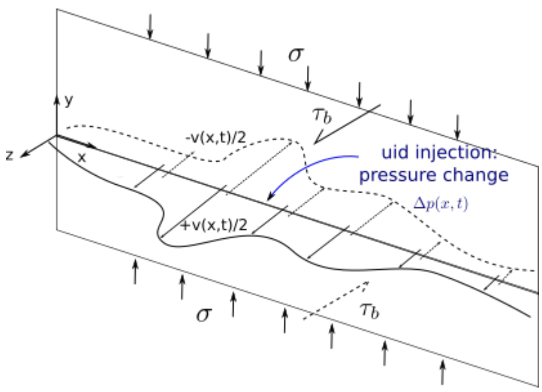

Figure 1: Fault system studied. Arrows along $y = 0$ indicate the orientation of slip rate V. σ and τ_b are the normal and shear stress boundary conditions.

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