EARTHQUAKE NUCLEATION ON A HETEROGENEOUS RATE-AND-STATE INTERFACE

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Earthquakes are often interpreted as frictional instabilities releasing tectonic stresses along crustal faults. These instabilities occur as a sudden acceleration of slip rate along the fault, which triggers the radiation of elastic waves. However, observations show that some instabilities do not fully develop, leading instead to aseismic transients. This could be possibly related to the frictional heterogeneity of fault zones. Here we investigate the very early stage (or nucleation) of such instabilities on heterogeneous faults, coupling stable and unstable frictional behavior. For that we consider a simple model of fault consisting in a planar interface between two elastic half-spaces representing the rock medium. The system is loaded at a constant rate, and slip along the interface is resisted by a heterogeneous friction, governed here by the laboratory-derived rate-and-state laws [2].

Our main results could be summarized as follows : (1) major instabilities occur if $a_0 - b_0 < 0$, a_0 and b_0 being the spatial averages of the a and b rate-and-state parameters, which extends the results by [4, 5]; (2) in the limiting case of a short wavelength heterogeneity we observe similar regimes of nucleation under heterogeneous and constant frictional conditions [3, 6, 1]; (3) the transition between the different regimes, the timescale of slip acceleration and the length-scale of slip localization are in this case controlled by the ratio a_0/b_0 (Fig. 1); (4) an increase in the wavelength of the heterogeneity results in an increase in complexity: the nucleation process involves a cascade of smaller seismic events (foreshocks) before the occurrence of the main instability. Such a model therefore provides insights into the way heterogeneity controls the transient acceleration of slip, and the occurrence of foreshocks preceding a major earthquake, which has strong implications for seismic hazard assessment.

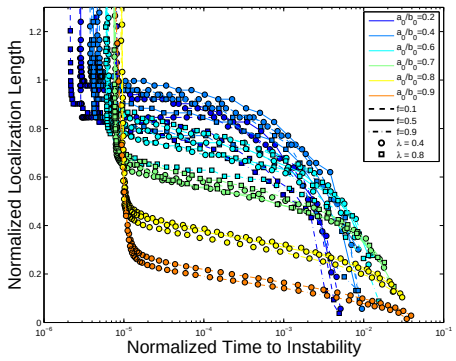

Figure 1. Localization of the slip acceleration zone on a planar fault with different levels of frictional heterogeneity. Colors indicate the ratio a_0/b_0. Heterogeneity is characterized by a small normalized typical wavelength $\lambda < 1$.

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