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EFFECTIVE FAULT FRICTION AND SEISMIC NUCLEATION PHASE: SCALE-DEPENDENT OR NON-LINEAR FRICTION ?

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We show how fault friction properties can be retrieved from the shape of the gradual onset of some seismograms. Based on a mechanical model, we derive a method to estimate the slip weakening rate W from an exponential fit to the seismic nucleation phase. Clues on fault zone structure and state of stress can be additionnaly obtained in the same process. The basic ingredients of the model are: (1) linear slip weakening friction on a planar fault, (2) a non uniform, locally peaked, prestress and (3) a slow tectonic load at constant rate. As characterized by numerical and analytical tools, the nucleation process is composed of two phases: (I) quasi-static nucleation and (II) dynamic nucleation. Phase I starts as soon as the stress overcomes fault strength in the region of initial stress concentration. It is characterized by stable slip on a slowly growing patch, driven by the slow tectonic load, and ends when the size of the slipping patch reaches the critical size $L_c \approx \mu/2W$. Phase II is dynamically unstable and is the focus of this paper, because of its potential for wave radiation, hence observability in seismograms. This phase is itself composed of two stages: (IIa) an early transition phase, controlled by the lateral growth of the slipping patch and (IIb) a late stage dominated by the exponential acceleration of slip inside the patch. During this last stage, seismic moment behaves as $M_0(t) \propto \exp(s_m t)$ where the growth rate $s_m = 2W/\rho V_S$ is the ratio between weakening rate and fault impedance. This behavior is the basis of our proposed method to estimate properties of fault friction and fault zone by measuring s_m directly on the seismic nucleation phase of seismograms from the ratio velocity/displacement. Testing the method with the Kobe earthquake we get insights on the influence of fault zone structure on nucleation, and we obtain an estimate of critical slip $D_c \approx 10$ cm. This value is smaller than previous seismological estimates

but still huge compared to laboratory observed ones. In order to explore possible transitions between laboratory and geophysical scales we measure s_m on a selected set of events in the Beroza and Ellsworth (1996) catalog, spanning a broad magnitude range $3 < M_0 < 8$. The following scaling is observed: $s_m \propto M_0^{-1/3}$. Its interpretation in terms of classical seismological scaling laws leads to two competing paradigms: (1) a scale-dependent friction paradigm or (2) a unique, non-linear and convex, slip dependent friction law. Both will be discussed in view of their implications and their additional support from laboratory and independent seismological observations.