# Models of preseismic sliding and slow earthquakes: Implication for precursory phenomena of great interplate earthquakes

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Slow accelerating preseismic sliding has often been observed for frictional sliding in pre-existing faults in rock samples in the laboratory (e.g., Dieterich, 1978). Experimental results on rate-, state-,

and displacement-dependence of rock friction were used to establish a constitutive law called a rate- and state-dependent friction law (Dieterich, 1979; Ruina, 1983), and the friction law successfully explains the preseismic sliding (Kato and Hirasawa, 1996). In this presentation, I demonstrate that slow preseismic sliding necessarily precedes seismic slip and perform numerical simulations of preseismic sliding using the rate- and state-dependent friction law.

Sliding behavior of a fault has often been analyzed with a simple single degree of freedom spring-block model, in which a rigid block is dragged through an elastic spring and frictional stress is applied on the base of the rigid block. Ruina (1983) theoretically showed that unstable (seismic) slip may occur for spring stiffness smaller than a critical value when the frictional stress obeys the rate- and state-dependent friction law. For a realistic fault in an elastic medium, an effective stiffness of the fault can be defined by $\Delta\tau/\Delta u$, where $\Delta\tau$ is a shear-stress change on the fault due to slip $\Delta u$ (e.g., Dieterch, 1992). Since $\Delta\tau/\Delta u$ is inversely proportional to the fault length, unstable slip cannot occur when the fault length is shorter than the critical length that corresponds to the critical stiffness. This leads to the existence of a slow stable fault propagation process before the fault length reaches the critical value. This was confirmed in numerical simulations, which well explain laboratory observations of preseismic sliding (Dieterich, 1992; Kato and Hirasawa, 1996). It is remarked that a slow earthquake occurs when the fault cannot propagate due to nonuniformity in frictional property and the fault length is narly equal to the critical length for unstable slip (Kato, 2004).

The rate- and state-dependent friction law has been applied to modeling of earthquake cycles on geological faults, and these models predict preseismic sliding (e.g., Tse and Rice, 1986). For instance, Kato and Hirasawa (1999) and Kuroki et al. (2002) performed simulations for preseismic sliding of the Tokai earthquake, which is anticipated to occur at a seismic gap along the Suruga trough, central Japan, to discuss the detectability of precursory crustal deformation by comparing the amplitudes of simulated crustal deformation with the noise levels of the borehole strainmeters installed in the Tokai region. They further suggested that preseismic sliding should perturb stresses around the source area of the coming Tokai earthquake, possibly generating seismicity changes such as seismic quiescence.

Thus, the existence of preseismic sliding has been confirmed in experimental and theoretical studies. However, uncertainty of the amplitudes of preseismic sliding remains because the friction parameters on natural faults are unknown.

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