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# Modeling of diverse aspects of slow earthquakes in a dynamical framework

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Slow earthquakes were modeled theoretically in a dynamical framework by Suzuki and Yamashita [2009], whose paper is referred to as Paper I below. What was essential in the modeling in Paper I was the consideration of fluid flow, frictional heating and inelastic pore creation. The dynamic fault slip was assumed to create pores inelastically near the fault; the frictional heating and pore creation promote the fluid flow. These effects were found to be described by the two nondimensional parameters Su and Su' [Suzuki and Yamashita, 2010]. The parameter Su represents the relative dominance of the effect of inelastic pore creation on the fluid pressure change over that of shear heating while Su' is associated with the dominance of fluid flow effect over the effect of shear heating. Hence, Su and Su' are proportional to the creation rate of pores and permeability, respectively. We found in Paper I that the simulated fault tip growth rate is negligibly small compared to the shear wave speed if we assume (1) the value of Su considerably larger than assumed for the simulation of ordinary earthquakes, (2) the fluid flow into the inelastically created pores, and (3) the initial shear stress significantly smaller than assumed for the simulation of ordinary earthquakes. However, seismological and geodetic observations imply that observed slow earthquakes are much more diverse. For example, all slow earthquakes are not necessarily represented by slow smooth fault growth. For example, slow slip events are accompanied by tremors. We now study the mechanism of such coupling.

In this study, we assume a 2-D fault in a thermoporoelastic medium and consider the effects of fluid flow, frictional heating and inelastic pore creation; the Coulomb friction law is assumed on the fault. These are the same assumptions as in Paper I. Although we assumed in Paper I that the fault slip is kept frozen once the fault slip speed becomes zero, we allow the reactivation of slip if the acting shear stress exceeds the static frictional stress again. The smooth slow fault growth is simulated if the value of Su is small enough as observed in Paper I. A new finding in the present study is the reactivation of fault slip due to the fluid flow into the fault zone. If the value of Su is much larger, such fluid inflow can reactivate the fault slip. In other words, the fault slip can occur intermittently. Note that the fault slip evolves continuously if the value of permeability is too large (large Su') because higher rates of fluid inflow can continuously drive the fault slip. On the contrary, if the permeability is too small, the effect of fluid flow is almost negligible, so that the fluid inflow cannot reactivate the fault slip. Our calculation shows that the fault slip reactivation is more frequent if the value of Su is larger and the value of Su' is in a certain range. The intermittency of fault slip accompanied by the slow fault growth can be a model for the non-volcanic tremor. Our calculation suggests that the slow slip events accompanied by tremors occur because the fault grows in a fluid-permeated zone where the value of Su is considerably large. As noted before, larger values of Su mean higher creation rates of inelastic pores.

Keywords: slow earthquake, earthquake fault, fluid, frictional heating