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The single nondimensional parameter controlling the dynamic fault slip behavior

Takehito Suzuki[1]; Teruo Yamashita[2]

[1] ERI, University of Tokyo; [2] ERI, Univ. of Tokyo

I review our recent study on dynamic earthquake rupture in which thermoporoelastic effects are taken into account including inelastic porosity change. I emphasize here the importance of slip-strengthening that is caused by the effects of thermoporoelasticity and inelastic porosity change for understanding dynamic earthquake rupture.

We have shown theoretically that dynamic earthquake phenomena can be understood in a single framework with a single nondimensional parameter Su, a quantity proportional to the ratio of increase rate of inelastic porosity to the rate of frictional heating (Suzuki and Yamashita, GRL, 2007). For example, a difference in the value of Su gives rise to both slip-weakening and -strengthening behavior; slip-weakening emerges when Su is less than Sc while slip-strengthening occurs when Su is greater than Sc, where Sc (less than unity) is a parameter dependent on material property. What should be emphasized here is the existence of possibility that stress-slip relationship on earthquake fault is caused not by surface properties of fault but by thermoporoelastic properties of materials near the fault.

Field study of exhumed faults suggests that melting does not occur over a whole fault in an individual event. If we assume based on this field study that the temperature elevation remains below the melting temperature of fault rocks, we found in our 1D analysis that the value of Su is close to zero or greater than unity. We therefore focused our attention only to this range for the value of Su and we carried out 2-D simulation (Suzuki and Yamashita, JGR, submitted). If we assume that Su is close to zero, our governing equations predict the occurrence of slip-weakening soon after the slip onset and remotely applied shear stress is almost completely released (Suzuki and Yamashita, JGR, 2006). On the other hand, the slip-strengthening behavior emerges when Su is greater than unity and the remotely applied stress is only partially released; this seems to be much more consistent with seismological observation. We therefore think that many shallow earthquakes are characterized by the value of Su that is larger than unity. Our 2-D analysis showed that the fault slip has a feature of pulse-like slip for Su greater than unity as observed by Wald and Heaton (1994) and others. This occurs because slip-strengthening suppresses the slip far behind the extending fault tip. We also showed that the static stress drop is only weakly dependent on the fault size and is in the range from 1MPa to 10MPa for Su greater than unity. This is also consistent with seismological observation (Venkataraman and Kanamori, 2004). Although the slip-strengthening has not attracted attention among seismologists until recently, our study points out the importance of slip-strengthening for the understanding of dynamic earthquake rupture.