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Strength drop as a detectable short-term precursor: feasibility of acoustic monitoring at a natural scale

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On the basis of the revised RSF proposed by Nagata et al. (2012), we reinvestigated frictional stick-slip cycles of earthquake faults. Simulation results showed a fairly large strength drop in the preslip period, which is localized within a few years preceding the earthquake. This suggests a possibility of earthquake forecast by monitoring the strength drop of a natural fault by acoustic methodology. In laboratory, Nagata et al. (2008, 2012) conducted rock friction experiments in a double-direct-shear apparatus, where they simultaneously measured P-wave transmissivity across the frictional interface to monitor the state of contact (= strength). The acoustic transmissivity |T| was found to reflect changes in the contact state very well. However, a critical problem is that how the acoustic monitoring can be realized at a natural scale. The present paper discusses its feasibility based on the earlier studies on the acoustic method for monitoring mechanical properties of imperfectly welded interfaces (Kendall and Tabor, 1971; Schoenberg, 1980).

We started from the laboratory experiment of Nagata et al. (2008) of the order of strength 10MPa, fc_lab = 1MHz and L_lab = 1micron, where fc is a cutoff frequency and L is a characteristic slip distance of the interface. We theoretically derived that I times greater strength and J times greater L lead to fc = (I/J)fc_lab. For our simulation values of I=10 (100MPa strength) and J=10^5 (L=10cm), fc can be estimated as 100 Hz. Recently reported large L=1m (J=10^6) (Hori and Miyazaki, 2011; Kato and Yoshida, 2011) and weak strength of 10MPa (I=1) (Hasegawa et al., 2011) for the 2012 Mw9.0 Tohoku earthquake, fc could be as low as 1 Hz. We think that the frequency range between 1 to 100 Hz is seismically observable. In fact, the explosion reflection surveys conducted over the plate boundary on the forearc slope of the Japan Trench successfully revealed the intensity distribution of plate boundary PP reflection around 5 - 20 Hz (Fujie et al., 2002; Mochizuki et al., 2005). Because acoustic reflection |R| is theoretically related to |T| (Schoenberg, 1980), acoustic monitoring of strength via |R| looks feasible at a natural scale. Note that though expected change of |T| in the preslip period would depend on the ratio of the change to the absolute value (Nagata et al., 2012), and the ratio is arbitrary in the simulations (only the change from an arbitrarily chosen reference value is necessary). The ratio could be more than 50% if a weak fault is considered in our simulation, and it would be easily detected by seismic reflection surveys.

Reference
Kame, N., Fujita, S., Nakatani, M. and Kusakabe, T., Earthquake cycle simulation with a revised rate- and state-dependent friction law, Tectonophysics (2012), http://dx.doi.org/10.1016/j.tecto.2012.11.029