Conceptual Model for Precursory Slow Slip and Foreshocks based on the Balance of Stiffness on and around the Fault

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We propose a conceptual model to understand the occurrence of precursory slow slip and foreshocks, both of which may occur prior to the mainshock. First, we summarize our experimental results of large-scale bi-axial shear friction experiments using the NIED large-scale shaking table (e.g. Fukuyama et al., 2014, Yamashita et al., 2015). In a series of experiments using an Indian metagabbro sample whose nominal slip area was 1.5m long and 0.1m wide, precursory slow slip events occurred in most cases but foreshocks were only observed under certain conditions related to the fault surface damage. When foreshocks occurred, they initiated inside the slow slip area and both coexisted. In addition, from the hypocenter distribution of foreshocks and the observation of the fault damage evolution, foreshocks tend to be initiated at the edge of grooves on the fault surface. To understand the observation described above, we shall follow the idea of Leeman et al. (2016) and Kilgore et al (2017), where the balance between the stiffness of the apparatus and that of fault surface controls. Leeman et al. (2016) varied the fault stiffness by changing the amount of normal stress while Kilgore et al (2017) varied the apparatus stiffness using springs with different elastic constants. The evolution of fault damages could be related to the apparent change in the b-a value in rate- and state- dependent friction regime (Beeler et al., 1996, Urata et al., 2016). As fault damage evolves, apparent b-a value increases. Under steady state conditions, b-a value is proportional to the fault stiffness (if positive). And we could assume that the apparatus stiffness remain constant during the episodes. Therefore, we could say that slow slip occurs where the fault stiffness is smaller than the apparatus stiffness and foreshocks occur where the fault stiffness is larger than the apparatus stiffness. In addition, Yamashita et al (2015) showed a heterogeneous distribution of local normal stress on the fault surface, especially around the grooves, and Leeman et al. (2016) showed that normal stress is also proportional to the fault stiffness. These heterogeneous distributions of normal stress and friction parameters may also cause a coexistence of slow slip and foreshocks, since the groove distribution is not uniform on the fault. In nature, stiffness of the apparatus corresponds to the stiffness of the surrounding materials of the fault. Precursory slow slip events and foreshocks can be understood based on the differences in stiffness of the fault and surrounding materials.

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