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2-D simulation of shear faulting: the slip- and time-dependent fault constitutive law and a diversity of slip behaviour

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The occurrence of interplate earthquakes can be regarded as the process of tectonic stress accumulation and release in source regions, driven by relative plate motion. Stress accumulation between earthquakes results from slip deficit relative to steady plate motion. Recently, on the basis of detailed analysis of geodetic and seismic data, it have been revealed that many slow earthquakes that have extraordinary low slip-velocity occur at plate interfaces. This indicates a diversity of slip behaviour to release the accumulated stress at plate interfaces. The mode of fault slip is prescribed by constitutive properties there. Thus, to understand the process of tectonic stress accumulation and release in plate subduction zones, it is crucial to make clear the dependence of slip behaviour on the constitutive properties.

In the present study, we developed a simple two-dimensional simulation model of shear faulting to examine in detail the dependence of slip behaviour on fault constitutive properties through the entire process of earthquake generation cycles. The coupled non-linear system prescribing the process of stress accumulation and release in a strength asperity consists of the equation of equilibrium for two-dimensional shear faulting, fault constitutive relation, and steady slip motion as a driving force. First, we used a simple slip-weakening fault constitutive law. In this system, slip behaviour in the strength asperity is controlled by a single non-dimensional parameter defined by (rigidity∗critical weakening displacement)/(peak strength∗characteristic length indicating the size of the strength asperity). In the case that the non-dimensional parameter is small, accumulated stress is released by unstable slip, while in the case that the non-dimensional parameter is very large, accumulated stress is released by stable slip. Only in the case that the non-dimensional parameter is moderately large, a slow slip event can be realized. Second, we used the slip- and time-dependent constitutive law by Aochi & Matsu'ura (2002), which has been derived from theoretical consideration on the fault-surface abrasion with slip and adhesion with contact. Through numerical simulation, we reproduced recurrent stable/unstable fault slip in the strength asperity. In this case, the dependence of slip behaviour on the constitutive parameters is not so simple. The essential parameters controlling the slip-and time-dependent fault constitutive law are the abrasion rate and the adhesion rate. Given the values of the abrasion rate and the adhesion rate, and the past history of the fault slip, the values of fault constitutive parameters, the breakdown strength drop and the critical weakening displacement, can be defined at each moment. Such a process dependence of the fault constitutive parameters causes complicated fault slip behaviour.