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# Change in Fault Constitutive Properties during a Complete Earthquake Generation Cycle

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We constructed a 3-D simulation model for earthquake generation cycles by combining the viscoelastic slip-response function, the slip- and time-dependent fault constitutive law and the steady relative plate motion as a driving force into a single closed system. With this model we examined change in fault constitutive properties during one complete earthquake generation cycle in detail. After the arrest of dynamic slip, the peak strength of fault is restored rapidly in the seismogenic region. On the other hand, the restoration of the critical weakening displacement Dc proceeds gradually with time through the interseismic period. The restoration of Dc can be regarded as the macroscopic manifestation of the microscopic recovery process of fractal fault surface structure.

The earthquake generation cycle consists of tectonic loading, quasi-static rupture nucleation, dynamic rupture propagation and stop, and subsequent stress redistribution and fault restrengthening. From a macroscopic point of view, the entire process of earthquake generation cycles can be consistently described by a coupled nonlinear system of a slip-response function, a fault constitutive law and a driving force. On the basis of such a general idea, we constructed a realistic 3-D simulation model for earthquake generation cycles at a transcurrent plate boundary by combining the viscoelastic slip-response function for a two-layered elastic-viscoelastic structure model, the slip- and time-dependent fault constitutive law that has an inherent mechanism of fault restrengthening, and the steady relative plate motion as a driving force into a single closed system.

With this model we numerically simulated the earthquake generation cycles repeated in a seismogenic region on a plate interface, and examined space-time changes in shear stress, slip deficits and fault constitutive properties during one complete cycle in detail. The occurrence of unstable dynamic slip brings about decrease both in fault strength and shear stress to a constant residual level. After the arrest of dynamic slip, the peak strength of fault is restored rapidly and the process of stress accumulation starts again in the seismogenic region. On the other hand, the restoration of the critical weakening displacement Dc proceeds gradually with time through the interseismic period. The change in fault constitutive properties can be regarded as the macroscopic manifestation of inherent break and recovery processes of fractal fault surface structure. In the slip- and time-dependent law the Fourier amplitude of fault surfaces decreases with fault slip and increases with contact time. After the arrest of dynamic slip, the Fourier amplitude is gradually restored with time to its inherent fractal amplitude. The restoration rate of the Fourier amplitude is faster in larger wavenumber (smaller wavelength), and slower in smaller wavenumber (larger wavelength). This indicates that the smaller-scale fractal structure is restored more rapidly. The key to understand the evolution of fault constitutive properties is the decrease of the critical wave number kc with time during the interseismic period. The critical weakening displacement Dc is in proportion to the inverse of the critical wavenumber kc, and so, the decrease of kc (increase of the upper fractal limit of fault surface topography) with time means the increase of Dc with time.