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Mechanical effects of fluid migration in a fault zone on seismic activity

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Spatio-temporal variation of rupture activity is modeled assuming fluid migration in a narrow, porous fault zone formed along a vertical strike-slip fault in a semi-infinite elastic medium. The principle of the effective stress coupled to the Coulomb failure criterion introduces mechanical coupling between fault slip and pore fluid. The fluid is assumed to flow out of a localized high-pressure fluid compartment in the fault at the onset of earthquake rupture. Our simulations show that the model can explain a foreshock-mainshock-aftershock sequence in a unified way.

If the rate of pore creation is large enough, rupture sequences with features of earthquake swarms are simulated. Such sequences generally start and end gradually with no single event dominating in the sequence. The b-value of the Gutenberg-Richter (GR) relation is shown to be unusually large. These are consistent with seismological observations on earthquake swarms.

If the rate of pore creation is relatively small, the occurrence of ruptures culminates in a large-size event regarded as the main-shock. The frequency-magnitude statistics of these events obey the GR relation; the b-value is close to unity.

Aftershocks can be simulated if the cohesive strength is assumed to drop at the instant of the earliest slip at each fault segment in a sequence of slips. It is actually observed that simulated aftershocks satisfy the Omori law of aftershock activity, the GR relation, the occurrence of secondary aftershock sequences, and the migration of aftershock activity. A large majority of simulated aftershocks consist of repeated slips, that is, slips on fault segments that have experienced slips earlier in the sequence. The emergence of the GR relation is shown to be closely related to the occurrence of these repeated slips.

Statistical features of rupture activity are simulated quite well as shown above. However, a wide range of permeabilities, generally observed in the fields, is an obstacle to estimate the length of each rupture sequence quantitatively. In addition, the knowledge of fine hydro-mechanical structure of fault zone is required to understand the details of nucleation process of rupture.