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Numerical simulation of a shape of an off-fault microcrack distribution observed in natural faults

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Rupture propagation on a fault plane forms microcracks outside the slip zone. Formation of microcracks consumes the energy for the rupture propagation. Off-fault microcracks are thus important and has been investigated in both field observations (Vermilye and Scholz, 1998) and numerical calculations (Andrews, 2005; Hok *et al*., 2010). The number density of the microcracks outside the slip zone inferred from numerical experiments sometimes differs from those obtained in the field observations. Field observations show that the number density of the microcracks is almost constant along the fault direction whereas, in the numerical experiments, the width of the region in which microcracks distribute increases linearly with the rupture propagation distance. This result from numerical experiment suggests that number density of microcracks around a fault increases proportionally to the propagation distance.

In this study, we assume a two-dimensional mode III fault and show that the initial stress field affects the microcrack distribution. We use the Coulomb failure criterion both for the rupture propagation on the fault plane and formation of the microcracks. In order to use the Coulomb failure criterion for the off-fault failure, we calculate maximum shear stress and normal stress at each locus. When these stresses satisfy the Coulomb failure criterion, off-fault microcracks form. We vary the initial stress field and cohesion as parameters.

We find that, when the initial shear stress (sigma_yz) which drives the on-fault rupture propagation decreases linearly along the fault, the final stress drop becomes negative and fault-tip growth is arrested. In this situation, the width of the microcrack distribution does not increase as a function of the rupture propagation distance, but becomes almost constant. This result is similar to the distribution observed in natural faults. In contrast, when the initial shear stress decreases linearly perpendicular to the fault plane, the width of the microcrack distribution perpendicular to the fault plane does not decrease.

Another our finding is that larger cohesion makes the width of the microcrack distribution smaller. We obtain similar results when the lithostatic stress is larger. This is because both cohesion and the lithostatic stress increases the critical stress to cause failure.

We infer that the microcrack distribution can become a measure of the initial stress field.

Keywords: microcrack, numerical simulation, stress field, arrest of fault-tip growth