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Dependence of deformation field around an interfacial fault on the orientation of background principal stress axis

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Natural faults form various angles with the orientation of background principal stress axis. However, its orientation was not considered in previous studies on the stress field around faults, which will be because many authors were interested only in the change of Coulomb Failure Function (delta CFF) in some direction (in many cases, in the direction parallel to existing faults) in order to explain spatial distribution of aftershocks [King et al., 1994 and others]. The delta CFF is affected only by the stress change due to the fault slip and independent of the background stress orientation as long as one assumes a homogeneous isotropic medium and homogeneous background stress.

However, it will be more appropriate to assume earthquake faults that are embedded in a heterogeneous medium at least in some cases. For example, we will have to assume a bimaterial medium to model plate boundary earthquakes. Moreover, recent seismological observation showed the existence of an intraplate event occurred on a bimaterial interface [Kato et al.,2005].

Here, we theoretically study the deformation around a fault located on a planar bimaterial interface and examine the possibility of secondary ruptures; each medium has different elastic constants and the deformation is assumed to be quasistatic and 2-D in-plane.

Elasticity theory indicates that the existence of material interface makes the stress field heterogeneous [Hearly, 2009; Rybicki and Yamashita,2009]. In fact, it is theoretically derived that the orientation and magnitude of the background stress change discontinuous across a material interface. Hearly [2009] suggested the existence of such stress heterogeneity on the basis of seismological observation. This suggests that the employment of delta CFF is not appropriate for the consideration of generation of secondary ruptures because of the possibility of heterogeneity in the background stress. We therefore calculate not the delta CFF but the absolute value of Coulomb Failure Stress (CFS) in all directions at locations near the fault for the consideration of the possibility of secondary shear ruptures.

Our calculation shows that the absolute value of CFS depends on the angle between the orientations of interface and the axis of background maximum principal stress. Its distribution is shown to be asymmetric with respect to the center of fault. What is noteworthy is that the spatial distribution of the absolute value of CFS shows a nonmonotonic change with the change of the orientation of the axis of background principal stress. We find that the area where the CFS has high values is broader in the stiffer medium when the angle between the orientations of the interface and the axis of background maximum principal stress is near zero or 90 degree. If the above angle takes medium values, the area is found to be broader in the softer medium.

We additionally calculate the strain invariant ratio $I_1/\mathrm{sqrt}(I_2)$ to examine the possibility of the excitation of tensile microruptures near the fault. Lyakhovsky and Myasnikov [1987] employed this ratio to represent the damage evolution; the rate of damage evolution is higher for larger values of this ratio.

We found that the change of the spatial distribution of the strain invariant ratio on the model parameters are almost the same as that of the absolute value of the CFS. This suggests that the generation zone of tensile microcracks roughly agrees with that of secondary shear ruptures.

Our results of calculation specifically imply that the extent of damaged zone and the degree of damage are determined by the contrast of elastic constants of each media as well as the orientation of maximum background principal stress. This suggests that observational study of damaged zone around a fault should investigate not only the damage itself but also stiffness and orientation of maximum principal stress at the region.

Keywords: fault, heterogeneity, fracture, damage, stress