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Complexities of strike-slip faults in the SISZ interpreted in terms of material heterogeneities

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We have studied the singular behaviour of strike-slip faults crossing a material discontinuity, employing the asymptotic theory of generalized Cauchy integral equations. Planar crack surfaces across interfaces are characterized by jump discontinuities in the dislocation density distribution which must be accompanied by discontinuities of the stress drop since $\Delta\sigma_1/\Delta\sigma_2 = \mu_1/\mu_2$ (Bonafede et al. 2002). It is shown that this stress drop discontinuity condition cannot be fulfilled in several cases and in such cases a planar strike-slip fault cutting across the interface comes into conflict with the welded-boundary conditions. A simple way out of the mentioned problem is assuming that the fault surface is affected by a sharp change of the angle of dip at the intersection with the interface. The problem can be addressed in terms of a deep vertical planar crack, interacting with a shallower inclined planar crack. An asymptotic study of the singular behaviour of the dislocation density at the interface reveals that the density distribution has an algebraic singularity at the interface of degree ω between 0 and $\frac{1}{2}$, depending on the dip angle δ of the upper crack section and on the rigidity contrast between the two media. From the welded boundary condition at the interface between medium 1 and 2, a modified stress drop discontinuity condition is obtained,

$$\frac{\Delta\sigma_1}{\Delta\sigma_2} = \frac{\mu_1}{\mu_2}\sin\delta$$

which can be fulfilled if the stress drop in the upper medium is lower than required for a planar trough-going surface: as a corollary, a vertically dipping strike-slip fault at depth may cross the interface with a sedimentary layer, provided that the shallower section is suitably inclined (fault "refraction"); this results has important implications for our understanding of the complexity of the fault system in the SISZ; in particular, we may understand the observed offset of secondary surface fractures w.r. to the

strike direction of the seismic fault, imaged through accurately relocated aftershocks. Alternative solutions must be considered if $\Delta\sigma_1/\Delta\sigma_2 > \mu_1/\mu_2$, which may be the case when anelastic processes relax deviatoric stress in layer 2. In such a case one through-going crack cannot fulfil the welded boundary conditions and unwelding of the interface may take place. We have solved this problem within the theory of fracture mechanics, employing the boundary element method. The fault terminates against the interface in a T-shaped configuration, whose segments interact among each other: the lateral extent of the unwelded surface can be computed in terms of the main fault parameters and the stress field resulting in the shallower layer can be modelled. A wide stripe of high and nearly uniform shear stress develops above the unwelded surface, whose width is controlled by the lateral extension of unwelding. Secondary shear fractures may then open within this stripe, according to the Coulomb failure criterion, and the depth of open fractures opening in mixed mode may be computed and compared with the well studied fault complexities observed in the field. In absence of the T-shaped decollement structure, stress concentration above the seismic fault would be difficult to reconcile with observations, being much higher and narrower.