Geophysical Research Abstracts, Vol. 8, 04369, 2006
SRef-ID: 1607-7962/gra/EGU06-A-04369

Effective normal stress changes induced by alteration of pore pressure due to near-fault heterogeneity during rupture propagation

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Recent, detailed observations of mature fault zones have revealed that primary slip is confined to a very narrow zone that is much less permeable than the adjacent material and that slip often occurs at an interface between dissimilar materials that are more damaged than material further from the slip zone. Because a propagating slip pulse induces compression on one side of the slip plane and extension on the other, a pore pressure change is induced on the slip plane when the poroelastic properties of the materials abutting the slip plane differ. In particular, the pore pressure is increased if the compressive side is more permeable than the extensile and decreased if the compressive side is less permeable. The magnitude and effects of these induced pore pressure changes are examined by incorporating them into the steady-state, slip weakening pulse model of Rice, Sammis and Parsons (BSSA, 2005). The formulation assumes undrained conditions except for narrow boundary layers, of the order of a few 10's of millimeters, adjacent to slip plane where diffusion can be effective over the time scale of slip propagation. Because the induced pore pressure change is proportional to the along fault gradient of the slip, it has the same form as does the normal stress change induced by slip between dissimilar elastic solids. Since both effects may be of either sign, they can augment or offset each other. For a representative difference in properties, the effective normal stress change due to the pore pressure can exceed that for slip between dissimilar elastic solids if the permeability contrast is large and the rupture velocity is not too large. But the magnitude of the normal stress change for slip between dissimilar solids increases rapidly as the rupture speed approaches the generalized Rayleigh velocity and may dominate at higher rupture speeds.