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Brittle-ductile coupling: role of ductile viscosity in the pattern of brittle fracturing

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The mechanical coupling between brittle and ductile layers in the continental lithosphere produces rheological contrasts, which are supposed to trigger localized or distributed mode of faulting. A plane-strain 2D finite-element model is used to highlight the mechanical role of the brittle-ductile coupling in defining the patterns of fracturing. It especially points out the influence of the viscosity of a ductile layer in the fracturing mode (distributed or localized) of a brittle layer. The coupling is performed through the shortening of a Von Mises elasto-viscoplastic layer rimed by two ductile layers behaving as Newtonian incompressible fluids. By increasing the viscosity of the ductile layers by only one order of magnitude, the fracturing mode evolves from localized to distributed. The localized mode is characterized by the localization of deformation on few faults. In contrast, the distributed mode corresponds to the development of dense fault patterns. Between these two modes of fracturing, the density of the fault pattern increases with the viscosity of the ductile layers, defining a viscosity-dependent fracturing mode.

The mechanics of brittle-ductile coupling is explained by the limitation of the fault displacement rate imposed by the ductile layers. The ductile shear stress concentration at the fault tip is indeed an increasing function of the fault displacement rate and of the ductile viscosity. Since the ductile fault tip stress cannot exceed the brittle layer yield stress, the larger the viscosity is, the lower the fault displacement rate is. As a consequence, an increase of the viscosity will induce the necessity of new fault nucleation to accommodate the boundary shortening rate. The ductile deformation related to fault motion limits the fault displacement rate, as a kind of a fault viscous friction. Analytical estimates of the number of faults necessary to accommodate the boundary shortening rate for different values of the ductile viscosity are in good agreement with

numerical results and thus validate this concept of fault viscous friction.