THE WIDTH OF FAULT ZONES IN A BRITTLE-VISCOUS LITHOSPHERE: STRIKE-SLIP FAULTS; E.M. Parmentier, Department of Geological Sciences, Brown University, Providence, RI 02912

A fault zone in an ideal brittle material overlying a very weak substrate could, in principal, consist of a single slip surface. Real fault zones have a finite width consisting of a number of nearly parallel slip surfaces on which deformation is distributed. This study explores the hypothesis that the finite width of fault zones reflects stresses due to quasistatic flow in the ductile substrate of a brittle surface layer. Because of the simplicity of theory and observations, strike-slip faults are examined first, but the analysis can be extended to normal and thrust faulting.

Other factors have been suggested to explain the finite width of strike-slip fault zones. For example the fault zone may be a zone of preexisting faults whose width was determined by some unspecified process. In a more analytical approach, thin viscous sheet models, based on a vertically averaged deformation and rheology of the lithosphere, have been used to calculate the width of fault zones (1). The only length scale in such a model is the along-strike length of the fault; and the width of a fault must be proportional to its length. There is no evidence that the width of fault zones is proportional to their length. The width of well studied terrestrial oceanic transform faults appears to relatively independent of their length (2), but depends on their slip rate.

Consider a strike-slip fault zone in a lithosphere consisting of a brittle layer overlying a viscous layer in which the viscosity η varies with depth. For a stike-slip fault that is long compared to either its width or the lithosphere thickness, d, the horizontal velocity u along the fault is the only nonzero velocity component. This leads to the boundary value problem defined in Figure 1. Outside a fault zone of width w, the velocity at the top of the viscous layer is defined by the strike-slip motion of the lithosphere across the fault zone with relative velocity U. Within the fault zone the shear stress on vertical planes in the brittle layer averaged over its thickness h, is $\mu\rho gh/2$ where μ is coefficient of sliding friction (3). Since the product of this average stress and h is independent of x, the viscous shear stress, $\tau=\eta\partial u/\partial z$, on the bottom of the brittle layer (top of the viscous layer) must vanish. Shear stress on the bottom of the lithosphere vanishes if the mantle beneath it is very weak. Solutions for u(x,z) are obtained using finite difference approximations. For a prescribed fault width, the stress within the brittle fault zone is obtained by integrating τ along the bottom of the rigid brittle layer assuming that the stress in the brittle layer far from the fault zone is small compared to the frictional sliding stress.

For a fault width w=d, the calculated velocity distributions are shown in Figure 2 for two cases: a uniform viscosity ductile lithosphere and one containing a low viscosity layer representing a weak, ductile lower crust. In this case the the viscosity in the low viscosity layer is 0.1η, and the layer thickness is 0.2d. In these two cases the horizontal velocity distribution across the fault zone is shown in Figure 3. For a prescribed fault zone w/d, the resulting stress within the fault zone corresponds to a particular value of the parameter $\eta U/\mu\rho gh^2$, given in Figure 4 for a range of w/d. For $\mu=0.6$ (3), $\rho=3\times10^3$ kg/m^3, g=10 m/sec^2, u=1 cm/yr, h=15 km, and $\eta=10^{22}$ Pa-s, $\eta U/\mu\rho gh^2 \cong 0.7$. For the range of parameters considered thus far (see Figure 4), this choice of physical parameters predicts a fault zone width comparable to the thickness of the viscous lithosphere. Note that the predicted fault zone width is proportional to d, increases with decreasing h, and increases with increasing η and U.

Because they are simpler than continental faults, oceanic transforms are an obvious first application of this model. The width of transform faults along the Mid-Atlantic Ridge range from 1-5 km (2) and shows a clear dependence on slip (spreading) rate, becoming progressively wider as the spreading rate increases southward. On the fast spreading East Pacific Rise, tranform fault zones, which have been frequently described as multiple transforms, have a width sometimes exceeding 20 km. After confirming that the model explains characteristics of terrestrial fault zones, it will be applied to interperet the structure of fault zones on Venus and the Icy satellites.

References: (1) England, P.C., et al., J.G.R. 90, 3551-3557, 1985. (2) Searle, R.C., J. Geol. Soc. Lond. 143, 743-756, 1986. (3) Brace, W.F., and D.L. Kohlstedt, J.G.R. 85, 6248-6252, 1980.

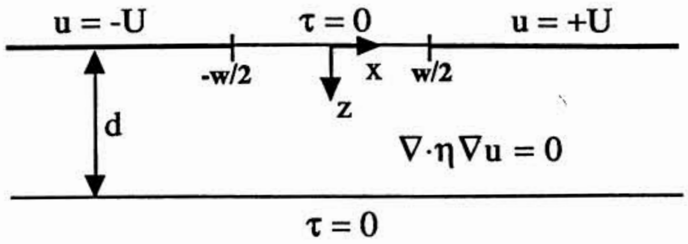
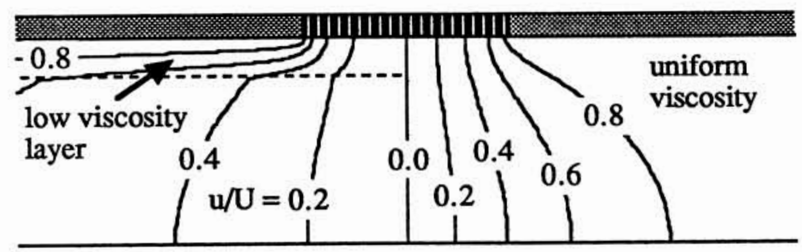


Figure 1. Boundary value problem for quasistatic flow in the ductile (viscous) layer of the lithosphere. Velocities within the layer are governed by the equilbrium equation. See text for discussion of boundary conditions.

Figure 2. Velocity distributions in the ductile layer of the lithosphere due to stike-slip motion across a fault zone (vertical lines) in the brittle surface layer.(shaded). Two solutions are shown, one on each side of the diagram. Both velocity distributions are antisymmmtric about x=0. The viscosity in the low viscosity layer is $.1\eta$ and the bottom of this layer is shown by the dashed line. With a low viscosity zone present, shearing motions are concentrated in a this layer and the lithosphere deformation is distributed horizontally over a larger region.



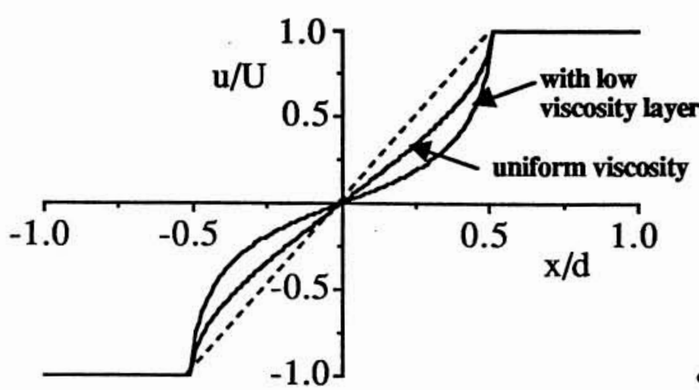


Figure 3. Velocity distributions within the fault zone for uniform viscosity and with a low viscosity layer. The shear strain rate in the fault zone is not uniform, but has a distribution consistent with a vanishing viscous shear stress on the bottom of the deforming brittle layer.

Figure 4. Relationship of fault zone width and a dimension-less parameter that controls the magnitude of stresses.