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Viscoelastic properties combined with relevant boundary conditions can produce the arctangent shape of the geodetic displacement field

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The screw dislocation model (Weertman & Weertman, 1966) gives the horizontal displacement u as a function of the vertical distance d to the dislocation, the horizontal distance x and the slip s on each side of the dislocation.

$u = -(s/\pi)\arctan(x/d)$

Savage and Burford (1973) interpreted this model in terms of horizontal displacement across a strike slip fault which is locked down to depth d, s being the plate velocity. Because of its simplicity and because the arctangent shape well represents the displacement that can be measured around most of the major strike slip faults, this model is commonly used to match geodetic data.

We present numerical simulations that have been made with the software CASTEM, a finite element code for structural and mechanical modeling. The models are rectangular boxes that have elastic or viscoelastic properties, and three different kinds of conditions are applied on the boundaries of the domain that may have an impact on the localization of the displacement near the fault plane.

The first boundary condition imposes the displacement under the plate, this case has been chosen because of its similarity to the Weertman's screw dislocation model. The second boundary condition imposes the displacement in the front, it corresponds to an extrusion. For the third boundary condition, the displacement is imposed laterally and simulates the general plate motion that drags the domain on both sides. We found that the displacement at the free surface does not fit an arctangent in all cases. If a perfectly elastic, homogeneous domain is used, only the first two types of boundary conditions lead to a displacement field resembling the geodetic data. This is awkward since the third kind of boundary conditions seems to be geologically the more relevant one.

We then introduced local rheological modifications to reduce locally the equivalent elastic plate thickness in the vicinity of the fault. This is achieved by introducing a viscoelastic relaxation in the model. We point out that a shorter maxwell relaxation time beneath the strike slip fault results in an arctangent like displacement field at the surface and discuss the long term geodynamic basis for this low viscosity zone to form, with regard to the metamorphic core complexes formation. Finally, we compare the results with 3D thermo-mechanical models made with Gale, a CIG code that solves Stokes' problems with a viso-plastic formulation. These models localize the deformation on longer time scale with the formation of a self-consistent viscous notch beneath the fault. Thus, we show that our model, combining viscoelastic properties and geologically relevant boundary conditions, also matches long term rheological behaviors of strike slip faults, and then, that it is compatible with both short and long time scales.