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On the dependence of stress states on viscoelastic rheologies.

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According to the World Stress Map, stresses in the earth crust change as a function of location and depth. Explaining the origin of the stresses is usually done by referring to active tectonic processes and by assuming that the crust is critically stressed. Although this is true in many areas around the world, we believe that the rheology of the rocks can also have an impact on the stress situation observed at depth.

Considering viscoelastic materials, we investigate how the viscous component can lead to changes in stress situations with time and depth. Our setup is taken to represent a succession of perfectly bonded horizontal layers with different material properties overlain on top of each other. We use MILAMIN, a fast finite element code, to numerically study the impact of different viscoelastic rheologies on the stress distribution as a function of time. The code is purely mechanical but assuming a constant temperature gradient with depth and an Arrhenius law for viscosity we also include a first degree approximation of the temperature dependence of viscosity.

Using our numerical code, we consider two sets of boundary conditions for a setup where a low viscosity layer is surrounded by much viscous ones. In the first set, we prescribe velocities at the bottom boundary and we determine how low a low viscosity layer should be to decouple the deformations seen in the layers above and below for time scales much shorter than the tectonic ones. We provide orders of magnitude for these low viscosities. In the second set, we prescribe tractions along a vertical boundary and we study how the stresses away from this boundary get redistributed between layers as a function of time. The low viscosity layer quickly reaches a hydrostatic state and the neighboring layers have to support the extra deviatoric stresses.

Both sets of boundary conditions show that viscoelasticity can have an impact on the stress situation even at short time scales compared to the tectonic ones. It is the transition from elastic to viscous behavior that brings the time dependency to the problem. In the first case, the decoupling caused by the low viscous layer leads to very different stress situations in the bottom and top layer and in the second case the stresses get redistributed between layers as a function of time. One should hence be careful when considering stress data from a certain depth to be representative of a location, it might not be possible to extrapolate what is true at one depth to another.