Effects of elasticity on the Rayleigh-Taylor instability: implications for large-scale geodynamics

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Elasticity is typically ignored in numerical models of mantle convection, which has resulted in vigorous discussions in the previous two editions of this workshop. In order to continue the discussion, we have analyzed the Rayleigh-Taylor instability for a Maxwell viscoelastic rheology. Both an analytical thick-plate perturbation technique and direct numerical simulations have been employed.

Results for the 2-layer setup of a dense layer overlying a lower density material show that three different deformation modes exist: the 'classical' viscous mode, an intermediate viscoelastic mode and an elastic mode. Whereas elasticity has only a minor effect on the dominant wavelength, it may increase the dominant growthrate significantly, compared to the purely viscous case. The transition between viscous and elastic deformation modes is dependent on the Deborah number, which is given in the present setup by $De = \frac{\Delta\rho g H}{G}$ (where $\Delta\rho$ denotes the density difference, g gravitational acceleration, H total height of the system and G elastic shear module). For typical Earth-like parameters, $De = 10^{-3}$–1. For the 2-layer system, with a free-slip upper boundary condition, the critical Deborah number for elasticity to be important is $\sim$ 1–10. If, however, a fast erosion/mass redistribution boundary condition is present, the critical Deborah number may decrease significantly for large viscosity contrasts. Under these conditions, elastic effects may influence lithospheric dynamics.

Additional results will be presented for a 3-layer setup with various upper boundary conditions (free-surface, free-slip, no-slip and fast erosion). It was previously demonstrated that elasticity may result in stress-enhancement in the lithosphere (*e.g.* Poliakov *et al.*, 1993; Vasilyev *et al.*, 2000), due to non-relaxed elastic stresses and plume-lithosphere interaction. We study this effect systematically for various boundary conditions and material parameters.

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