Anisotropic Viscosity and Geodynamical Flow Models - Rayleigh-Taylor Instabilities as a Test Example

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Rocks often develop fabric when subject to deformation, and this fabric leads to anisotropy of properties such as viscosity and seismic wave speeds. We employ analytical solutions and numerical flow models to investigate the effect of anisotropic viscosity on the development of Rayleigh-Taylor instabilities, a process strongly connected to lithospheric instabilities.

Our results demonstrate a dramatic effect of anisotropic viscosity on the development of instabilities - their timing, shape and, most notably, their wavelength are strongly affected by the initial fabric. An interplay between regions with different initial fabric gives rise to striking irregularities in the downwellings. Our study show that for discussions of lithospheric instabilities, and likely of other mantle processes, the approximation of isotropic viscosity may not be adequate, and that anisotropic viscosity should be included.

As part of our investigation we also compare the anisotropic fabric predicted by three different methods for various flow fields. Such calibration of methods is essential as anisotropy predicted from geodynamical flow models becomes a widely used tool for constraining and discriminating between models.

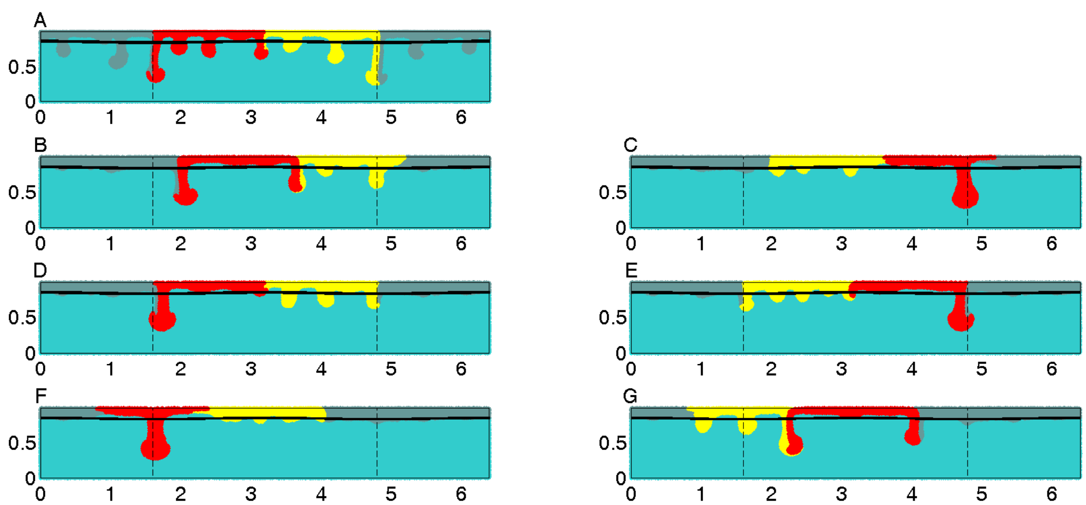

Figure 1: Results of a set of numerical experiments of Rayleigh-Taylor instabilities in the presence of anisotropic viscosity. The panels show material distribution in models with different configurations of initial anisotropic fabric. The snapshots are taken after the fastest downwelling sinks over half the box depth. Red material starts with a horizontal easy-shear direction; Yellow material starts with easy-shear direction dipping at 45°. Green materials are isotropic. Panel A shows the results for a purely isotropic model. The results show that:

a) The wavelength of instabilities at the initially-horizontal region is much longer than for the dipping or isotropic materials

b) The points of contact between regions of different fabric are particularly unstable

c) Anisotropic viscosity can offset the location of the major downwelling