The effect of anisotropic viscosity on mantle dynamics

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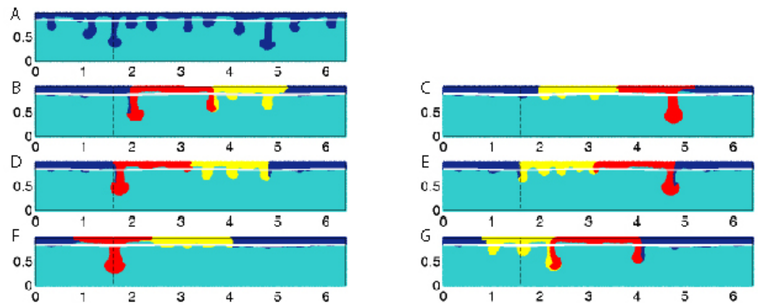
Rocks often develop fabric when subject to deformation, and this fabric causes anisotropy of physical properties such as viscosity and seismic velocities. We use the finite-element code ***Underworld*** to investigate the effect of anisotropic viscosity on a range if mantle flows, including lithosphere instabilities and plate subduction. ***Underworld*** is an evolution of the code *Ellipsis3D* and stands at the base of *Gale*. ***Underworld*** is unique among mantle convection codes in that it includes handling of anisotropic viscosity and tracks fabric evolution.

Rayleigh-Taylor instabilities are the fundamental process behind lithosphere instabilities and diapirism. The results of our experiments demonstrate a dramatic effect of anisotropic viscosity on the development of instabilities - their timing, location, and, most notably, their wavelength are strongly affected by the initial fabric. Specifically, we find a significant increase in the wavelength of instability in the presence of anisotropic viscosity which favors horizontal shear. We also find that interplay between regions with different initial fabric gives rise to striking irregularities in the downwellings. Our study shows that for investigations 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.

Figure 1 - RT instabilities developed in isotropic (blue), anisotropic with horizontal easy glide planes (red) and anisotropic with 45-dgree dipping planes (yellow). Note the difference in wavelength and location of drips.



The thermal structure of the mantle wedge in subduction zones controls the distribution of melting and the derived volcanism, as well as dehydration reactions and seismicity. Physical parameters such as subduction geometry, velocity and mantle rheology influence the thermal structure of wedges; we focus here on the effect of anisotropic viscosity. The abundant observations of seismic anisotropy in subduction zones collected in recent years suggest that the material in the mantle wedge has a strong fabric and may be mechanically anisotropic. We use two-dimensional finite-elements kinematic models constructed in ***Underworld***. We find that anisotropic viscosity leads to two substantial changes: (1) a large increase in the partially-molten area through narrowing of the overlying lithosphere (figures 2, 3 below), and (2) time variability of the melt area and excess temperatures (figure 3). This behavior is observed for both linear and non-linear viscosities. The observed time-variability, a result of heterogeneity in alignment of the flowing material, can provide an explanation for temporal changes in melt observed in some volcanic regions, without having to invoke a change in the wedge geometry, slab age or composition.

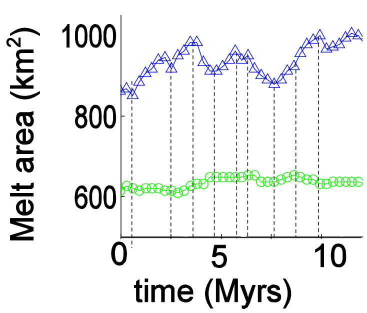


Figure 2 - total melt area as a function of time for isotropic (green) and anisotropic (blue) wedge viscosities.

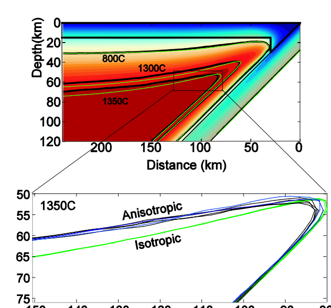


Figure 3 - Thermal structure of the wedge nose. Note variability of anisotropic T=1350C contours (blue) versus the isotropic ones (green)

<u>The above work is further discussed in the following articles</u>**:**

Lev and Hager, *Anisotropic viscosity changes the thermal structure at subduction zone wedges*, in preparation for Geophys. Res. Lett.

Lev and Hager, *Prediction of anisotropy from flow models – a comparison of three methods*, G-cubed, 2008

Lev and Hager, *Rayleigh-Taylor instabilities with anisotropic lithosphere viscosity*, Geophys. Jour. Int., 2008