CONSTRAINTS ON THE RHEOLOGICAL STRUCTURE OF THE MANTLE

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Rheological models of the mantle are at present limited to radial symmetry, usually with homogeneous linearly viscous or viscoelastic incompressible layers. While such models are probably overly simple, they readily allow calculation of geophysical effects, such as post glacial rebound and related changes in the earth's shape. They are also directly applicable to problems of global mantle flow and plate motions.

Mantle viscosity was initially constrained by observations of post glacial rebound and secular changes in length of day. These have been more recently supplemented with observations of gravity anomalies, secular polar motion and changes in J_2. In addition, the association of long wavelength components of the geoid with the effects of subducted density anomalies and seismically inferred density anomalies in the lower mantle further constrains the viscosity structure.

Analytic solutions of the deformation of spherically symmetric, self gravitating sphere with incompressible, homogeneous, linearly viscous layers have been obtained in a form simple enough to allow various effects of particular models to be clearly identified. The lithosphere is represented by a purely elastic layer. Density contrasts between layers correspond to non-adiabatic density gradients in the mantle; the presence of such non-adiabatic density contrasts introduces additional modes into the relaxation spectrum, and complicates its interpretation. Such effects may account for differences among results for similar models that have appeared in the literature.

The viscosity of the lower mantle is constrained by the relaxation of the lowest degree (ℓ=2) deformation of the mantle, which is associated with measurements of changes in l.o.d., J_2 and the rate of polar wander. The relaxation is mantle wide, and hence depends on the complete viscosity structure, as well as lithosphere thickness and rigidity. Recent determinations (by Dziewonski and Woodhouse, and Clayton and Comer) of lateral variations of seismic velocities in the lower mantle may provide another, new constraint.

Assuming that the seismic velocity variations are associated with density variations, Hager et al. have shown that they can account for most of the low degree variance in the geoid. By further assuming that the anomalies are due to temperature variations, one can calculate the convective flow field driven by the density anomalies, and the resulting advected heat flux, which is inversely proportional to the viscosity. This requires the lower mantle viscosity to be greater than $\sim 10^{23}$ poise.