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Variations in mantle microstructure and mantle rheology influencing post-glacial rebound modeling

Auke Barnhoorn (1), Wouter van der Wal (2,3), Martyn Drury (3), and Bert Vermeersen (2)

(1) Department of Earth Sciences, Utrecht University, Utrecht, The Netherlands (auke.barnhoorn@geo.uu.nl), (2) Faculty of Aerospace Engineering, Delft University of Technology, Delft, The Netherlands, (3) Department of Earth Sciences, Utrecht University, Utrecht, The Netherlands

The viscosity of the mantle has a major control on modelling of post-glacial rebound. The viscosity of the mantle is determined by a combination of linear viscous (diffusion creep) and non-linear (dislocation creep) viscous responses of the mantle to the applied load. Temperature, depth and stress levels conditions, but also the mantle composition and structure have the potential to highly influence the contributions of linear and non-linear rheologies to the mantle viscosity in post-glacial rebound modelling. From a geological point of view, the mantle is very complex and heterogeneous in structure and phase content and as a result the viscosity of the mantle can also be very complex and heterogeneous. Possible variations in structure and content of the mantle need to be assessed and where applicable incorporated into post-glacial rebound models.

In this study we asses the range of conditions at which linear viscous rheology (diffusion creep) or non-linear viscous rheology (dislocation creep) can be expected over a range of mantle microstructures. We use published olivine flow laws for diffusion and dislocation creep (Hirth and Kohlstedt, 2003) for a dry and wet upper mantle to calculate mantle viscosities in the different scenarios and apply the result in particular to the Scandinavian shield. The study shows that variations in grain size and geotherm have the main effect on the viscosity of the mantle. Stress is a second order variable influencing the dislocation creep regime only. Across a realistic range of temperature conditions, grain sizes and stress levels, both linear viscous diffusion creep and non-linear dislocation creep can be expected to occur in the mantle during post-glacial rebound with diffusion creep dominating the viscosity at shallower depths ($<\sim$200 km) and dislocation creep at deeper upper mantle depths ($>\sim$200 km). We have used information on mantle microstructures from mantle rocks exposed in Norway and from xenoliths in Finland to restrict the range of grain size present beneath Scandinavia. Those grain sizes are used to determine the best possible profile in viscosity beneath Scandinavia which then can be used to improve the Scandinavian post-glacial rebound models.

References

Hirth, G., Kohlstedt, D., 2003. Rheology of the upper mantle and the mantle wedge: a view from experimentalists. In: Eiler, J. (Ed.), Inside the Subduction Factory: AGU Geophysical Monograph Series Washington D.C. 138, pp. 83–105.