EARLY PHYSICAL PROCESSES IN THE MANTLE OF TERRESTRIAL PLANETS

S. Padovan[1], N. Tosi[1,2], & A.-C. Plesa[1]
[1]*Department of Planetary Physics, German Aerospace Center (DLR), Berlin, Germany*
[2]*Department of Astronomy and Astrophysics, Technische Universität Berlin, Berlin, Germany*

Key words Convection, Impacts, Tides, Mercury

The early phases of the evolution of the terrestrial bodies of the Solar System correspond to a period when vigorous convection dominate the energy transport across the mantle, an effect of the high interior temperature and the large amount of energy available from radioactive decays. During about the first billion of years, large number of bodies would hit the surfaces of the recently formed planets, in events that can affect the dynamics of the underlying mantle by inducing large thermal perturbations in the subsurface. In addition, depending on the orbital geometry, tidal dissipation may also contribute significantly to a body's energy budget, as was the case for the young Moon and is still the case for Jupiter's natural satellite Io. In order to model all these processes and consistently estimate their effects on a body's thermal evolution, we are creating a numerical tool that combines the finite-volume convection code Gaia [1] with a code that can estimate the tidal dissipation in the interior. We treat impacts as instantaneous thermal perturbations in the interior by employing scaling laws (e.g., [5]). Convection and tides are characterized by extremely different timescales. Thus, to consistently model the rheological response of mantle materials for these two processes it is necessary to employ a timescale-dependent rheology. We adopt the Andrade pseudo-period model [2, 4] which includes the rheological effects of temperature, pressure, grain size, and forcing period. The model parameters are obtained by fitting torsional oscillation data for olivine at forcing periods no longer than 1000 s [2]. We extrapolated the model to longer periods to test its applicability to convection and tidal problems. Figure 1 shows the dynamic viscosity as a function of the period. At very large forcing periods, corresponding to convective timescales, and for a reasonable range of parameters, the viscosity compares favorably with the reference viscosities commonly adopted in convection studies (e.g., [6]). At timescales relevant to the post glacial rebound process, the viscosity also matches the value inferred from geodetic observations (e.g., [3]). These findings indicate that the Andrade pseudo-period model is appropriate to consistently evaluate the rheological response of the mantle for convective and tidal processes.

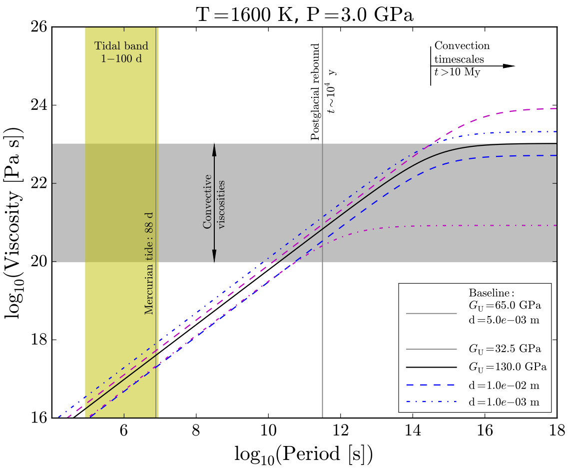

Figure 1. Viscosity as a function of the forcing period for the Andrade rheological model at T = 1600 K and P = 3 GPa. The baseline model has an unrelaxed shear modulus G_U = 65 GPa and a grain size d = 5 mm. The other models are obtained by varying a single parameter as indicated by the legend. Additional parameters correspond to melt-free olivine (for additional details see [2] and [4]).

We present the initial results that we obtain when applying the code to the case of the early evolution of the planet Mercury.

References

[1] Hüttig, C., Tosi, N. and Moore, W. B. (2013), An improved formulation of the incompressible Navier-Stokes equations with variable viscosity, *Phys. Earth Planet. Inter.*, *220*, 11–18, doi:10.1016/j.pepi.2013.04.002.

[2] Jackson, I., U. H. Faul, D. Suetsugu, C. Bina, T. Inoue, and M. Jellinek (2010), Grainsize-sensitive viscoelastic relaxation in olivine: Towards a robust laboratory-based model for seismological application, *Phys. Earth Planet. Inter.*, *183*, 151–163, doi:10.1016/j.pepi.2010.09.005.

[3] Kaufmann, G. and Lambeck, K. (2000), Mantle dynamics, postglacial rebound and the radial viscosity profile, *Phys. Earth Planet. Inert.*, *121*, 301–324, doi:10.1016/S0031-9201(00)00174-6.

[4] Padovan, S., J.-L. Margot, S. A. Hauck II, W. B. Moore, and S. C. Solomon (2014), The tides of Mercury and possible implications for its interior structure, *J. Geophys. Res. Planets*, *119*, 850–866, doi:10.1002/2013JE004459.

[5] Roberts, J. H., and O. S. Barnouin (2012), The effect of the Caloris impact on the mantle dynamics and volcanism of Mercury, *J. Geophys. Res. Planets*, *117*, E02007, doi:10.1029/2011JE003876.

[6] Tosi, N., M. Grott, A.-C. Plesa, and D. Breuer (2013), Thermochemical evolution of Mercury's interior, *J. Geophys. Res. Planets*, *118*, 2474–2487, doi:10.1002/jgre.20168.