Geophysical Research Abstracts
Vol. 15, EGU2013-3108, 2013
EGU General Assembly 2013

Seismic structure of the deep mantle arising from thermal, chemical and phase variations in spherical convection simulations with self-consistent mineral physics

Paul Tackley (1), Takashi Nakagawa (2), Frederic Deschamps (3), James Connolly (4), Ludwig Auer (1), and Lapo Boschi (5)

(1) ETH Zurich, Institute of Geophysics, Earth Sciences, Zurich, Switzerland (ptackley@erdw.ethz.ch), (2) Institute for Research on Earth Evolution, Japan Agency for Marine-Earth Science and Technology, Yokohama, Japan, (3) Institute of Earth Sciences, Academia Sinica, Taipei, Taiwan, (4) Institute of Geochemistry and Petrology, Department of Earth Sciences, ETH Zurich, Switzerland, (5) IPGP, Paris, France

Numerical thermo-chemical mantle convection simulations in spherical geometry with self-consistently calculated mineral physics (phase assemblages and material properties) are used to predict deep mantle seismic structures (Vs, Vp and bulk sound velocity Vb), which are compared to seismological observations in order to guide the interpretation of seismic observations and to test the realism of the model. The mantle composition is described a linear combination of a MORB and harzburgitic endmember compositions in the Na2O-CaO-FeO-MgO-Al2O_3-SiO_2 model system. Chemical differentiation occurs through partial melting and crustal production over 4.5 Gyr; the convection model includes strongly temperature-dependent viscosity and plastic yielding leading to plate tectonic-like behavior. Robust features of results are accumulations of basaltic material above the core-mantle boundary (CMB) and in the transition zone [1], the latter due to the MORB density inversion for $\sim$10s km below 660 km depth. To assess the influence of chemical variability, four different sets of endmember compositions are evaluated, as [2] found that the composition of MORB makes a significant difference to the resulting compositional structure. Here we focus on deep mantle structure, both volumetric and radial profiles, calculated using an updated mineral physics database [4]. Piles of segregated MORB are seismically slow in both Vs and Vb despite being intrinsically fast in Vs, because they are much hotter than the surrounding material. Anelasticity has a significant influence on Vs only in the lower thermal boundary layer where temperatures are substantially higher than the extrapolated adiabat, which corresponds to below 2600 to 2800 km depth depending on region. Results confirm that the post-perovskite (pPv) phase causes anti-correlated Vs and Vb anomalies in the deep mantle, due to pPv being fast in Vs but slow in Vb; whether this is sufficient to cause the observed seismic anticorrelation without additional compositional variations is a key point we are investigating. Local 1-D seismic profiles display great lateral variability, and often have multiple discontinuities in the deep mantle due to MORB layers in folded slabs (with a positive Vs anomaly and negative Vb) or the perovskite-pPv phase transition [3]. The pPv transition is not visible inside piles of segregated MORB because of their high temperature and the small velocity contrast of pPv in MORB. Applying a “seismic filter” to the results to approximate the tomographic imaging process turns bimodal Vs and Vp distributions into skewed unimodal ones; purely thermal models have a skewness that is opposite to that observed due to the influence of the post-perovskite phase transition whereas thermo-chemical models display a skewness and range that resembles those of actual seismic tomographic models. In conclusion, thermo-chemical models in which MORB accumulates above the CMB can explain the main features of seismic tomographic models.

[1] Nakagawa, T., P. J. Tackley, F. Deschamps, and J. A. D. Connolly (2009), Geochem. Geophys. Geosyst. 10(Q03004), doi:10.1029/2008GC002280.
[2] Nakagawa, T., P. J. Tackley, F. Deschamps, and J. A. D. Connolly (2010), Earth Planet. Sci. Lett., 296(3-4), 403-412.
[3] Nakagawa, T., P. J. Tackley, F. Deschamps and J. A. D. Connolly, (2012), Geochem. Geophys. Geosyst. 13(Q11002), doi:10.1029/2012GC004325.
[4] Stixrude, L., and C. Lithgow-Bertelloni (2011), Geophys. J. Int., 184, 1180-1213.