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Dynamics of thermochemical mantle plumes

Juliane Dannberg[1], Stephan V. Sobolev[1]
[1] *Geodynamic Modelling, GFZ German Research Centre for Geosciences, Potsdam, Germany*
dannberg@gfz-potsdam.de

Widely accepted geodynamic models describe the origin of large igneous provinces (LIPs) as a consequence of a plume rising from the core-mantle boundary and the resulting massive melting when the plume head reaches the bottom of the lithosphere [1]. Most of these models include kilometer-scale topographic uplift before and during the eruption of flood basalts [2]. On the contrary several paleogeographic and paleotectonic field studies indicate lack of surface uplift or even subsidence during the development of LIPs.

Recent geodynamic models use different approaches to explain these geological observations: When a rising mantle plume reaches the 660-km-discontinuity, the phase boundary within the hot plume is uplifted. The resulting negative buoyancy counteracts the thermal buoyancy and reduces surface uplift [3]. This effect, however, is of a scale of hundred meters and thus can not counteract the expected kilometer-scale uplift atop of a thermal plume head.
Recently, it was demonstrated [4] that the interaction of thermochemical, rather then purely thermal, plumes with the lithosphere explains observations for LIPs much better. This includes small premagmatic uplift and enormous magmatic activity at thick cratonic lithosphere. Such thermochemical plumes are formed by the entrainment of dense material derived from recycled oceanic crust while the plume ascends from the D"-layer. This material generates a reduced buoyancy and thus smaller surface uplift [4]. However, study [4] considered neither the interaction of the thermochemical plume with transition zone phase boundaries nor its motion in the lower mantle.

In this work we begin systematic study of the dynamics of the thermochemical plumes in the deep mantle and transition zone and their interaction with the lithosphere. Therefor we use a two-dimensional axisymmetric finite-element model that includes 410 km and 660 km phase boundaries as well as different phase changes for the MORB material. We employ a modified version of the Citcom code [5,6,3] that includes mantle compressibility [7], a tracer-ratio method to incorporate the two chemical components and strongly temperature- and depth-dependent viscosity.
We plan to investigate plume dynamics and especially the vertical surface movement during the plume ascent and its spreading below the lithosphere as a function of plume initial temperature, its composition and rheology of the mantle. First results of this study will be presented.

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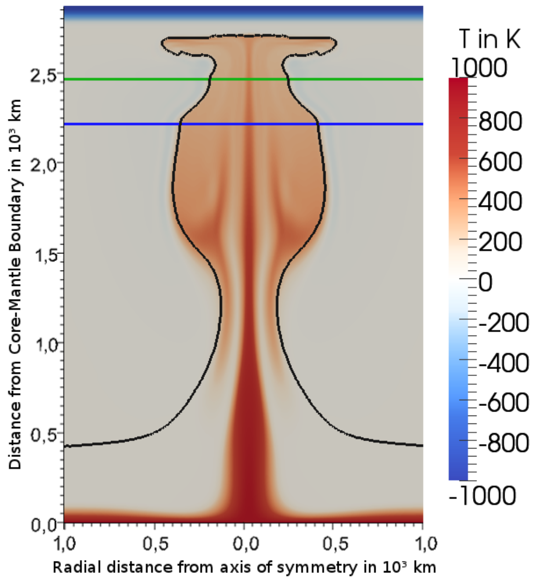

Figure 1: Snapshot of a plume spreading below the base of the lithosphere, shown is the difference between temperature field and the adiabatic temperature profile. The black line marks a fraction of 50% of the denser chemical component. Horizontal green and blue lines indicate depths of 410 km and 660 km. Phase changes clearly influence the shape of the plume and the contour of the plume shows that the depth of the phase change from spinel to perovskite is slightly reduced.