Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SIT004-12 会場:105 時間:5 月 25 日 15:45-16:15

Channel Flow in transition zone and bounds on lower-mantle lateral viscosity contrast
Channel Flow in transition zone and bounds on lower-mantle lateral viscosity contrast

Yuen David[1*], Nicola Tosi[2], Z. Q. Wu[3], Renata M. Wentzcovitch[4]
David Yuen[1*], Nicola Tosi[2], Z. Q. Wu[3], Renata M. Wentzcovitch[4]

[1]Dept. Geol. Geophys., Univ. Minnesota, [2]German Aerospace Center, [3]Dept. Earth and Planetary Sciences, USTC, [4]Dept. Chem. Eng. Mater. Sci. U.Minnesota
[1]Dept. Geol. Geophys., Univ. Minnesota, [2]German Aerospace Center, [3]Dept. Earth and Planetary Sciences, USTC, [4]Dept. Chem. Eng. Mater. Sci. U.Minnesota

Recent high-resolution seismic imaging of the transition-zone thickness beneath the Hawaiian hotspot by the M.I.T.-Purdue group (Cao et al., 2010), using curvelet transform of multiple scattered S waves, has shown convincingly a considerable uplift of the 660 km discontinuity west of Hawaii without a correspondent depression of the 410 km discontinuity. Such a structure is consistent with the geodynamical scenario of a deep-mantle plume first deflected horizontally as a channel flow at 660 km depth and the reentrance into the upper mantle away from its lower mantle source, as a secondary plume aligned with the present-day location of the hot-spot. Using a cylindrical model of mantle convection featuring multiple phase transitions and pressure-dependent thermodynamic properties according to recent mineral physics evidence both taken experimentally and computationally, we investigate the conditions under which such a peculiar plume morphology can be realized. we have employed a temperature- and pressure-dependent thermal expansivity based on tabulated results from first-principles calculations. We focus on the magnitude ¥Delta¥eta$_T$ of the lateral viscosity contrast due to temperature variations and show that this factor plays a first-order role on the dynamics of plumes if pressure-dependent thermal expansivity and conductivity are taken into account. For small values (¥Delta¥eta$_T$~10), large-scale upwellings are generated at the bottom thermal boundary layer that have enough buoyancy to pass undisturbed the endothermic transition at 660 km depth in an essentially vertical fashion. For higher values (¥Delta¥eta$_T$~10^2-10^3) mantle layering becomes more pronounced, plumes are thinner and weaker, still with enough buoyancy to reach the 660 km discontinuity but not to penetrate it. Instead, they travel horizontally along the 660 km boundary following the top part of lower mantle convection cells and rise again through the upper mantle at a distance from their parent plume also controlled by ¥Delta¥eta$_T$. Our findings argue for the importance of using a temperature-dependent viscosity in numerical models that feature also pressure- and temperature-dependent thermodynamic properties and on the possibility of using plume dynamics as imaged from seismic waves to bound the temperature viscosity contrast in the lower mantle to be between one hundred and a few hundred.

Cao Q., R.D. van der Hilst, M.V. de Hoop, S. Shim. Complex plume dynamics in the transition zone underneath the Hawaii hotspot: seismic imaging results. DI23C-02, AGU Fall Meeting 2010, San Francisco.