Geophysical Research Abstracts
Vol. 15, EGU2013-6753-1, 2013
EGU General Assembly 2013

Double Layering and Bilateral Asymmetry of a Thermochemical Plume in the Upper Mantle beneath Hawaii

Maxim D. Ballmer (1), Garett Ito (1), Cecily J. Wolfe (2,3,4), Sean C. Solomon (4,5)

(1) Univ. Hawaii, SOEST, Geology & Geophysics, Honolulu, USA (ballmer@hawaii.edu), (2) Univ. Hawaii, SOEST, Hawaii Inst. Geophysics & Planetology, Honolulu HI, USA, (3) US Geological Survey, Earthquake Hazards Program, Reston VA, USA, (4) Dept. Terrestrial Magnetism, Carnegie Inst. Washington, Washington DC, USA, (5) Lamont-Doherty Earth Observatory, Columbia University, Palisades NY, USA

Classical plume theory describes purely thermal upwellings that rise through the entire mantle, pond beneath the lithospheric plate in a thin “pancake,” and generate hotspot volcanism. High-resolution seismic velocity images obtained from the Plume–Lithosphere Undersea Melt Experiment (PLUME) support the concept of a deep-rooted mantle plume beneath the Hawaiian hotspot. However, in detail these images challenge traditional concepts inasmuch as they indicate a broad low-velocity body in the upper mantle that is much thicker and more asymmetric than a thermal pancake predicted from purely thermal plume models. Geochemical observations also argue against a purely thermal (i.e. isochemical) mantle source for Hawaiian lavas and instead indicate a heterogeneous plume involving mafic lithologies such as eclogite.

To explore the dynamical and melting behavior of hot plumes that also contain eclogite, we perform three-dimensional numerical simulations of thermochemical convection. The models simulate eclogite with an excess density relative to ambient-mantle peridotite that peaks at depths of 410–300 km due to solid phase changes in the quartz and olivine systems. Because of the effects of these phase transitions, a mantle plume containing >12% eclogite pools as a wide body (hundreds of kilometers wide) at depths of 450–300 km (the “deep eclogite pool”, or DEP). From the top of the DEP rises a shallow plume that narrows rapidly due to removal of eclogite by melting. The shallow plume supplies material into a thin sublithospheric pancake and feeds hotspot volcanism. Seismic resolution tests indicate that the double layering of hot plume material (DEP and shallow pancake) can account for the thick low-velocity body imaged by PLUME.

A subset of models predicts pulsations in plume ascent and variations in magmatic activity over timescales of $\sim$10 Myr, as are observed. In these models, the complex upper-mantle dynamics of the eclogitic plume moreover give rise to intermittent bilateral asymmetry in the contribution of mafic materials to partial melting, a prediction that is consistent with the geochemical distinction between the Loa and Kea trends among Hawaiian volcanoes. Therefore, a deep origin of characteristic Loa and Kea sources, as previously suggested, may not be required. Furthermore, any deep-rooted asymmetry in eclogite content of the plume is shown to be veiled by the complex dynamics of the DEP and the shallow plume. This study reveals that phase transitions exert important effects on thermochemical convection in the upper mantle that influence the overall dynamics of mantle plumes, the genesis of intraplate volcanism, and ocean-island geochemistry.