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TI: The thermal state of the Earth

AU: ***Lee, C**
EM: *ctlee@rice.edu*
AF: *CIDER working group, Kavli Institute of Theoretical Physics, UCSB, Santa Barbara, CA 93106*
AU: **Courtier, A**
EM: *cour0090@umn.edu*
AF: *CIDER working group, Kavli Institute of Theoretical Physics, UCSB, Santa Barbara, CA 93106*
AU: **Halama, R**
EM: *rhalama@geol.umd.edu*
AF: *CIDER working group, Kavli Institute of Theoretical Physics, UCSB, Santa Barbara, CA 93106*
AU: **Jackson, M**
EM: *mjackson@whoi.edu*
AF: *CIDER working group, Kavli Institute of Theoretical Physics, UCSB, Santa Barbara, CA 93106*
AU: **Larson, A M**
EM: *alarson@geosc.psu.edu*
AF: *CIDER working group, Kavli Institute of Theoretical Physics, UCSB, Santa Barbara, CA 93106*
AU: **Lawrence, J**
EM: *jlawrence@ucsd.edu*
AF: *CIDER working group, Kavli Institute of Theoretical Physics, UCSB, Santa Barbara, CA 93106*
AU: **Wang, Z**
EM: *zwang@whoi.edu*
AF: *CIDER working group, Kavli Institute of Theoretical Physics, UCSB, Santa Barbara, CA 93106*
AU: **Warren, J**
EM: *jwarren@whoi.edu*
AF: *CIDER working group, Kavli Institute of Theoretical Physics, UCSB, Santa Barbara, CA 93106*
AU: **Workman, R**
EM: *rworkman@gps.caltech.edu*
AF: *CIDER working group, Kavli Institute of Theoretical Physics, UCSB, Santa Barbara, CA 93106*
AU: **Xu, W**
EM: *xuwenbo@umich.edu*
AF: *CIDER working group, Kavli Institute of Theoretical Physics, UCSB,*

Santa Barbara, CA 93106

AU: **Hirschmann, M**

EM: *Marc.M.Hirschmann-1@umn.edu*

AF: *CIDER working group, Kavli Institute of Theoretical Physics, UCSB, Santa Barbara, CA 93106*

AU: **Hart, S**

EM: *shart@whoi.edu*

AF: *CIDER working group, Kavli Institute of Theoretical Physics, UCSB, Santa Barbara, CA 93106*

AU: **Stixrude, L**

EM: *stixrude@umich.edu*

AF: *CIDER working group, Kavli Institute of Theoretical Physics, UCSB, Santa Barbara, CA 93106*

AU: **Lithgow-Bertelloni, C**

EM: *crlb@umich.edu*

AF: *CIDER working group, Kavli Institute of Theoretical Physics, UCSB, Santa Barbara, CA 93106*

AU: **Chen, W**

EM: *wpchen@uiuc.edu*

AF: *CIDER working group, Kavli Institute of Theoretical Physics, UCSB, Santa Barbara, CA 93106*

AB: There is currently a debate over whether the mantle source regions of ¡§hotspots¡¨ are hotter than the ambient mantle. Some of the assumptions involved in estimating mantle temperatures have been questioned, leading to the suggestion that temperatures beneath ¡§hotspots¡¨ may fall within the range of that beneath mid-ocean ridges. If ¡§hotspots¡¨ are not hot, the existence of hot thermal plumes originating from a hot lower thermal boundary layer would be called into question. To shed light on this debate, we present independent estimates of the potential temperature of the mantle beneath ridges (ambient) and hotspots. Mantle potential temperatures were determined in four independent ways: 1) the calculated primary magma compositions of a global compilation of mid-ocean ridge basalts (MORBs) and ocean island basalts (OIBs); 2) transition zone thicknesses from SS precursors and receiver functions, 3) comparisons between melting models and the average thickness of oceanic crust, and 4) the bathymetry of ridge axes. Primary magma compositions for both MORBs and OIBs were calculated by incremental equilibrium addition of olivine back into primitive magmas until an olivine composition of forsterite 90 was reached. The calculated primary composition was assumed to represent the aggregate of polybaric fractional melts. The MgO and SiO2 contents of the primary magma were then used with an established olivine thermometer and a new barometer based on silica activity to calculate, respectively, the average temperature and pressure of equilibration with the mantle. The average potential temperature of the Earth's mantle based on thermobarometry of MORBs is 1370 +/- 50 oC. Seismic estimates of the transition zone thickness coupled with a thermodynamic-based model on how the transition zone thickness varies as a function of temperature yield a similar mantle potential temperature. Finally, average mantle potential temperature inferred from the thickness of

oceanic crust and seafloor bathymetry also fall in this range. In contrast, temperatures of OIBs based on thermobarometric calculations indicate that they derive from mantle source regions having potential temperatures at least as high as 1500 +/- 50 oC, suggesting that the OIB source region is 130 oC hotter than MORB source region (correcting magmas to Fo91 would increase this temperature difference). OIBs near ridges (Iceland, Azores, Galapagos) yield temperatures intermediate between 1370 and 1500 oC. Combining the results from ridges and hotspots reveals a negative correlation between petrologically-determined potential temperature and seismically determined transition zone thickness. The sense of this correlation is consistent with that predicted by mineral physics. The agreement arrived from these completely independent approaches suggest that the assumptions involved in our calculations are reasonable. Collectively, our study provides the most robust estimate so far on the average potential temperature of the mantle, and moreover, shows that OIBs derive from mantle source regions, which are at least 130 oC hotter than ambient mantle. This work comes from the CIDER 2006 conf at the Kavli Institute.

DE: 8130 Heat generation and transport
DE: 8410 Geochemical modeling (1009, 3610)
DE: 8415 Intra-plate processes (1033, 3615)
DE: 8416 Mid-oceanic ridge processes (1032, 3614)
DE: 8450 Planetary volcanism (5480, 6063, 8148)
SC: Volcanology, Geochemistry, Petrology [V]
MN: 2006 Fall Meeting

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