Geophysical Research Abstracts
Vol. 16, EGU2014-14669, 2014
EGU General Assembly 2014

Earth's Fiercely Cooling Core — 24 TW

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Earth's mantle and core are convecting planetary heat engines. The mantle convects to lose heat from slow cooling, internal radioactivity, and core heatflow across its base. Its convection generates plate tectonics, volcanism, and the loss of $\sim$35 TW of mantle heat through Earth's surface. The core convects to lose heat from slow cooling, small amounts of internal radioactivity, and the freezing-induced growth of a compositionally denser inner core. Core convection produces the geodynamo generating Earth's geomagnetic field. The geodynamo was thought to be powered by $\sim$4 TW of heatloss across the core-mantle boundary, a rate sustainable (cf. Gubbins et al., 2003; Nimmo, 2007) by freezing a compositionally denser inner core over the $\sim$3 Ga that Earth is known to have had a strong geomagnetic field (cf. Tarduno, 2007). However, recent determinations of the outer core's thermal conductivity(Pozzo et al., 2012; Gomi et al., 2013) indicate that >15 TW of power should conduct down its adiabat. Conducted power is unavailable to drive thermal convection, implying that the geodynamo needs a long-lived >17 TW power source. Core cooling was thought too weak for this, based on estimates for the Clapeyron Slope for high-pressure freezing of an idealized pure-iron core.

Here we show that the $\sim$500-1000 kg/m̂3 seismically-inferred jump in density between the liquid outer core and solid inner core allows us to directly infer the core-freezing Clapeyron Slope for the outer core's actual composition which contains $\sim$8$\pm$2% lighter elements (S,Si,O,Al, H,…) mixed into a Fe-Ni alloy. A PREM-like 600 kg/m̂3 -based Clapeyron Slope implies there has been $\sim$774K of core cooling during the freezing and growth of the inner core, releasing $\sim$24 TW of power during the past $\sim$3 Ga. If so, core cooling can easily power Earth's long-lived geodynamo. Another major implication of $\sim$24 TW heatflow across the core-mantle boundary is that the present-day mantle is strongly 'bottom-heated', and diapiric mantle plumes should dominate deep mantle upwelling.