Ancient mantle heterogeneity: observations and models

FRANCIS NIMMO[1]

[1]Dept. Earth & Planetary Sciences, University of California Santa Cruz, CA 95064, USA (fnimmo@es.ucsc.edu)

Short-lived isotopic systems such as ^{182}Hf-^{182}W, ^{146}Sm-^{142}Nd and ^{129}I-^{129}Xe record early differentiation events in the Earth [1-3]. Archean rocks in many cases provide evidence for progressive mixing and dilution of these ancient isotopic [4-6] and elemental [7] heterogeneities. Initial growth of isotopic anomalies depends on the partition coefficients, the differentiation time and the decay constants; the measured present-day heterogeneity also depends on the mixing timescale and the sampling lengthscale [8-9]. Several systems imply survival of heterogeneities for > 1 Gyr [1,5,6,10], suggesting a mixing timescale comparable to that inferred for the present-day mantle [9,11].

Accretion of the Earth involved multiple giant impacts, likely resulting in several generations of magma oceans [12] and an initially highly heterogeneous mantle. For siderophile elements, a potential additional source of heterogeneity is late addition of material following the end of core formation [2,7]. Although Hadean mantle convection is often assumed to be more vigorous than the present day [11], the long-term survival of heterogeneities argues against this. The Early Earth may have removed most of its heat via advection of melt [13] rather than convection; density stratification may have inhibited mixing [14]; and dehydration [15] or reduced mantle stresses [6] may have resulted in more sluggish plate tectonics at early times.

Mantle mixing timescales that do not vary greatly over 3.5 Gyr are compatible with petrological esimates of the rate of mantle cooling; whether such sluggish heat transfer can also be reconciled with the existence an ancient geodynamo (which requires rapid cooling) remains to be seen. Geoneutrino quantification of the Earth's radiogenic element abundance and spatial distribution will ultimately help resolve these issues.

[1] Rizo *et al Nature* 2012 [2] Willbold *et al Nature* 2011 [3] Mukhopadhyay, *Nature*, 2012 [4] Bennett *et al Science* 2002 [5] Touboul *et al Science* 2012 [6] Debaille *et al EPSL* 2013 [7] Maier *et al Nature* 2009 [8] Caro *et al GCA* 2006 [9] Kellogg *et al EPSL* 2002 [10] Cabral *et al Nature* 2013 [11] Blichert-Toft and Albarede *Science* 1994 [12] Tucker and Mukhopadhyay *LPSC* 2013 [13] Moore and Webb *Nature* 2013 [14] Labrosse *et al Nature* 2007 [15] Korenaga *GRL* 2003