Equilibrium core formation loses it's lustre: High pressure & temperature partitioning of gold

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Experiments to determine the distribution of highly siderophile elements (HSE) between core-forming metal and the magma ocean suggest that the primitive upper mantle (PUM) should be highly depleted in most of these constituents relative to what is observed. This is not the case for Au. We have measured Au solubility at 2GPa and 1800-2315°C, at ~IW-IW+2.5, under both C-bearing and C-free conditions. Metal-silicate partition coefficients ($D_{Met/Sil}$) were then calculated using the relation of [1]. After combination with the low temperature results of [2], the following temperature dependence for $D_{Met/Sil}$ was found:

$$D_{Met/Sil} = 1.14(0.07)*10^4/T\,(\mathrm{K}) - 1.41(0.34)$$

$D_{Met/Sil}$ is essentially independent of fO_2 and the results from previous studies at 0.1MPa-23GPa [2], [3] agree well with our 2GPa data. Temperature therefore appears to be the primary factor controlling the affinity of Au for Fe-metal. Os isotope systematics and concentrations of the other HSEs in the PUM are best explained by a late veneer of LL-chondrite, comprising 0.5% of the bulk silicate earth [4]. $D_{Met/Sil}$ values for Au limit metal-silicate equilibration to ~2450°C if an over-abundance of Au in the PUM is to be avoided, placing the base of the magma ocean at ~400km. This is much shallower than the >800km depth required by the convergence of Ni-Co partitioning [5]. Low $D_{Met/Sil}$ values at high temperature also predict Au/Ir ratios much greater than estimated for the PUM. Metal-silicate equilibrium therefore appears unable to account for the Au content of the PUM. One solution to this discrepancy may be incomplete equilibration between the magma-ocean and the accreting cores of large, differentiated planetesimals [6]. In this scenario, Au may be transported to the Earth's proto-core deprived of communication with molten-silicate, thus imbuing the core with a Au content greater than predicted by metal-silicate partitioning.

[1] Borisov *et al* (1994) *GCA* **58**, 705-716. [2] Borisov & Palme (1996) *Min. & Pet.* **56**, 297-312. [3] Danielson *et al* (2005) *LPSC XXXVI*, 1955. [4] Brenan & McDonough (2009) *Nature* **2**, 798-801 [5] Bouhifd & Jephcoat (2011) *EPSL* **307**, 341-348. [6] Dahl & Stevenson (2010) *EPSL* **295**, 177-186.

Expanding early Earth frontiers: A new Eoarchean-Hadean(?) terrane in Southwestern Greenland

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The strongest controls on early Earth processes and environments are obtained through direct study of the rock record, which currently, with few exceptions, terminates at ca. 3.9 Ga. Although rare >4.0 Ga zircons and their inclusion suites preserved in Western Australian Mesoarchean metasediments provide a wealth of information about early Earth history and conditions, they are an incomplete and likely restricted record of early processes.

Here we present new geochemical observations from metagabbros and associated felsic rocks from a previously unstudied region of SW Greenland. Minimum age constraints on the metagabbros are provided by U-Pb zircon (SHRIMP) ages of cross-cutting granitoids; a dated tonalite has a dominant population of euhedral, oscillatory-zoned magmatic zircons with an age of 3889±5 Ma. Two adjacent relatively older gabbros yielded populations of small, oval zircons with only ca. 2.97 Ga ages, which are interpreted to have formed in a recognized regional metamorphic event. This event is not recorded at either Isua or on Akilia, demonstrating that this is a distinct block of ancient crust, rather than contiguous with previously documented Eoarchean domains. Initial εHf values of the ca. 3.89 Ga zircons are within error of estimated chondritic compositions, with no evidence for early Lu/Hf fractionation. This is in accord with Lu-Hf data from zircon populations extracted from >3.7 rocks worldwide.

Measured Hf isotopic compositions of the metagabbro Mesoarchean metamorphic zircons determined by LA-MC-ICPMS range from εHf= -79 to -83; initial compositions calculated at the metamorphic age are highly negative (-13 to -16). Two-stage chondritic mantle model ages calculated using plausible $^{176}Lu/^{177}Hf$ ratios for the pre-zircon first stage are >4.0 Ga. For example, using $^{176}Lu/^{177}Hf$ =0.018 as typifies Isua metabasaltic rocks, yields chondritic model ages of ca. 4.3 Ga. In contrast, similar-aged metamorphic zircons from a nearby Mesoarchean metasedimentary rock have positive initial εHf values =+8 with DM model ages equal to zircon crystallization age. The ancient Hf model ages combined with the minimum 3.89 Ga age provided by cross-cutting tonalites point to a ≥4.0 Ga age for the metagabbros. Continued investigations of these potential Hadean rocks are in progress.

The majority of rocks analysed from SW Greenland Eoarchean terranes have ^{142}Nd isotopic anomalies when compared with modern terrestrial rocks, with the magnitude of ^{142}Nd generally increasing with crystallization age as shown by Bennett et al, (*Science*, 2007). In the absence of igneous zircons in the ≥3.89 Ga metagabbros, ^{142}Nd compositions may provide confirmation of the Hadean age suggested by Hf isotopic modelling. These recently recognised earliest Eoarchean and possibly Hadean suites are a significant new laboratory for testing models of early Earth formation and evolution.