Evidence for Hadean mantle depletion in the sources of ~3.75 Ga subduction-related rocks, Isua, SW Greenland

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The Hf isotope compositions of Earth's oldest zircons provide growing evidence that crust-mantle differentiation started as early as 4.4 Ga. Yet, the size of these differentiated Hadean reservoirs and their persistence over Earth's history are still under debate. Lu-Hf studies on zircons younger than 3.8 Ga do not reveal any evidence for the long term presence of ancient depleted mantle reservoirs [e.g. 1].

Rocks from the ~3.71-3.81 Ga Isua supracrustal belt (ISB) comprise the oldest preserved record of mafic crustal material, thus potentially providing evidence for any large scale mantle depletion in the early Archean. Here, we report Hf and Nd isotope data for the least altered samples from a suite of ~3.75 Ga old, submarine boninite-like metabasalts from the central tectonic domain of the eastern ISB [2]. These metabasalts are among Earth's oldest preserved subduction related rocks [2]. They were metamorphosed under amphibolite to greenschist facies conditions.

Initial εHf values of the boninite-like metabasalts range from -1.3 to +7.9. The samples have $^{176}Lu/^{177}Hf$ values as high as 0.9, indicating a previous depletion of the mantle source(s) in the garnet stability field. These εHf values are clearly of primary origin, as the initial εHf, εNd and γOs [3] correlate with major and trace elements [2], exhibiting a magmatic differentiation trend. All samples follow AFC curves, suggesting assimilation of up to 30 % enriched crustal material, possibly marine sediments or igneous rocks with TTG-like composition. Two different parental mantle sources can be identified: one has an initial εHf value of ca. +7.9 and the other of ca. +1.3. In order to have an initial εHf of +7.9, a source must have an old and strong depletion in incompatible elements. Hence the presence of a complementary enriched component is required, which may be the earliest continental crust. These results provide the first evidence from mafic Archean rocks for the persistence of Hadean mantle depletion into the early Archean. As other ISB rocks do not display such strongly depleted initial εHf values, the volume of these depleted mantle domains was probably small.

References

[1] Amelin *et al*. (1999), *Nature* **399**, 252-255.
[2] Polat, A. *et al*. (2002), *Chem. Geol.* **184**, 231-254.
[3] Frei, R. *et al*. (2004), *GCA* **68**, 1645-1660.

Is D″ a low-mu reservoir?

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Preservation of a "hidden" reservoir in the lowermost mantle, the D″ layer, since the early Earth has recently been proposed to explain unbalanced geochemical signatures of accessible terrestrial reservoirs relative to a chondritic Earth, on the basis of xenon (Tolstikhin and Hofmann, 2005) and ^{142}Nd isotopes (Boyet and Carlson, 2005). How could such a reservoir have formed and subsequently survive for more than 4 Ga? Here we explore the possibility that following large-scale early mantle melting, the partially molten lowermost mantle solidified by downward migration of a dense melt fraction. This is the inferred consequence of the measured crossover of melting temperatures of silicate perovskite and magnesio-wüstite at about 1200 km depth, and the predicted Fe-rich eutectic and low melting temperatures in the lowermost mantle (Boehler, 2000). This suggests that D″ formed during early solidification of the lower mantle and that it survives because of its Fe-rich composition.

The high melting temperatures of Mg and Ca perovskites in the lowermost mantle suggest that both phases remain in the residual solid. Corgne *et al*. (2005) have measured remarkably high partition coefficients for U and Th in Ca-perovskites. They suggested that this might provide an explanation for the "HIMU" (high mu = high U/Pb) ocean island source reservoir. In contrast, we suggest that the downward solidifying scenario should create a low-mu lowermost mantle region, because Pb is incompatible in the perovskites and is therefore enriched in the liquid, whereas U and Th are enriched in the Ca perovskite of the residual solid. Using the partition coefficients of Corgne *et al.* (2005) with simple fractional crystallization models yields a low-mu D″ layer and a higher-mu overlying mantle. If the time scale of this lower-mantle solidification was on the order of 100 to 500 Ma, this offers a simple solution to the classic "Pb paradox" (estimated bulk silicate lead lying "to the right" of the Pb-Pb geochron) and the well-known two-stage evolution of terrestrial lead. We also explore possible solutions of other geochemical puzzles, such as the high, time-integrated Th/U ratios calculated from early Archean galenas and feldspars, the subchondritic Nb/Ta ratios of accessible terrestrial reservoirs, and the decoupled ε(Hf) and ε(Nd) values of early Archean rocks in terms of this model.

References

Boehler, R. (2000) *Reviews Geophys*. **38**, 221-235.
Tolstikhin, I.N. & Hofmann, A.W. (2005) *Phys. Earth Planet. Int.* **148**, 109-130.
Boyet, M. & Carlson, R.W. (2005) *Science* **309**, 576-581.
Corgne, A. *et al*. (2005) *Geochim. Cosmochim. Acta*. **69**, 485-496.