

No REE into the Earth's core

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Introduction

The earliest history of the Earth was marked by accretion and core formation within about 100 Myr [1, for a review]. Short-lived radioisotope systems such as ¹⁴⁶Sm-¹⁴²Nd (composed by two refractory elements) are useful in determining how the silicate Earth, for example, evolved during and after accretion. Recent Sm-Nd data show that all terrestrial samples have on average 20 ppm ¹⁴²Nd excess relative to chondritic meteorites [2]. It is thus evident that an enriched Hadean reservoir has to exist, unless the bulk Earth accreted with a Sm/Nd ratio that was higher than the chondrite average. Within several hypothesis [3], the enriched Hadean reservoir maybe the core since rare earth elements (REE) are not strictly lithophiles in more reducing conditions [4]. In order to test this hypothesis, experiments at core-forming conditions (*P*, *T*, *f*_{O₂}, etc) are needed to assess whether or not the core plays an active role in the observed ¹⁴²Nd anomalies.

To simulate Earth's core formation under conditions of segregation from a deep magma ocean, we performed multi-anvil experiments between 3 and 8 GPa at various temperatures between 2073 and 2373 K, to determine the partition coefficients of REE between molten C1-chondrite model composition and various Fe-rich alloys (including Fe₉₀Ni₁₀, Fe₈₃Si₁₇, and Fe₈₀Ni₁₀S₁₀). The run products indicate that the oxygen fugacity (*f*_{O₂}) ranges from 1.5 to 5 log units below the iron-wüstite (IW) buffer, and is in agreement with core-formation models in which metallic liquid equilibrates with molten silicate under reducing conditions. The chemical compositions of the run products were determined by laser ablation ICP-MS and electron microprobe. Our results show a low liquid metal-silicate melt partition coefficients of all REE that range between 10⁻³ and 10⁻⁵ (an increase of the partition coefficients with decreasing the *f*_{O₂} is observed). More importantly, our experiments show that the metal-silicate partition coefficients of Sm and Nd are similar within the investigated conditions, meaning that the Sm/Nd ratio is not fractionated by metal-silicate segregation. Another line of support of this conclusion is found by an independent work on the cosmochemical and petrological study of enstatite chondrites [5].

Conclusion

If the bulk Earth has chondritic ¹⁴²Nd/¹⁴⁴Nd ratio, an enriched Hadean reservoir has to exist within the deep mantle. In contrast, if the bulk Earth has an Nd isotopic composition distinct from that of the chondrites, then there is no need to invoke a hidden reservoir. In any case the Earth's core is out of the equation concerning the ¹⁴²Nd anomalies.

[1] Kleine *et al.* (2009) *GCA* **73**, 5150-5188.

[2] Boyet and Carlson (2005) *Science* **309**, 576-581.

[3] Andreasen *et al.* (2008) *EPSL* **266**, 14-28.

[4] Lodders (1996) *Meteoritics & Planetary Science* **31**, 749-766.

[5] Gannoun *et al.* (2011) *GCA* **75**, 3269-3289.

Mg,Fe-rich carbonates stability at lower mantle conditions

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Only a small fraction of the total carbon budget of the Earth is found at the surface; with the mantle and core likely being the largest carbon (C) reservoirs in the planet [e.g. 1, 2]. Carbonates are the main C-bearing minerals that are recycled into the deep Earth. Previous studies, focusing on the stability of Ca and Mg rich carbonates in the upper mantle, demonstrated the possibility of C to be recycled into the lower part of the mantle [e.g. 3]. A few experimental studies have been conducted on the stability of magnesite (MgCO₃) in equilibrium with silicates at lower mantle pressure and temperature (*P-T*) conditions. The decarbonation reaction: MgCO₃(magnesite) + SiO₂ (stishovite) → MgSiO₃ (perovskite) + CO₂ (solid) has been reported at lower mantle conditions limiting the carbon cycle to about the first 1200 km deep (about 45 GPa - 2200 K) [4]. On the other hand, Seto *et al.* [5] supports the possibility for a deeper recycling of carbon in the Earth in relatively cold slabs, as they observed decarbonation of magnesite in equilibrium with mid ocean ridge basalt (MORB) at higher temperature. However, several carbonate phase transitions have been reported at higher *P-T* [e.g. 6].

We conducted high *P-T* experiments on iron-bearing carbonates stability. We used both *in situ* and *ex situ* analyses including synchrotron based X-ray diffraction and transmission electron microscopy to characterize the structure and the chemistry of the different phases in the samples. Two new high *P-T* phases were observed for two compositions: (1) the (Mg,Fe)CO₃ system above 85 GPa – 2000 K [7] and (2) the FeCO₃ composition above 40 GPa – 1500 K [8]. In both of these new phases, the structures determined from *ex situ* analyses led us to propose a change in the C environment as the C formed (CO₄)⁴⁻ tetrahedra instead of triangular (CO₃)²⁻ groups as in carbonates. We will discuss the influence of such structural changes on carbonate stability and its solubility within mantle silicate phases.

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