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Silicon Mantle/Core Fractionation and the Origin of Pallasites

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Experimentally determined metal/olivine partition coefficients and diffusion rates will help answer questions relating to Earth's elevated Mg/Si ratio and will provide better tools for the determination of the origin of pallasites.

It is known that the Mg/Si ratio of the Earth's primitive upper mantle (PUM) is elevated relative to all types of chondrites (possibly not CV chondrites), Mars, and the solar photosphere [1]. Theories to explain these differences fall into two distinct camps. On the one hand are those that propose that Earth's Mg/Si ratio is a primordial property of the planet. On the other are those that propose Si fractionation into the core during metal/silicate equilibration in Earth's magma ocean (e.g., [2]) or earlier on during asteroid and planetesimal differentiation [3]. If Malavergne [3] is correct, we should be able to measure such fractionation in pallasite meteorites. The value of these measurements is dependent on our knowledge of the formation of pallasites, however.

Pallasite meteorites are intimate mixtures of olivine (forsterite) and metal. It has been proposed that they originated as samples of the core-mantle boundaries of now disrupted asteroids or planetesimals (e.g., [4]). Their olivines have been described as chemically homogeneous in the major elements [4] but have chemical gradients in the minor elements (e.g. Ca, Cr, Co, Ni). It is assumed that these chemical profiles are the result of diffusion during slow cooling, as the phases attempted to re-equilibrate at progressively lower temperatures.

Measured chemical profiles in pallasitic olivines have been used with a one-dimensional, spherical, cooling model to obtain cooling rates for the pallasites' parent bodies [5]. The results are four orders of magnitude faster than metallographic derived cooling rates (~10^{-6} ºC/yr) [4] and if correct hint at a complex history for the formation of the pallasites. In fitting the profiles [4] found that it is impossible to obtain a result using a fixed boundary condition and that a varying condition is necessary. Due to a lack of experimental data, [5] were not able to constrain how the boundary condition changes. Boundary conditions are dependent on the partition coefficient (D) of elements between olivine and the adjacent metal. We have obtained metal/olivine partition coefficients for Ni, Co, Cr and Si at 1550 ºC and IW -1. Ni and Co Ds reveal a small dependence on metal composition. Metal/olivine D_{Si} values ($1*10^{-6}\pm1*10^{-7}$ to $5*10^{-5}\pm3*10^{-6}$) are too low to account for Earth's Mg/Si ratio. Olivine diffusion profiles for Cr are in line with those measured by [6] and provide validation for our method and for the values obtained for Ni and Co. Ongoing work will determine the effect of lowering temperatures and varying redox conditions on partitioning and diffusion of these elements. We expect, however, that Ds and diffusion rates will decrease with decreasing T but that D_{Ni} and D_{Co} will increase as a function of lowering fO_2.

[1] M.J. Drake and K. Righter (2002) *Nature* **416**, 39-44. [2] J. Wade and B. Wood (2005) *EPSL* **236**, 78-95 ([3] Malavergne et al. (2004) *Geochim et cosmochi acta* 68, 4201-4211. [4] Buseck and Goldstein (1969) *Geol. Soc. Amer. Bull.* **80**, 2141-2158. [5] Tomiyama and Huss (2006) *LPSC XXXVII* (2132) **40,** A156. [6] Ito et al., (2004) *LPSC XXXV* (1324)