An improved understanding of Martian Hf-W geochronology

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Based on Hf-W chronometry, recent studies suggest rapid accretion and an old age for core formation for Mars, making it a starved planetary embryo that did never reach full planetary size [1] [2]. Beyond the ^{182}W composition of Martian samples, the Hf/W ratio of the Martian mantle is a key parameter for this Hf-W approach. As Mars is more oxidised than Earth or many smaller asteroids, its Hf/W ratio is closer to the chondritic value, and the Martian Hf/W needs to be known to greatest accuracy. Previous attempts to determine this ratio relied on literature compilations using ratios of W to lithophile Th and U, both considered to behave similar to W.

In a comprehensive study on representative Martian meteorites, we measured the concentrations of W and similarly incompatible elements (e.g., Th, U, Nb, Ta) on the same meteorite specimen, mostly employing isotope dilution. Our results indicate that Th-U behaved more incompatible than W during Martian silicate differentiation, making these elements less suited to reliably estimate the W content of the Martian mantle. Rather, Nb and Ta behave most similar to W, in marked contrast to the Earth, where Nb-Ta behave more compatibly. This feature is explained by recent experimental findings [3], showing a more compatible behaviour of W at higher proportions of W^{4+}/W^{6+}. Initial Martian differentiation may thus have occurred at more reducing conditions.

When W is compared to Ta, nakhlites yield a Ta/W that is resolvably higher than that of shergottites, in line with the more radiogenic ^{182}W compositions of nakhlites. Using the chondritic Ta/Hf from [4], we obtain a Hf/W of 3.87±0.24 for the nakhlite source and of 3.05±0.22 for the shergottite source. Using the measured $^{180}Hf/^{184}W$ for carbonaceous chondrites of 1.31±0.15 ([5], corrected), a single stage Hf-W model age of up to 4.5 Ma after solar system formation is obtained for the shergottite source. For the nakhlite source, a model age older than the solar system age is obtained. This finding is in line with ^{142}Nd evidence [6] and a more complex history of the nakhlite source, involving metal segregation and early silicate melting during the lifetime of ^{182}Hf.

[1] Dauphas & Pournand (2012) *Nature* **473**. [2] Mezger *et al.* (2013) S*p. Sci. Rev.* **174**. [3] Fonseca *et al.* (2009) *EPSL* **404**. [4] Palme & O'Neill 2014 *ToG* **3** [5] Kleine et al. 2004 *GCA* **68**. [6] Debaille et al. (2009) *Nature Geoscience* **2**.