CONSTRAINTS ON THE ACCRETION HISTORY OF MARS.

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Introduction: To understand the mechanisms of planetary formation, we must constrain the timescales of major planetary differentiation processes. These processes have been studied using the daughter isotopes of short-lived radionuclides observed in planetary samples, often using the ^{182}Hf–^{182}W [1-5] and ^{146}Sm–^{142}Nd [6-9] systems. Samples from Mars are ideal for this purpose because they show obvious anomalies in these isotope systems. As such, isotopic variations in martian samples suggest that Hf/W and Sm/Nd were fractionated early in the history of the Solar System, implying that martian core formation and silicate differentiation occurred soon after accretion of the planet.

Samples and Methods: Ten basaltic martian meteorites derived from a mix of incompatible-element enriched (Los Angeles, NWA1068, Dho378, NWA4468, NWA4878), depleted (Tissint, DaG476, SaU005), and intermediate (EET79001A, NWA480) source regions were analyzed in this study. Samples were investigated for Sm−Nd isotope systematics and were measured using long-duration, high-intensity multi-dynamic Nd analyses to achieve high precision ^{142}Nd/^{144}Nd ratio measurements.

Results and Discussion: From our data, the age of shergottite source formation is calculated to be 4504 ± 5 Ma. Additionally, both ^{146}Sm–^{142}Nd and ε^{142}Nd−ε^{143}Nd isochron plots demonstrate that Mars has a near terrestrial present-day ^{142}Nd/^{144}Nd value of 1.141830 (ε^{142}Nd = −0.06 ± 0.06).

Implications. Any petrogenetic model for martian differentiation must account for three observations: (1) a significant metal/silicate segregation event occurred around 4559 ± 8 Ma [1-5], (2) silicate differentiation of the shergottite source region occurred at 4504 ± 5 Ma, and (3) there are significant differences in the ^{182}W isotopic composition of nakhlites and shergottites [1-5].

The young age of silicate differentiation presented here requires that either solidification of the primordial martian magma ocean occurred over 55 ± 13 Ma or that the Hf−W and/or Sm−Nd ages do not record planetary-scale differentiation events. Protracted cooling of the magma ocean is not consistent with thermal models that suggest this process requires only a few Ma [10], and it does not account for the variability of ^{182}W isotopic compositions observed in the martian meteorites [1-5]. If the thermal modeling is correct, an additional heat source would be required to keep the martian interior hot until ~4504 Ma. This heat source could reflect protracted accretion occurring more or less continuously for ~60 Ma, or the heat source may have come from a giant impact occurring around ~4504 Ma. Such an impact could produce a mantle that is compositionally heterogeneous on a planetary scale, as well as result in large-scale melting of portions of the mantle relatively late in the history of Mars. In this case, the Sm−Nd model age of 4504 ± 5 Ma would not reflect a planetary-scale differentiation event, but instead reflect differentiation associated with a portion of the mantle cooling after a giant impact.

References: [1] Kleine et al. 2004. *GCA* 68:2935. [2] Kleine et al. 2009. *GCA* 73:5150. [3] Foley et al. 2005 *GCA* 69:4557. [4] Nimmo & Kleine 2007. *Icarus* 191:497. [5] Dauphas & Pourmand 2011. *Nature* 473:489. [6] Borg et al. 1997. *GCA* 61:4915. [7] Borg et al. 2003 *GCA* 67:3519. [8] Debaille et al. 2007 *Nature* 450:525. [9] Caro et al. 2008. *Nature* 452:336. [10] Elkins-Tanton 2008. *EPSL* 271:181.