THE ROLE OF LARGE COLLISIONS IN FORMING EARLY COMPOSITIONAL HETEROGENEITIES ON MARS. S. Marchi[1], R. J. Walker[2], and R. M. Canup[1], [1]Southwest Research Institute, Boulder, CO, USA (contact: marchi@boulder.swri.edu), [2]Department of Geology, University of MD, College Park, MD, USA.

Introduction: A common trait of the evolution of terrestrial planets (Earth and Mars, for which we have samples), the moon, and large planetesimals (such as Vesta, the parent body of the HED meteorites), is their protracted accretion period. Based on the concentration of highly siderophile elements (HSE, e.g. Pt and Au) in rocks derived from their crusts and mantles, it is estimated that these bodies have accreted ~ 0.1-2% of their final mass after the formation of their cores was concluded [1,2]. The roughly chondritic relative distribution of HSE has further suggested that this "late" accreted mass was delivered via collisions. For the Earth, HSE may have been delivered by large, differentiated planetesimals (>1000 km in diameter) [3]. Such large collisions could have resulted in substantial mantle compositional heterogeneities, potentially resulting in detectable W isotopic anomalies, such as those from Isua supracrustal rocks or Schapenburg komatiites [2].

In this work we investigate projectile mixing in large collisions on Mars with a suite of dedicated high resolution smoothed-particle hydrodynamics (SPH) simulations. In doing so, we study the potential for large collisions to generate isotopic anomalies in the martian mantle, and compare our results to HSE and ^{182}W isotopic data from the shergottite-nakhlite-chassigny (SNC) meteorites.

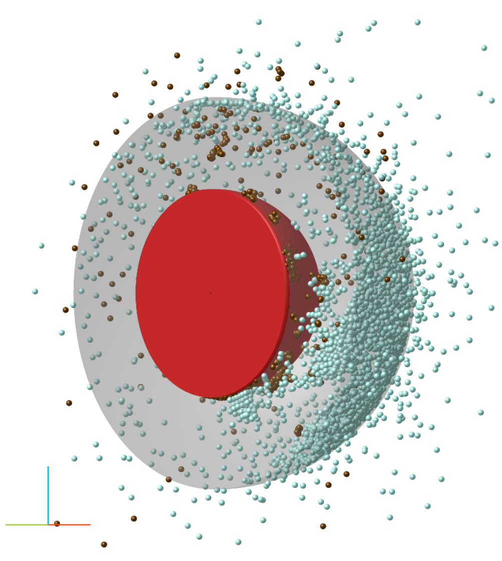

Figure 1. An example of one of our SPH simulation, with $M = 0.03M_m$, $\beta = 30°$, and $v/v_e = 2$. Grey and red half-spheres schematically show Mars' mantle and core (their SPH particles are not shown for clarity). Green and brown particles indicate projectile's mantle and core, respectively. The image shows the last time step of the SPH simulations (13 hr after collision), before the dispersed projectile material has settled on to Mars, or escaped the system.

Collisional mixing: To investigate mixing of projectile material into Mars, we performed of SPH simulations with 0.5 to 1.2 x 10^6 particles for two projectile masses, $M = 0.003M_m$ and $0.03M_m$, where M_m is Mars' mass, with impact angles β = 0, 30, 45, and 60°, and impact velocities (v) of v/v_e = 1.5, 2, 2.5, where v_e is the system's escape speed. These ranges of projectile mass and velocity encompass those inferred for the Borealis basin [4,5], and those seen in dynamical models of late accretion onto the terrestrial planets [6]. We consider projectiles with metallic cores comprising 30% of their mass, with cores resolved by 10^3 to 10^4 SPH particles. We use our SPH simulations to track the fate of the projectile's core that contains its HSE budget (Fig. 1), and define three end states: merges with Mars' core, remains suspended in the martian mantle, or ejected from the system. In this analysis, we closely follow the approach developed for the Earth [2].

Preliminary conclusions: We find that, for average impact angle and velocity conditions, about 10-20% of the projectile core is delivered to the martian mantle for $M = 0.003M_m$ and $0.03M_m$. This result implies that 1 to 4 collisions are capable of delivering the average concentration of HSE (Pt ~ 3 ppb) in SNC meteorites. Under these conditions, Mars is likely to develop large-scale impact-induced compositional heterogeneities. Within these domains, we predict a significant HSE concentration variation (Pt ~1-30 ppb), and well as W isotopic variations. To first order, these compositional variations are compatible with that observed in SNC meteorites. This reinforces the view that Mars's mantle is heterogeneous, and raises a word of caution about using SNC data to derive global properties for that planet.

References: [1] Day et al., *Reviews in Mineralogy and Geochemistry* 81, 161, 2016. [2] Marchi et al., *Nature Geoscience* 11, 81, 2017. [3] Bottke et al., *Science* 330, 1527, 2010. [4] Nimmo et al., *Nature* 453, 1220, 2008. [5] Marinova et al., *Icarus* 211, 960, 2011. [6] Raymond et al., *Icarus* 226, 671, 2013.