

**Martian mantle HSE abundances do not require late chondritic addition.** K. Righter<sup>1</sup>, <sup>1</sup>Mailcode KT, NASA Johnson Space Center, Houston, TX 77058; [kevin.righter-1@nasa.gov](mailto:kevin.righter-1@nasa.gov)

**Introduction:** The highly siderophile elements (Au, Re and the platinum group elements, PGE) can provide constraints on the processes of core formation and accretion for differentiated bodies [1]. For example, the near chondritic relative ratios of the HSE in the terrestrial upper mantle have been used to argue for the addition of chondritic material to the Earth's upper mantle following core formation [2]. More recently, analyses of martian meteorites have revealed an overall similarity to HSE contents in terrestrial basalts and mantle-derived melts [3] (Figure 1). This evidence has been used by some to argue that Mars also experienced late chondritic addition much the same as Earth [4]. The HSE database for martian meteorites will be reviewed and an assessment made of primitive mantle abundances of the HSE. It will be shown that the martian meteorite HSE abundances can be explained by derivation from a primitive mantle with a non-chondritic HSE pattern, thus obviating the need for late chondritic accretion to Mars.

**Background:** The abundances of 8 siderophile elements (Ni, Co, Mo, W, Ga, P, V and Cr) in the martian mantle can be explained by metal-silicate equilibrium during core formation at conditions of 14 GPa and 2000 °C [5]. Any modeling of HSE partitioning between core, mantle and crust, must take this 1st stage of differentiation into account. Subsequent second stage evolution of the martian mantle has resulted in the formation of depleted and enriched reservoirs. Combining siderophile element modeling of the first stage, with mantle melting modeling of the second stage allows the HSE content of possible primitive mantle, lower mantle, and enriched and depleted mantle to be calculated.

**Core formation modelling:** Metal-silicate partitioning of Re, Au, Pd, Pt, and Ir can be predicted using simple expressions that quantify the dependency on temperature, pressure, oxygen fugacity, and metallic and silicate liquid compositions [6,7]. For Mars, if core formation occurred at pressures near 14 GPa and 2000 °C, and between peridotite liquid and FeNiS metallic liquid ( $X_s = 0.17$ ),  $D(\text{Au})$ ,  $D(\text{Pt})$ ,  $D(\text{Pd})$  and  $D(\text{Ir})$  metal/silicate can be predicted. Using a core mass of 21%, and a melt fraction of 0.65 [5], the mantle abundances are: Au = 0.17 ppb, Pd = 5.1 ppb, Pt = 5.8 ppb, and Ir = 3.2 ppb. Similar exercise for Re and Os, where  $D(\text{Re}) = 100$  and  $D(\text{Os}) = 1000$ , results in mantle abundances of Re = 1.2 ppb and Os = 2.4 ppb. The results for Pd are shown in Figure 1, where the martian

upper mantle contains 5.1 ppb Pd compared to 7.1 ppb for the Earth.

The results are model dependent and critical information includes knowledge of  $D(\text{metal/silicate})$  as a function of pressure and temperature, the percentage of mantle unmelted during the magma ocean stage, and the partitioning of elements between the deep solid and shallow molten mantle. Depleted mantle HSE concentrations can be estimated by inverting the HSE content of primitive depleted basalts.

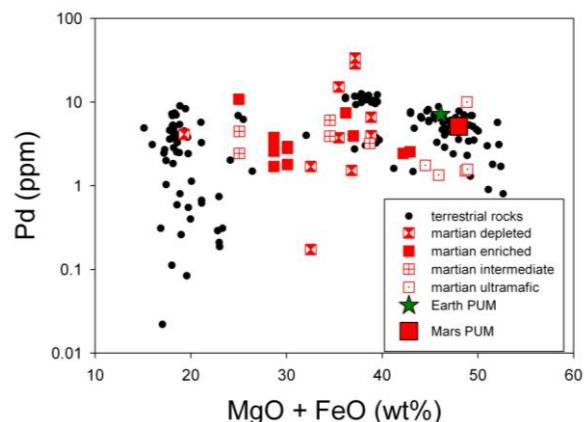


Figure 1: Pd (ppm) vs. MgO+FeO (wt%) for a variety of terrestrial igneous rocks (komatiites, basalts, peridotites), martian meteorites ([3] and references therein), and estimate of [8] for Earth's PUM composition. Also shown is the martian primitive upper mantle from this study and using MgO+FeO from [9].

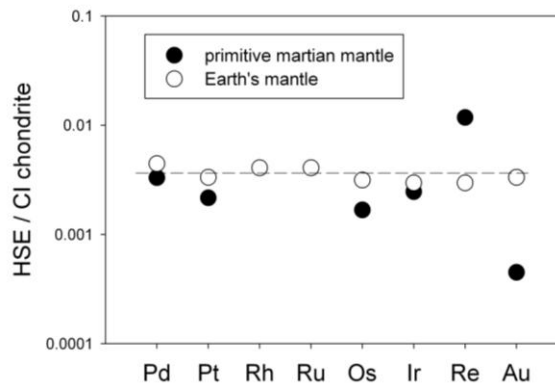


Figure 2: Calculated HSE contents of the primitive upper mantle of Mars from this study, as well as the Earth's PUM [8], both normalized to CI values [10].

**Conclusions:** The martian basalt array of HSE contents can be explained by melting of a mantle with non-chondritic relative HSE contents. This approach predicts a mantle with supra-chondritic Re/Os and sub-

chondritic Au/Ir and Pt/Ir ratios. Therefore a late chondritic veneer is not required to explain HSE content of martian basalts.

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