THE ^{182}Hf-^{182}W ISOTOPIC SYSTEMATICS OF H CHONDRITE METAL: CONSTRAINING THE THERMAL HISTORY OF THE H CHONDRITE PARENT BODY G. J. Archer[1], J. Tino[1], R. J. Walker[1], and J. T. Wasson[2]. [1]Department of Geology, University of Maryland, College Park, MD 20742 (garcher@umd.edu). [2]Dept. of Earth, Planetary & Space Sciences, University of California, Los Angeles, CA 90095.

Introduction: The thermal history of the H chondrite body is still a matter of debate. Some prior studies have proposed an onion-shell model for the H chondrite parent body (e.g., [1]). In this model, the decay of short-lived radionuclides (e.g., ^{26}Al), internally heated and metamorphosed the H chondrite parent body. The degree of thermal metamorphism increased from H3-6 due to increasing depth within the parent body.

The ^{182}Hf-^{182}W isotopic system ($t_{1/2}$ = 8.9 Ma) can be used to constrain the timing of early Solar System metal-silicate equilibration because Hf is strongly lithophile, whereas W is moderately siderophile. This system has typically been used to constrain the timing of planetary accretion and core segregation [e.g., 2], but it can also be used as a thermochronometer to constrain the cooling of metal-silicate systems after metamorphic heating [3].

The H chondrites experienced a large range of thermal-metamorphic conditions [4]. Determining isotopic closure ages of H chondrites of different metamorphic grades, using different radiogenic isotope systems with a range of closure temperatures can, therefore, be used to constrain the thermal history of the parent body.

Metal grains in H chondrites occur as irregular grains smaller than 0.1 mm^2, large metal nodules [5], veins [6], and small metal grains within chondrules [7]. Prior studies have reported that large metal nodules of some H chondrites have different siderophile element abundances (HSE) than fine-grained metal grains [8,9], which suggests that fine- and coarse-grain metal may have formed by different processes.

It was reported by [3] that ^{182}W/^{184}W may increase slightly with metamorphic grade, suggesting an inverse correlation between petrologic type and cooling rates, which is most consistent with an onion-shell model for the structure of the H chondrite parent body. However, the reported ^{182}W/^{184}W of individual H chondrite metal fractions were generally indistinguishable within analytical uncertainties of typically greater than ±15 μ^{182}W unit 2SD uncertainties reported for individual metal measurements (where μ^{182}W is the isotopic deviation in parts per million of ^{182}W/^{184}W from a terrestrial standard). The study, therefore, relied on linear regressions of data for metals and silicates to constrain initial ^{182}W/^{184}W for the bulk rock. This approach, however, did not resolve variations in ^{182}W/^{184}W among different sized metal fractions, which do not necessarily record the same thermal history.

Here we present high-precision (±4.5 ppm 2SD external precision) ^{182}W isotopic compositions and HSE abundances for metal fractions from H4, H5, and H6 chondrites. The primary goal of the study is to assess the thermal history of the H chondrite parent body. Further, we consider whether different metal size fractions record different closure ages in these rocks. Finally, we explore evidence for nucleosynthetic variation with ^{183}W in H chondrite metal grains.

Methods: Chondrite metal was separated and refined in a procedure described by [12]. Tungsten was purified using cation and anion exchange chromatography [13]. Purified W was analyzed by negative thermal ionization on the the UMd *Thermo-Fisher Triton* using Faraday cup collectors, with the oxide correction method of [13] for Faucett and Richardton, and a recently developed method [14] for Avanhandava and Oakley (stone). The new oxide correction method allows measurement of ^{183}W/^{184}W to an external precision of ±4 ppm, however the two samples analyzed here had internal 2SE of ~±8 ppm.

The HSE abundances of separate aliquots of chondrite metal were determined by isotope dilution using procedures described by [15], and references therein.

Results: The ^{182}W/^{184}W isotopic compositions of the >150 μm metal separates from H4 (Avandhandava and Faucett) and H5 (Richardton) chondrites are indistinguishable within uncertainties **(Fig. 1)**. The Faucett (H4) >150 μm metal separate has the lowest μ^{182}W of -313±5, which corresponds to a relative model age after CAI formation (Δt_{CAI}) of 3.29±0.47 Myr. By contrast, the <150 μm metal separate from Oakley (H6) has the highest μ^{182}W of -284±7, corresponding to a Δt_{CAI} of 6.74±0.91 Myr.

The ^{182}W/^{184}W isotopic compositions of two metal fractions from Faucett (H4) are resolved from one another, within uncertainties **(Fig. 1)**. The μ^{182}W for the >150 μm metal fraction and <150 μm metal fraction of -313±5 and -299±5, respectively, correspond to Δt_{CAI} of 3.29±0.47 Myr and 4.86±0.53 Myr, respectively.

The ^{183}W/^{184}W isotopic compositions of Avanhandava (H4; >150 μm) and Oakley (H6; <150 μm) metal fractions overlap, but are well resolved from the terrestrial standards **(Fig. 2)**, with μ^{183}W values of -12.5±8 and -14.6±8, respectively.

The HSE abundances of <150 μm metal are higher than those of >150 μm metal **(Fig. 3)**, but there is no correlation between metamorphic grade and HSE abundance.

Discussion: The Hf-W closure ages of H chondrite metals inversely correlate with metamorphic grade, with the oldest ages for H4 and H5 chondrites (Δt_{CAI} =3.29±0.47), and the youngest age (Δt_{CAI}=6.74±0.91 Myr) for an H6 chondrite (Fig. 1). This observation is generally consistent with an onion-shell model, with the most metamorphosed H6 chondrites cooling to Hf-W closure temperatures significantly later than the less metamorphosed H4 and H5 chondrites. The overlapping closure ages and uncertainties of the >150 μm metal fractions from H4 and H5 chondrites indicate that the maximum Δt for Hf-W closure between H4 and H5 >150 μm metal was 1.6 Myr.

The <150 μm metal fraction of Faucett has a $^{182}W/^{184}W$ that is ~15 ppm higher than the >150 μm metal fraction. The higher $^{182}W/^{184}W$ of the finer-grained <150 μm metal fraction is consistent with greater rates of diffusion of radiogenic W into the interior lattice of the finer-grained fraction during thermal metamorphism, because of the higher surface area/volume. This model is consistent with the higher HSE abundances of fine-grained metal **(Fig. 3)**. Thus, fine-grained metal may be a more sensitive thermo-chronometer, and date later metamorphism.

Finally, it is possible that genetic differences in the fine- and coarse-grained metal can account for the difference in $^{182}W/^{184}W$. A prior study [17] argued that large metal nodules in H chondrites formed by impact vaporization followed by fractional condensation. In addition, the systematically different HSE abundances between >150 μm and <150 μm metal could potentially reflect genetic differences.

Prior studies have reported nucleosynthetic W anomalies in early Solar System materials, including IVB iron meteorites [10] and calcium-aluminum-rich inclusions [11]. Nucleosynthetic anomalies are typically interpreted to result from the incorporation of diverse presolar materials that were inherited from multiple stellar sources and incompletely mixed in the early Solar System. Such anomalies can be used to establish genetic links among planetary materials.

The $^{183}W/^{184}W$ isotopic anomalies of H chondrites Avanhandava (H4) and Oakley (H6) are most likely caused by nucleosynthetic effects, as cosmogenic and radiogenic effects can only substantially affect ^{182}W. The negative $^{183}W/^{184}W$ anomalies are consistent with either a nucleosynthetic *s*-process excess or an *r*-process deficit.
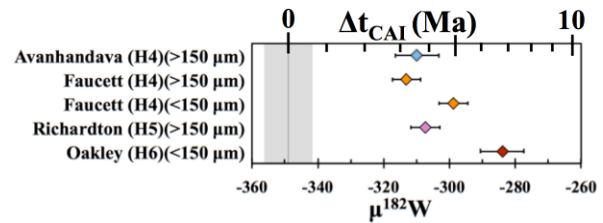

Figure 1. $\mu^{182}W$ of H4-6 metal separates. Grey line and field are initial $\mu^{182}W$ of CAIs and 2σ uncertainity, respectively, from [16].
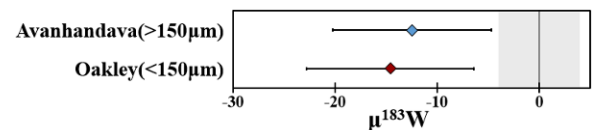

Figure 2. $\mu^{183}W$ of metal separates from Avanhandava (H4) and Oakley (H6). Grey line and field represent the terrestrial standard $\mu^{183}W$=0 and 2SD external uncertainty, respectively. Error bars are 2SE internal precisions.
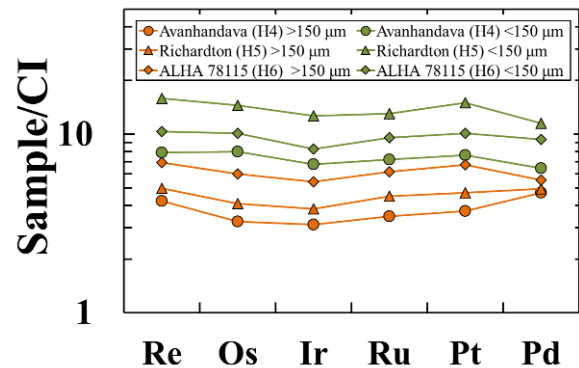

Figure 3. CI-normalized HSE abundances of size-sorted H4-6 metal grains. Uncertainties are smaller than symbols.

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