^{182}Hf-^{182}W ISOTOPIC SYSTEMATICS OF H CHONDRITES: THERMAL HISTORY OF THE H CHONDRITE PARENT BODY

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Introduction: The short-lived ^{182}Hf-^{182}W isotopic system ($t_{1/2}$ = 8.9±0.09 Ma) is useful for constraining the timing of early Solar System metal-silicate equilibration, given the strongly lithophile nature of Hf and the moderately siderophile nature of W. Consequently, this isotopic system has commonly been used to constrain the timing of planetary accretion and core segregation [e.g., 1]. On a finer scale, the system can also potentially be used as a thermochronometer to determine relative closure ages for the cooling of metal-silicate systems following metamorphic heating [2]. Thus, the thermal evolution of some metal-bearing parent bodies can be constrained using this system.

Chondritic meteorites commonly contain evidence for complex processing on their respective parent bodies, including aqueous alteration and thermal metamorphism. For example, the H chondrites experienced a large range of thermal-metamorphic conditions [3]. Comparative isotopic closure ages of H chondrites of different metamorphic grade can, therefore, be used to constrain the thermal history of the parent body. The Hf-W isotopic system is ideal for this as H chondrites contain abundant, W-rich metal grains (~660 to ~926 ppb [2]), which are appropriate for high-precision W isotopic measurements.

Metal grains in H chondrites typically occur as irregular grains smaller than 0.1 mm^2, large metal nodules [4], veins [5], and small metal grains within chondrules [6]. Prior studies have reported that large metal nodules of some H chondrites have different siderophile element abundances than fine-grained metal grains [7,8]. Large metal nodules and veins have extreme depletions (up to a factor of 240 [7]) of the refractory siderophile elements.

Prior studies have investigated the Hf-W isotopic systematics of H chondrites to constrain the thermal history of the H chondrite parent body. For example, [2] reported that ^{182}W/^{184}W may increase slightly with metamorphic grade, which suggests an inverse correlation between petrologic type and cooling rates. They argued that this correlation is most consistent with an onion-shell model for the structure of the H chondrite parent body. For that study, however, the ^{182}W/^{184}W of individual H chondrite metal fractions were generally indistinguishable within analytical uncertainties (typically greater than 15 μ^{182}W 2SD uncertainties for individual metal measurements; where μ^{182}W is defined as the isotopic deviation in parts per million of ^{182}W/^{184}W from a terrestrial standard). They therefore relied on linear regressions of metals and silicates to constrain high-precision initial ^{182}W/^{184}W for the bulk rock. However, this approach was unable resolve variations in ^{182}W/^{184}W among different sized metal fractions, which do not necessarily record the same thermal history.

Here we report high-precision (±4.5 ppm 2SD external precision) W isotopic compositions for two metal size fractions from the H4 chondrite Faucett. One objective of this study is to assess whether or not different metal size fractions record different closure ages in these rocks, as might occur if the finer metal grains continued to incorporate ^{182}W from the Hf-rich, silicate portion of the rock to lower temperatures compared with coarser fractions. The ultimate goal of this work will be to compare results with comparable data for H chondrites of higher and lower metamorphic grade.

Methods: Fifteen grams of the H4 chondrite Faucett were gently crushed using a mortar and pestle. The crushed sample was then sieved into two size fractions, >150 µm and <150 µm. Metal from each size fraction was then separated using a hand magnet. Metal was then purified by repeatedly crushing, immersing in H_2O, and then separating using a hand magnet. Samples were digested for 2 days with 40 mL of 8N quartz distilled HCl. Tungsten was purified using cation and anion exchange chromatography [9]. Purified W was analyzed by negative thermal ionization on the the UMd *Thermo-Fisher Triton* using Faraday cup collectors, with the oxide correction methods of [9]. A separate, small aliquot of each metal fraction was spiked with appropriate amounts of ^{182}W and ^{178}Hf and digested for isotope dilution analysis. Hafnium and W were then purified in a method similar to that described above. Hafnium and W concentrations were analyzed using the UMd *Nu Plasma* multi-collector-ICP-MS. All measured sample/blank were greater than ~6500, requiring negligible blank correction for terrestrial W.

Results: The Hf/W of ~0.008 and ~0.03 for the > 150 µm metal fraction and the < 150 µm metal fraction, respectively, were estimated from separate aliquots of the metal fractions. The Hf/W of the two metal fractions indicate that ingrowth of radiogenic W would have been negligible, and any correction to the μ^{182}W for ingrowth would be smaller than the reported uncertainties. Thus, the ^{182}W/^{184}W ratios of the metal fractions have remained essentially unchanged since the most recent metal-silicate equilibration.

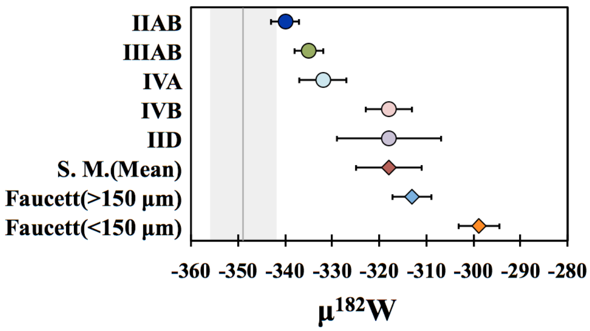

Figure 1. $\mu^{182}W$ of H4 Faucett metal separates. Grey line and field represents initial $\mu^{182}W$ of CAIs and 2σ uncertainity, respectively [10,11]. Magmatic iron data (IIAB, IIIAB, IVA, IVB, and IID) from [12]. Mean H4 Ste. Marguerite data (S. M.) from [2].

The $^{182}W/^{184}W$ isotopic compositions of the two metal fractions from Faucett (H4) are distinguishable, within uncertainties, from each other as well as from the initial $^{182}W/^{184}W$ of CAIs (Fig. 1). The $\mu^{182}W$ for the > 150 μm metal fraction and < 150 μm metal fraction of -313.1±4.5 and -298.8±4.5, respectively, correspond to relative model ages after CAI formation (Δt_{CAI}) of 3.29±0.44 Myr and 4.86±0.33 Myr, respectively.

Discussion: The $^{182}W/^{184}W$ of the coarse-grained (>150 μm) metal fraction of H4 Faucett is in agreement with previously published results for metal grains without size control reported for the H4 chondrite Ste. Marguerite (Fig. 1) [2]. These data indicate that accretion of the H4 Faucett parent body must have occurred no later than 3.29±0.44 Myr after CAI formation. Further, the Hf-W age of the coarse-grained Faucett fraction may date early thermal metamorphism on the H chondrite parent body. However, this model requires that H4 Faucett was heated to a temperature above the Hf-W closure temperature of H4 chondrites. [2] argued that H4 chondrites were probably not sufficiently heated (~725-850°C) to reset the Hf-W system.

Instead, the Hf-W age of the coarse-grained Faucett fraction is within uncertainty of Al-Mg ages of chondrule formation [e.g., 13]. Thus, the Hf-W age of this fraction may date metal grain formation, rather than any metamorphic event.

If the $^{182}W/^{184}W$ of the coarse metal fraction dates thermal metamorphism, then thermal metamorphism on the H4 chondrite parent body may have occurred after core formation on the parent bodies of most magmatic iron meteorites (IIAB, IIIAB, and IVA). Alternatively, metal grain formation may have post-dated core formation on most magmatic iron parent bodies.

The <150 μm metal fraction of Faucett has a $^{182}W/^{184}W$ that is ~15 ppm higher than the >150 μm metal fraction. These data are consistent with some data from [2], which reported $^{182}W/^{184}W$ for fine-grained (40-230 μm) metal grains from Richardton (H5) that were about ~30 ppm higher than that of the coarse-grained (>230 μm) metal grains. Those authors argued that the variation in metal $^{182}W/^{184}W$ could have been caused by incorporation of irradiated metals with low $^{182}W/^{184}W$. Low, irradiation-induced $^{182}W/^{184}W$ have been reported for iron meteorites [14]. This model could account for the low $^{182}W/^{184}W$ of coarse-grained metal from Faucett.

Alternatively, the higher $^{182}W/^{184}W$ of the finer-grained < 150 μm metal fraction could be consistent with greater rates of diffusion of radiogenic W into the finer-grained fraction during thermal metamorphism because of higher surface/volume. Thus, finer-grained metal grains of H chondrites may be a more sensitive thermochronometer, and may date more recent metamorphism.

Finally, it is possible that genetic differences in the fine- and coarse-grained metal can account for the difference in $^{182}W/^{184}W$. Prior studies [7,8] have reported that large metal nodules in Faucett are depleted in refractory siderophiles. [15] argued that these large metal metal nodules formed by impact vaporization followed by fractional condensation.

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