REVISED TUNGSTEN ISOTOPE CHRONOLOGY OF IVB IRON METEORITES FROM W-Os SYSTEMATICS. N. Wittig[1], M. Humayun[1], S. Huang[2] & A. D. Brandon[3]. [1]National High Magnetic Field Laboratory and Dept. of Earth, Ocean & Atmospheric Science, Florida State University, Tallahassee, FL 32310, USA (wittig@magnet.fsu.edu), [2]Dept. of Earth & Planetary Sciences, Harvard University, Cambridge, MA 02138, USA, [3]Dept. of Earth & Atmospheric Sciences, University of Houston, Houston, TX 77204, USA.

Introduction: Any sensible model of early Solar System formation necessitates that condensation of refractory solids (CAI) precedes asteroidal parent-body accretion and magmatic differentiation into Fe-Ni cores and silicate mantles. However, the time difference between the formation of CAIs and iron meteorites must be established empirically. ^{182}Hf-^{182}W dating of CAIs [1, 2] and iron meteorites [e.g., 3-6] implies condensation of refractory solids and differentiation of planetesimals within 1-2 m.y. [2]. An exception is group IVB irons which exhibit ε^{182}W values that are apparently less radiogenic (ε^{182}W -3.6±0.1, [3-5]), than the CAI initial (ε^{182}W -3.28±0.12 [1,2]). Such a result could imply that either the Allende CAI initial is too radiogenic due to parent-body metamorphism [7], or that corrections for galactic cosmic-ray (GCR) neutron capture and burn-out [2-5] are insufficient.

Previous attempts to correct the GCR impact on W isotopes relied on noble gases as a GCR exposure proxy [3] or on a 2-step process: 1) the samples with the lowest ε^{182}W were corrected by the maximum possible calculated neutron dosage and the corrected values were taken as an upper bound; and 2) the samples with the highest ε^{182}W were taken as a lower bound [5].

Huang and Humayun [8] showed that neutron capture on ^{189}Os creates measurable deficiencies in ^{189}Os/^{188}Os (and correlated excesses in ^{190}Os/^{188}Os) in IVB irons, and that stable Os isotope ratios could serve as a neutron dosimeter for W isotopes.

We present W isotope data from 12 of the 13 known IVB iron meteorites including 5 irons for which W isotope data have not been reported previously (Dumont, Iquique, Kokomo, Tinnie and Weaver Mountains). We couple this nearly complete characterization of group IVB ε^{182}W to Os isotope data from the same samples. Coupling W and Os isotopes allows us to precisely determine the degree of GCR modification of ^{182}W and then to establish an accurate pre-irradiation ε^{182}W from which relative chronology of irons relative to CAIs can be obtained.

Analytical Methodology: Approximately 0.5 g of each of the IVB irons were digested in inverse aqua regia (3:1 HNO_3:HCl) in sealed carius tubes. Os was extracted by solvent extraction and W was purified by a combination of cation and anion exchange procedures, generally following [4,9].

Tungsten isotope measurements were performed on a Thermo Neptune™ MC-ICP-MS on 10-25 ng aliquots using an ESI Apex™ introduction system and Thermo SuperJet8.3 Ni sampler and Spectron T1001Ni-X skimmer cones [10]. The data are reported against reference material NIST SRM 3163. Our current W isotope procedures allow determination from small aliquots with a long-term (12 months, SRM 3163 n = 200) reproducibility of ± 0.18ε (2σ). Replicate measurements of IVB aliquots yield a reproducibility that is on the order of 0.10 to 0.24 ε (2σ). Os isotope data were determined previously on a sub-set of IVB irons and are reported as ε^{189}Os and ε^{190}Os relative to a terrestrial Os standard solution (HPS) [8]. Precision of standard runs was 0.14 and 0.03 ε on ε^{189}Os and ε^{190}Os, respectively. Extending the Os isotope data with improved precision is our current focus.

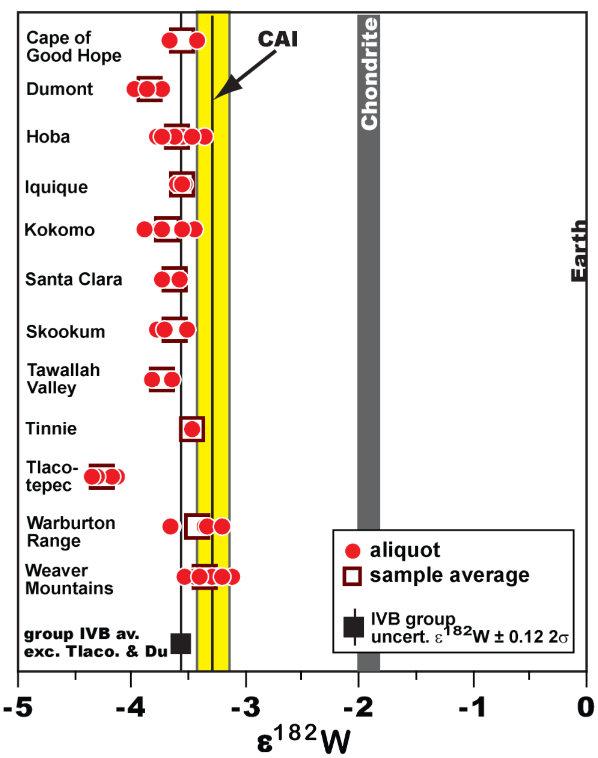

Fig. 1. ε^{182}W of group IVB iron meteorites [this study], chondrites ([2, ref. therein] gray band) and CAI ([1,2] yellow band).

Results: Our $\varepsilon^{182}W$ data (Fig. 1) for samples previously characterized (Cape of Good Hope, Hoba, Santa Clara, Skookum, Tawallah Valley, Tlacotepec, Warburton Range) agree well with literature data [3-6]. The majority of group IVB iron meteorites define a mean value of $\varepsilon^{182}W$ -3.55 ± 0.12 (2σ, n = 10, excluding Dumont, Tlacotepec). Among the newly characterized samples, Dumont exhibits lower $\varepsilon^{182}W$ (-3.88 ±0.14 (2σ)) relative to the majority of IVBs, but is less extreme than Tlacotepec ($\varepsilon^{182}W$ -4.25 ±0.2). Iquique and Kokomo have typical group IVB $\varepsilon^{182}W$ clustering around the average value of -3.6, whereas Weaver Mountains and Tinnie, together with Warburton Range have higher $\varepsilon^{182}W$ approaching the CAI value. Our Os data are in good agreement with those of [11]. Among the currently characterized group IVB iron meteorites, Tlacotepec shows distinct $\varepsilon^{189}Os$ deficit and $\varepsilon^{190}Os$ excess from GCR exposure [8]. Fig. 2 shows the correlation between $\varepsilon^{190}Os$ excesses and $\varepsilon^{182}W$ deficits for IVB irons.

Discussion: Our nearly complete W isotope characterization of IVB irons shows larger variability among the group than previously reported [3-6]. Fig. 2 shows that the $\varepsilon^{182}W$ variations in IVBs are anti-correlated with $\varepsilon^{190}Os$ excesses. For example, Tlacotepec shows the strongest GCR-signal with $\varepsilon^{182}W$- $\varepsilon^{189}Os$ deficits/ $\varepsilon^{190}Os$ excesses. Warburton Range has a $\varepsilon^{182}W$ within error of the CAI value [1], and an $\varepsilon^{190}Os$ excess within error of the terrestrial value ($\varepsilon^{190}Os$ 0.05 ±0.08 2σ), indicating essentially no GCR neutron burn-out on ^{182}W or ^{189}Os. We currently do not have Os isotope data for Weaver Mountains, but it has the highest $\varepsilon^{182}W$ ($\varepsilon^{182}W$ -3.29 ±0.23, 2σ) among the measured IVB irons well within range of the CAI value (-3.28±0.12, 2σ, [1]). Thus, Warburton Range and Weaver Mountains set lower bounds on the pre-irradiation $\varepsilon^{182}W$ of the IVB irons. The intercept of the Os-W regression line projected to an $\varepsilon^{190}Os$ of 0 yields the pre-irradiation $\varepsilon^{182}W$ of -3.37±0.19 (2σ) for the IVB irons for which Os-W data are available (Fig. 2). An identical pre-irradiation $\varepsilon^{182}W$ of -3.36±0.16 (2σ) is derived from $\varepsilon^{189}Os$. The error on the current Os-W regression is dominated by Tawallah Valley. Our previous pre-irradiation $\varepsilon^{182}W$ of -3.12±0.15 (2σ [12]) resulted from a smaller sample set and utilized weighted regression parameters. Regardless of the mathematical treatment of IVB iron Os-W isotope correlation, the Os-corrected $\varepsilon^{182}W$ is within uncertainty of the CAI value and indicates that IVB iron meteorites, like other magmatic irons [2], formed within ~2 Myr of the first solids (CAIs, Fig. 3), a time difference which is not resolvable.

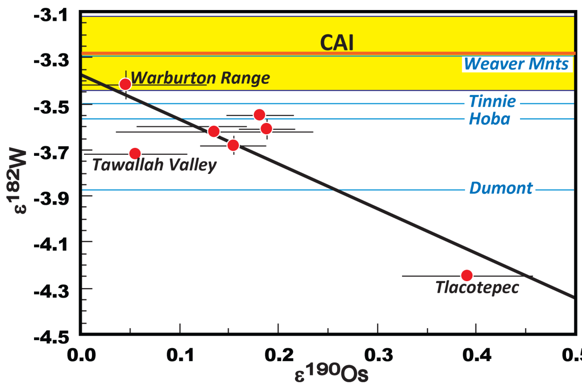

Fig. 2. $\varepsilon^{182}W$-$\varepsilon^{190}Os$ of IVB iron meteorites (red circle, 2σ) indicate a pre-GCR irradiation $\varepsilon^{182}W$ of -3.37 ±0.19 (2σ, black). $\varepsilon^{182}W$ of CAIs (red line, yellow band is ±2σ [1,2]) is given for comparison. Blue lines show $\varepsilon^{182}W$ for samples without Os isotope data.

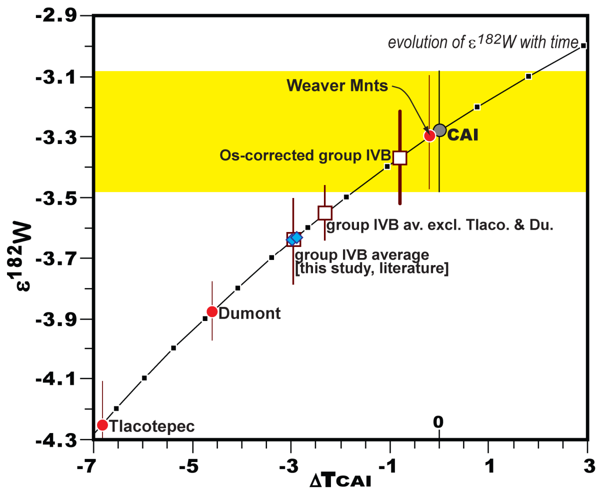

Fig. 3. $\varepsilon^{182}W$-ΔT_{CAI} of group IVB irons. Shown are the key samples Weaver Mountains, Dumont and Tlacotepec (red circle), group IVB averages (red square) using all samples (this study, literature {blue diamonds [3-5]}). Uncertainties are 2σ, the Os corrected $\varepsilon^{182}W$ error is driven by the deviation of Tawallah Valley from the regression line (Fig. 2).

References

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