RHENIUM ISOTOPE BASED COSMOGENIC EFFECT CORRECTION AND HAFNIUM-TUNGSTEN CHRONOLOGY OF SANDIA MOUNTAINS AND SIKHOTE ALIN.

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Introduction: The short-lived ^{182}Hf-^{182}W system has been widely applied for examining the timescales and processes of planetary accretion and differentiation (e.g., [1-4]). The interest in the ^{182}Hf-^{182}W system is based on its unique ability to constrain the timescale of metal-silicate separation (e.g., core formation in asteroids) [5]. Iron meteorites represent the initial ε^{182}W of their parent asteroids at the time of metal-silicate differentiation, which has been constrained to occur very early after the first solids formed in the solar system (e.g., [6-8]).

Resolving the temporal differences between various iron meteorite bodies requires higher precision W isotope analysis, which has been achieved (e.g., [9]). However, applications of this chronometer to iron meteorites are hampered by neutron capture reactions on W isotopes that alter the ^{182}W/^{184}W ratios, blurring the chronology [10-12]. Currently, a number of neutron capture proxies have been developed to help with reducing the neutron capture effects in W isotopes [6, 7, 13-17]. Neutron capture on W isotopes results in excess of ^{183}W from ^{182}W, ^{184}W from ^{183}W, ^{185}Re from ^{184}W and ^{187}Re from ^{186}W. The neutron capture cross-sections of ^{182}W and ^{186}W are larger than that of ^{184}W. Since ^{186}W/^{184}W is a widely used normalizing ratio for mass bias in the mass spectrometer, the effect of galactic cosmic rays (GCR) neutron capture is to distort the ^{182}W/^{184}W ratios, exacerbating the effects of ^{182}W burnout on chronology. Re isotopes, the production of ^{186}W isotope burnout, are expected to provide a straightforward approach to correct the cosmogenic shift in W isotopic composition of iron meteorites.

The IIAB iron meteorites show the widest range of W/Re ratios (from 0.55 to 523; [18]) of any meteorite group. The IIABs have a substantial range of galactic cosmic rays (GCR) exposure ages, thus providing an ideal system to develop and test the practicability of using Re isotopes for cosmogenic neutron capture correction. Prior work [19] indicated variable δ^{187}Re in IIAB irons.

Here, we report combined W-Re isotopic data for group IIAB iron meteorites. A correction method based on Re isotopes is presented to quantify the GCR effects on W isotopes in iron meteorites. Pre-irradiation W isotopic compositions for iron meteorites using this method are presented.

Analytical Methods: Tungsten and Rhenium purifications of four IIAB iron meteorites (i.e., Carver, Richland, Sandia Mountains, and Sikhote Alin) were achieved after a two-step ion-exchange chromatography.

High precision W and Re isotopic measurements were performed on a Thermo Neptune MC-ICPMS following previous studies [9, 19]. Mass fractionation during the W isotopic measurements was corrected by internal normalization, while the mass fractionation during the Re isotopic measurements was corrected by using W-doping method with NIST SRM 3163 [19]. All of the W and Re isotopic ratios were normalized to ^{186}W/^{184}W = 0.92767 using the exponential law. The ^{185}Re/^{184}W ratios in the spiked solution were maintained at the range of 0.60 to 0.75 in order to minimize the effects of WH^{+} and ReH^{+} [19]. The isobaric Os interference on Re was removed by sparging with Ar in warm nitric acid. The ^{190}Os peak was measured to monitor and correct the ^{187}Os interference, which shows that ^{187}Os/^{185}Re ratio in samples generally lower than 0.05‰. Iron meteorite Dumont (IVB) with ^{187}Os/^{185}Re of 0.15 ‰ shows exactly the same results as Dumont with ^{187}Os/^{185}Re of 0.02 ‰, which suggests that the Os interference on Re can be corrected properly.

The W isotopic composition is reported as ε^{18i}W: $\varepsilon^{18i}\mathrm{W} = [(^{18i}\mathrm{W}/^{184}\mathrm{W}_{\mathrm{sample}})/(^{18i}\mathrm{W}/^{184}\mathrm{W}_{\mathrm{NIST\ SRM3163}})-1]\times10000$, where i refers to 2 or 3. The Re isotopic composition is reported as δ^{187}Re: $\delta^{187}\mathrm{Re} = [(^{187}\mathrm{Re}/^{185}\mathrm{Re}_{\mathrm{sample}})/(^{187}\mathrm{Re}/^{185}\mathrm{Re}_{\mathrm{BDH}})-1]\times1000$.

Results: The W and Re isotopic compositions of the analyzed samples are shown in Fig. 1.

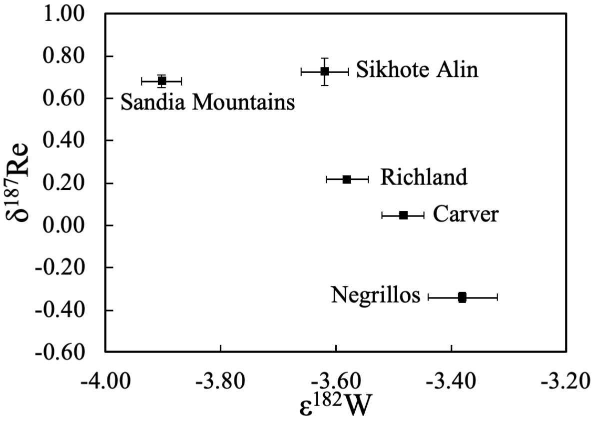

Fig. 1. Plot of ε^{182}W vs. δ^{187}Re for IIAB iron meteorites. Error bars represent 2SE. The W and Re isotopic data of Negrillos are from Kruijer et al. [8] and Liu et al. [19], respectively.

Carver, Richland, Sandia Mountains, and Sikhote Alin have ε^{182}W values of -3.48±0.04, -3.58±0.04, -3.90±0.03, and -3.62±0.04, respectively. Carver, Richland, Sandia Mountains, and Sikhote Alin have δ^{187}Re values of +0.05±0.01‰, +0.22±0.01‰, +0.68±0.03‰, and +0.72±0.07‰, respectively.

The δ^{187}Re values increase with the increasing W/Re ratios of the measured iron meteorites (Fig. 2).

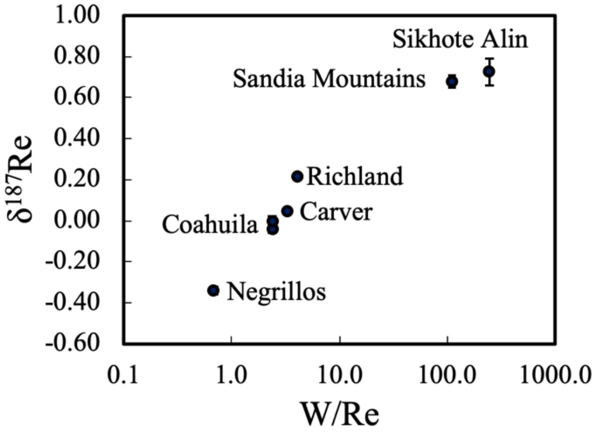

Fig. 2. Plot of W/Re ratios vs. δ^{187}Re for IIAB iron meteorites. Error bars represent 2SE. Data of Negrillos and Coahuila are from Liu et al. [19].

Discussion: Neutron capture on ^{184}W and ^{186}W produce ^{185}Re and ^{187}Re, respectively. The neutron capture cross-section of ^{184}W is small, and the cosmogenic effect is mainly burn-out of ^{186}W. While Sandia Mountains has a higher Re/W ratio than Sikhote-Alin, it has a longer GCR exposure age (720 Ma vs. 430 Ma [20]). The δ^{187}Re values of Sandia Mountains and Sikhote Alin were, therefore, used to restore the original ^{186}W/^{184}W. The restored ^{186}W/^{184}W ratios were then used to normalize the other measured W isotope ratios using the exponential law to obtain the excess ε^{183}W and restore the original ε^{182}W (Fig. 3). The restored ε^{182}W value for IIAB parent bodies is ~ -3.42, corresponding to a core formation age of ~ 0.6 Ma after the Solar System formation. This number is consistent with Kruijer et al. [8, 22] who analyzed the least irradiated members of the IIABs (i.e., Negrillos and Edmonton (Canada)). More IIAB iron meteorites will be processed in the future to improve the precision of the pre-irradiation ε^{182}W using Re isotopes correction.

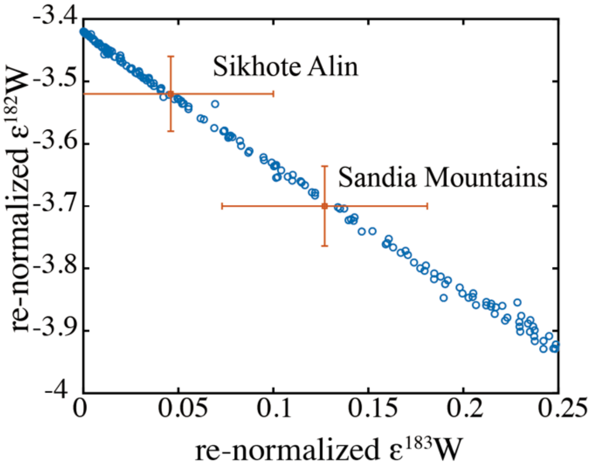

Fig. 3. Re-normalized ε^{182}W and ε^{183}W of Sikhote Alin and Sandia Mountains. Error bars represent 2SE. Data points of blue circles are from model presented by Leya and Masarik [21].

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