CRYSTALLIZATION HISTORY AND CHRONOLOGY OF METAL SEGREGATION IN THE IAB IRON METEORITE COMPLEX: NEW INSIGHTS FROM W AND Os ISOTOPES, AND HIGHLY SIDEROPHILE ELEMENT ABUNDANCES.

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Introduction: The IAB complex is a silicate-bearing iron meteorite group consisting of a chemical main group (MG) and several subgroups [1]. Previous studies of the IAB complex concluded that the elemental fractionations among the subgroups cannot be explained by fractional crystallization, unlike those in magmatic iron groups [1]. Proposed origins of the IAB complex include crystallization of a S-rich core in a partially differentiated body [2], crystal segregation in impact-generated melt pools in a chondritic body [1], and core formation in a partially differentiated body, followed by an impact(s) which disrupted the body and generated near-surface melt pools [3-5].

We have undertaken a study of a large number of IAB iron meteorites to better understand how the constituent groups crystallized, and how they may be related to each other. Highly siderophile element (HSE-Re, Os, Pt, Ru, and Pd) abundances are used to explore possible mechanisms by which metallic melts crystallized. We also apply the ^{182}Hf-^{182}W chronometer ($t_{½}$ = 8.9 Myr), which is ideal for determining the relative timing of metal-silicate segregation [e.g., 6]. When this chronometer is applied to individual subgroups within the IAB complex, the question of whether the MG and subgroups originated contemporaneously, or if they formed via similar processes at different times, potentially on distinct parent bodies, can be addressed. If it can be shown that the IAB complex represents multiple metal-silicate differentiation events, and/or multiple parent bodies, then it might ultimately be concluded that the processes that created the chemically and texturally similar subgroups were temporally and/or spatially widespread.

We also report isotopic data for Os. Osmium isotope ratios can be modified by radiogenic ingrowth of ^{187}Os from the decay of ^{187}Re ($t_{½}$ = 42 Gyr), and the burnout/production of Os isotopes due to cosmic ray exposure (CRE) [7]. Osmium isotope compositions are used here to assess the timing of closed-system behavior of the HSE (using the Re-Os system), and as a neutron fluence dosimeter (using ^{186}Os, ^{189}Os and ^{190}Os). Only irons with no evidence for CRE are considered for the application of the Hf-W system to determine relative metal segregation ages [7].

Experimental Methods: Highly siderophile element abundances were determined by isotope dilution. The experimental methods for the HSE are detailed in [8]. Osmium and W isotope compositions were determined for separate, but adjacent, pieces of metal from each iron meteorite, such that the pieces had similar shielding conditions. The digestion and chromatographic methods for Os and W are described in [7, 9].

All analyses were conducted at UMd. ^{187}Os/^{188}Os was determined using a *VG Sector 54* TIMS. Remaining HSE were analyzed using a *Nu-Plasma* MC-ICP-MS. Isotope compositions of Os and W were determined using a *Thermo-Fisher Triton* TIMS. The external reproducibility (2σ) of the repeated analysis of terrestrial standards is approximately ±4.5 ppm for ^{182}W and ±35, 8, and 7 ppm for $^{186, 189, 190}$Os, respectively.

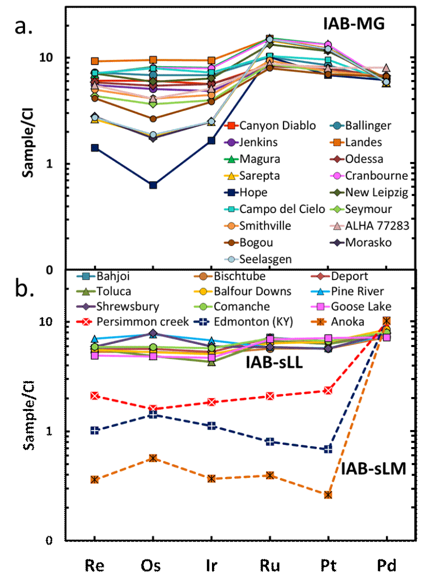

Fig. 1. Chondrite-normalized HSE abundances for (a) MG and (b) sLL (solid lines) and sLM (dashed lines) IAB irons.

Results: Rhenium, Ir, and Pt data for these irons are in good agreement with those of [1] for all samples but Sarepta and Cranbourne, which are lower and higher than [1], respectively. Osmium, Ru, and Pd data are also in agreement with literature data [10, 11]. Both relative and absolute HSE abundances differ between subgroups (Fig. 1). All IAB irons analyzed thus far are within uncertainties of a primordial Re-Os isochron [12], suggesting that the Re-Os system and other HSE did not experience open-system behavior more than 20 Ma after solar system formation. Thus, HSE abundances likely reflect those at the time of crystallization.

Of 14 IAB iron meteorites examined for CRE, only two show resolvable anomalies with respect to $^{186, 189, 190}$Os (Deport and Bischtube). Deport shows the largest Os isotopic anomaly yet measured (μ^{189}Os = -106±8; where μ is the deviation in ppm from terrestrial standards) [7, 13]. All other IAB irons analyzed have Os isotopic compositions indistinguishable from terrestrial standards (except in ^{187}Os). Some of these irons were also analyzed for W isotope compositions (Fig. 2). Canyon Diablo, Campo del Cielo (both MG), and Toluca (sLL) have overlapping μ^{182}W values of -308±7, -302±5 and -299±5, respectively. The isotopic compositions of Canyon Diablo and Toluca are in good agreement with [5, 14], whereas the μ^{182}W of Campo del Cielo is only slightly lower than that reported by [5]. Sombrerete (sHL) has a μ^{182}W of -327±5 that is ~9 ppm lower than the average of the MG irons.

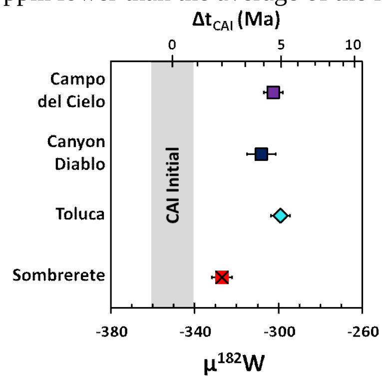

Fig. 2. Tungsten isotope data for IAB irons. The 2σ external reproducibility of the terrestrial standards is slightly larger than the size of the symbols. The CAI initial is from [15].

Discussion: The HSE patterns of the subgroups differ significantly. The MG, sLL, and sLM groups cannot be related by any crystallization path modeled, indicating that the groups had distinct starting compositions and did not crystallize from the same parental melt. This conclusion is in good agreement with [1].

The elemental trends within an individual subgroup also cannot be explained by fractional crystallization [16]. In the MG, the crystal segregation model of [1] can adequately account for the variations in the abundances of Re, Os, and Ir. However, variations in Pt and Ru, and a correlation between Pd and Ir, with a slope that is inconsistent with model parameters, are difficult to reconcile with the model. Some of the variance in Pt, and the slope in Pd vs. Ir can potentially be explained by a crystal segregation model if fractional crystallization was also active. A combination of fractional crystallization and crystal segregation is, therefore, a promising possibility we will pursue.

The μ^{182}W values for MG and sLL irons correspond to an average model age of metal segregation ~4.5±1 Ma after Ca-Al-rich inclusion (CAI) formation, in agreement with [5] (CAI initial μ^{182}W = -351±10 [15]). This is 1-2 Ma after the segregation ages of most magmatic irons [17]. The metal segregation age for Sombrerete is 2.1±0.9 Ma after CAIs, corresponding to an age difference of about 2.4 Myr between it and the MG and sLL subgroup. These model ages are calculated without any corrections for CRE, given the normal Os isotopic compositions measured for these specific meteorite pieces. The agreement between Campo del Cielo and Canyon Diablo, which have CRE ages of ~70 and ~545 Myr, respectively [18, 19], suggests that this approach is reasonable. It should also be noted that variations in μ^{182}W can potentially be due to growth of ^{182}W resulting from variable Hf/W in parental materials, rather than solely differences in segregation ages [20]. The generally chondritic relative abundances of siderophile elements in some members of each subgroup argue against this possibility, but it can't be completely discounted at this time.

The HSE abundances and W isotopic data show that the MG and sLL metallic melts likely segregated contemporaneously, but that they were of distinct compositions. A spatial difference between the groups is inferred. Further, the apparently older age of Sombrerete indicates that at least some of the metallic melts represented by IAB irons segregated at a different time, as was also noted in [5] using evidence of a ~13 Ma metal segregation event from the IAB-ungrouped meteorite, Mundrabilla. Sombrerete also has a lower Δ^{17}O than most IAB complex irons [1]. These lines of evidence suggest that Sombrerete (and possibly the sHL subgroup) is not genetically related to the MG. Thus, the IAB complex may not represent a single parent body. If this is the case, chemical similarities within the complex suggest that the processes that created these meteorites were widespread in time and space.

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