AGE AND ORIGIN OF IAB IRON METEORITES AND THEIR SILICATE INCLUSIONS INFERRED FROM HF/W CHRONOMETRY  

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Abstract: The decay of $^{182}$Hf (half life of 9 million years) to $^{182}$W provides a powerful tool to date metal-silicate fractionation in the early solar system. During segregation of metal the siderophile W partitions into the metal phase, whereas the lithophile Hf is preferably incorporated by silicate phases. The formation of iron meteorites during metal-silicate fractionation may have occurred during condensation in the solar nebula [1] or in the interior of planets and planetesimals [2-9]. Iron meteorites with silicate inclusions like the IAB-IIICD group are particularly interesting for the application of the Hf-W system as a chronometer for metal-silicate fractionation events during the early history of the solar system. We investigated this meteorite groups closer by systematic analyses of four IAB iron meteorites (Landes, Copiapo, Campo del Cielo and Caddo County) and their silicate inclusions. Data for metals are in agreement with earlier analyses of metal phases in IAB-IIICD irons [10] at around $\varepsilon_{w}$, whereas silicates display large excesses of $^{182}$W/$^{184}$W, between 0.9 and 6.6 units. From an internal silicate isochrone for Campo del Cielo an age significantly different from the model age for the metal phase of the same sample can be inferred. The silicates of Copiapo appear to be older than the metal phase, whereas the silicates for Campo del Cielo appear to be younger.

Introduction: Most iron meteorites exhibit geochemical trends that can be explained by fractional crystallization during core formation on a chondritic parent body [11,12]. These are magmatic iron meteorites, whereas non-magmatic iron meteorites show basically unfractionated siderophile element patterns. The non-magmatic groups exhibit a unique characteristic in the presence of abundant silicate clasts with up to a few centimeters in size. They contain planetary-type noble gases [9] and a chondritic to subchondritic composition and mineralogy, e.g. the basaltic to andesitic silicate phases of Caddo County [12]. Most silicate clasts appear to be unaffected by extensive partial melting and/or fractional crystallization in the interior of planets. Based on their oxygen isotope composition, the IAB meteorites are related to the non-magmatic IIICD meteorites and the primitive achnorhodies of the winonaites-group [13] and to a lesser extent to the acapulcoite-lodranite group. Although the formation and thermal history of the IAB parent body remains unconstrained, it may be related to condensation in the solar nebula [1], or to metal-silicate fractionation in the interior of planets or planetesimals, triggered either by internal heat sources [4-6], external heat sources such as impacts [2,3] or both [7-9].

Samples and analytical methods: From each of the selected iron meteorites a few chips were cleaned with steel-free abrasives and put in an ultrasonic bath before leaching in 0.05M HNO$_3$ for several minutes. From all samples, matrix metal and silicates were separated, for Caddo County, Landes and Copiapo a mixture of individual silicate phases was used, whereas for Campo del Cielo a single inclusion was extracted. All silicate phases were subsequently powdered in an agate mortar to reduce the grain size. During this procedure magnetic fractions were continuously removed using a hand magnet. In the case of Campo del Cielo the magnetic fraction was visibly free of silicates. Separation of Hf and W was performed by anion exchange methods [17]. All isotope compositions were determined using the Micromass IsoProbe MC-ICP-MS at Münster [17].

Results: Figure 1 shows two internal silicate inclusion isochrones for Campo del Cielo and Copiapo. In Figure 2 ages for the silicates and model ages of metals are plotted relative to Ste. Marguerite ($4565 \pm 0.7$ Ma) [18]. The isochrones define initials and ages which differ significantly from the model ages of the metals of the same meteorite. Isochrones for Copiapo and Campo del Cielo yield absolute ages of $4571.0 \pm 3.9$ Ma and $4555.9 \pm 2.5$ Ma, respectively. Model ages of the matrix metal phases are identical within analytical uncertainties. $\varepsilon_{w}$ for inclusion metal in Campo del Cielo is indistinguishable from the value for the matrix metal.

Discussion: Tungsten in silicate inclusions displays a very different isotopic composition than W in both matrix and in inclusion metals. In addition, isochrones defined by the silicate inclusions do not pass through matrix metal. This suggests a different origin of inclusions and metal. The identical composi-
tion of matrix and inclusion metal indicates that inclusion metal is derived from matrix metal and is unrelated to the host phase of W in the silicate inclusions. The age of Copiapo silicates defined by two points is older by 3.8 Ma years than the canonical solar system age. Planetesimals with ages older than the canonical CAI age were previously predicted by Kleine et al [10] on the basis of low $^{182}\text{W}/^{184}\text{W}$ ratios in iron meteorites. If the weakly magnetic fraction of Copiapo were contaminated with inclusion metal, the metal free Copiapo silicates would even be older. All ages that are calculated from the W-isotopes are older than typical silicate ages inferred from Rb-Sr and Sm-Nd chronometry which may record remelting of silicates. In contrast, Hf-W-ages require silicate metal equilibration. The uniform $^{182}\text{W}/^{184}\text{W}$ ratios of the four matrix metals enables a closer assessment of cosmic ray effects on W isotope compositions in iron meteorites.

Long exposure times of many iron meteorites to cosmic rays can cause significant cosmic ray effects in $^{182}\text{W}$, consequently reducing $^{182}\text{W}$ by neutron capture. Although this effect cannot be ignored, our first results indicate that the effect must be negligible: Caddo County and Landes metals display, within limits analytical error, the same $^{182}\text{W}/^{184}\text{W}$ ratios, although they have drastically different exposure ages, 240-270 my for Landes [14] and 2.8-3.9 my for Caddo County [15]. A more rigorous interpretation of the W-isotope data requires an independent monitor of the neutron flux. We therefore envisage to monitor the thermal neutron flux by analyzing Gd-isotopes in coexisting silicates.