Planetesimal differentiation revealed by high-precision ^{182}W measurements

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The distinct parent bodies of differentiated meteorites are characterized by order-of-magnitude variations in volatile element depletion, indicating that the conditions of planetesimal accretion varied in space and/or time. Differentiated meteorites also bear testimony to diverse evolutionary paths of planetesimals and include samples of fully (e.g., magmatic iron meteorites) and only partially differentiated bodies (e.g., ureilites). To assess the origins of these distinct chemical compositions and diverse differentiation histories, we determined the time of core formation in the parent bodies of magmatic iron meteorites and ureilites using the short-lived ^{182}Hf-^{182}W system.

For the magmatic irons we observe an inverse correlation between the ^{182}W/^{184}W ratios and volatile contents (e.g., S concentration) of each core. The ^{182}W data indicate that core formation occurred in two distinct stages and and involved an early segregation of Fe-FeS and a later segregation of S-poor Fe melts. Owing to their different segregation times, the two metal melts probably had distinct ^{182}W/^{184}W ratios, such that the final compositions of the metal cores would reflect the specific mix of the two segregated metal melts. Consequently, for a given accretion time, the metal cores of S-rich bodies (e.g., IIAB) would be characterized by a larger ^{182}W deficit as compared to S-poor bodies (e.g., IVB), because they would contain a larger fraction of the early-segregated Fe-FeS melt. The ^{182}W data indicate that the early segregation of Fe-FeS melts occurred at ~0.7 Myr after CAI formation and was followed by the separation of Fe melts ~1-2 Myr later. Despite this protracted interval of core formation, the iron meteorite parent bodies probably accreted concurrently at ~0.1 to ~0.3 Myr after CAI. Variations in volatile contents among these bodies, therefore, did not result from accretion at different times from an incompletely condensed solar nebula but must reflect local processes within the nebula.

Core formation in the ureilite parent body involved only the segregation of an Fe-FeS melt (+ silicate melt extraction), which based on our new ^{182}W data occurred at ~3 Myr after CAI formation and thus significantly later than in iron meteorite parent bodies. Thermal modeling combined with the ^{182}W data indicates ureilite parent body accretion at ~1.5 Myr after CAI formation. Consequently, this body may be partially differentiated because it accreted too 'late', at a time when too little ^{26}Al remained to induce complete melting.