THERMAL AND IMPACT HISTORY OF ORDINARY CHONDRITE PARENT BODIES INFERRED FROM Hf-W CHRONOMETRY.

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Introduction: Ordinary chondrites derive from at least three distinct parent bodies (H, L, and LL) that most likely accreted at ~2–3 Ma after solar system formation and subsequently underwent thermal metamorphism by internal heating through ^{26}Al decay. This presumably led to a concentrically layered internal structure, where more strongly metamorphosed material is located at increasing depth towards the center of the body [1]. However, if and for how long this 'onion-shell' structure persisted, how extensively it was disturbed by subsequent impacts, and whether impacts partially or wholly disrupted the parent bodies remains a matter of debate [*e.g.*, 2, 3]. Moreover, the concept of an onion shell structure has been mainly developed on the basis of thermochronological data for H chondrites, and as such it is largely unknown as to whether it is also appropriate for the L and LL chondrite parent bodies.

The short-lived ^{182}Hf-^{182}W system is well suited to address these issues. Because of its high closure temperature, the Hf-W system provides constraints not only on the timing of the thermal peak but also on the high-temperature cooling history of type 5 and 6 ordinary chondrites [4]. This makes the Hf-W system uniquely useful for examining the initial structure of ordinary chondrite parent bodies and to assess the occurrence of early disruptive impacts during high-temperature metamorphism. Here, new Hf-W data for metal and silicate separates from 15 equilibrated H, L, and LL chondrites (type 4–6) are used to constrain the internal structure and high-temperature cooling histories of ordinary chondrite parent bodies.

Methods: Samples were gently crushed, sieved and then separated into coarse-grained metal and silicate dominated fractions, where the latter consist of variable mixtures of silicates and very fine-grained metal. After digesting the samples in HNO_3-HCl-HF (metals) or HF-HNO_3 (silicates), 2-10% aliquots were taken to determine Hf and W concentrations by isotope dilution. For unspiked samples, W was separated by anion exchange chromatography [5] and W isotope compositions were measured on a Neptune *Plus* MC-ICPMS at Münster.

Results: For all samples the silicate-dominated fractions define precise Hf-W isochrons, which correspond to Hf-W closure ages of ~3–13 Ma after formation of Ca-Al-rich inclusions. In general, the Hf-W ages become younger with increasing metamorphic grade (i.e., petrologic type). Of note, for most samples coarse-grained metal plots below the isochron defined by the silicate-dominated fractions, indicating that W isotopic exchange between coarse-grained metals and surrounding silicates stopped before the Hf-W system closed in the silicate-dominated fractions. However, for a few type 5 and two type 6 chondrites coarse-grained metals and silicates define single isochrons.

Discussion: The offset between the ^{182}W composition of coarse-grained metal and the initial ^{182}W of the isochron defined by the silicate-dominated fractions can be used to determine cooling rates for each sample. This approach requires knowledge of the closure temperature difference between coarse-grained metal and silicate-dominated fractions. Numerical simulation of W diffusion between silicates and metal indicates that this closure temperature difference is ~10–20°C, and most likely results from the very low metal-to-silicate ratio of the bulk silicate-dominated fractions. The cooling rates calculated using this closure temperature difference and the ^{182}W difference between coarse-grained metals and the isochron initial are inversely correlated with the Hf-W ages, indicating that younger samples cooled at a lower rate. This correlation, combined with the observation that the Hf-W ages become younger with increasing petrologic type, indicates a common onion shell structure for the parent bodies of all ordinary chondrites. For some samples, metal and silicates plot on single isochrons, and so only minimum cooling rates can be estimated. For type 5 samples, these minimum cooling rates are consistent with the expected cooling rates for samples buried at shallower depth and these samples fit the overall correlation of Hf-W ages with cooling rates. Only one L6 chondrite does not fit this correlation. This samples likely cooled at >50°C/Ma through Hf-W closure, much faster as expected for type 6 samples buried deep inside the parent body. Thus, this type 6 sample was likely excavated to near surface areas prior to Hf-W closure. Taken together, the Hf-W data for most samples are consistent with an onion shell structure and undisturbed cooling of type 5 and 6 samples through Hf-W closure, but at least one sample provides evidence for impact excavation of type 6 material during this interval. This may either indicate partial disruption of the parent bodies, during which large parts of the bodies remained undisturbed, or separate parent bodies for excavated and non-excavated samples.

References: [1] Trieloff M. et al. 2003. *Nature* 422:502-506. [2] Scott et al. 2014. GCA 136: 13-37. [3] Blackburn T. et al. 2017. *GCA* 200: 201-217. [4] Kleine T. et al. 2008. EPSL 270:106-118. [5] Kruijer T. S. et al. 2014. *EPSL* 403:317-327.