HF-W CHRONOMETRY OF THE ACCRETION AND THERMAL METAMORPHISM OF ORDINARY CHONDRITE PARENT BODIES. T. Kleine1, A.N. Halliday2, H. Palme3, K. Mezger4, and A. Markowski1, 1Institut für Isotopengeologie und Mineralische Rohstoffe, ETH Zentrum, Sonneggstr. 5, 8092 Zürich, Switzerland (kleine@erdw.ethz.ch), 2Department of Earth Sciences, Oxford University, Parks Road, Oxford OX1, United Kingdom, 3Institut für Geologie und Mineralogie, Universität zu Köln, Zülpicherstr. 49b, 50674 Köln, Germany, 4Institut für Mineralogie, Universität Münster, Corrensstr. 24, 48149 Münster, Germany.

Introduction: \(^{182}\text{Hf}-^{182}\text{W}\) chronometry (half-life = 8.9 Myr) is well suited for dating metal-silicate fractionation processes in the early solar system. Such processes include metal segregation in planetesimals as well as the formation and subsequent thermal processing of metals in chondrites. Ordinary chondrites contain abundant metal and exhibit a range of metamorphic conditions from type 3 (unequilibrated) to type 6 (equilibrated). Metals from unequilibrated ordinary chondrites have relatively low W contents and probably formed by melting of oxidized precursors before or during accretion of their parent bodies [1, 2]. The higher W contents in metals from metals from unequilibrated ordinary chondrites result from the reduction and transfer of W from silicates into metal during thermal metamorphism [2, 3]. Thus, Hf-W chronometry of ordinary chondrite metal of different petrological type can constrain the timescales of parent body accretion and subsequent thermal metamorphism.

Kleine et al. [4] recently suggested that the accretion of and core formation in the parent bodies of magmatic iron meteorites (dated with Hf-W) predated the formation of chondrules (dated with Al-Mg and Pb-Pb). Comparing W isotopic compositions of metals from unequilibrated ordinary chondrites with those of magmatic iron meteorites provides an important test for this model. Here we report first results on the Hf-W systematics of ordinary chondrites. Using the Nu Plasma MC-ICPMS at ETH Zürich we obtained Hf-W data for magnetic (mostly metal) and non-magnetic (mostly silicates and oxides) fractions of several ordinary chondrites including Julesburg (L3.6), Bruderheim (L6), La Criolla (L6), Kernouvé (H6), Guarena (H6), and Dhurmsala (LL6).

Results: Metals in type 6 ordinary chondrites are enriched in W (~1-1.3 ppm W) relative to metals in type 3 ordinary chondrites (~300 ppb W), consistent with results from earlier studies [2, 3]. Despite these different W contents, all metals exhibit similar W isotopic compositions between ~3 and ~2.5 \(\varepsilon_{\text{W}}\) (\(\varepsilon_{\text{W}}\) is the deviation of \(^{182}\text{W}/^{184}\text{W}\) from the terrestrial standard value in parts per 10,000). Although no \(\varepsilon_{\text{W}}\) differences are yet resolvable, metals from highly equilibrated L ordinary chondrites appear to be slightly more radiogenic than those from the unequilibrated L ordinary chondrite Julesburg. The non-magnetic fractions exhibit \(\varepsilon_{\text{W}}\) values that are more radiogenic than the metals and are correlated with Hf/W. The initial \(^{182}\text{Hf}/^{180}\text{Hf}\) ratios inferred from these correlations are highest for Julesburg and lowest for La Criolla. This is consistent with the slight, albeit barely resolvable differences in W isotopic compositions of their metals.

Discussion: The similarity in W isotopic composition of ordinary chondrite metals regardless of petrological type indicates that the transfer of W from silicates into metals ceased early, in less than ~10 Myr after the start of the solar system. This short timescale contrast with results from U-Pb and I-Xe systematics of ordinary chondrites [7, 8] that indicate more prolonged timescales of metamorphic cooling. There are two endmember interpretations of the Hf-W age constraints. First, the difference between Hf-W and U-Pb/I-Xe ages could reflect a higher closure temperature for Hf-W exchange between metal and silicates compared to U-Pb and I-Xe isotopic closure in phosphates and feldspars. Second, the Hf-W ages of equilibrated ordinary chondrites might date the onset of metamor-
phic heating whereas U-Pb and I-Xe ages might reflect cooling from peak metamorphic temperatures [3]. In this scenario, W exchange between metal and silicates ceased because reduction of W terminated after exhaustion of the reductant. Humayun and Campbell [3] argue that this exhaustion occurred early, during the onset of metamorphic heating, and that the W isotopic composition of metal from equilibrated ordinary chondrites is already set by the metamorphic conditions reached in petrological type 4. In this case, metals separated from ordinary chondrites of type 4-6 should exhibit identical W isotopic compositions. If the Hf-W ages instead reflect cooling from metamorphic peak temperatures, metals from type 4 ordinary chondrites might be less radiogenic than those from type 6 ordinary chondrites. With the precision now obtainable for W isotopic measurements we might ultimately be able to resolve such small differences.

The initial $^{182}\text{Hf}/^{180}\text{Hf}$ of Julesburg based on data for two metal separates and one non-magnetic fraction is slightly lower than the initial $^{182}\text{Hf}/^{180}\text{Hf}$ of Allende CAIs of $(1.07\pm0.10) \times 10^{-4}$ [4], consistent with the enhanced $\varepsilon_W$ value of the Julesburg metal compared to the initial $\varepsilon_W$ of Allende CAIs (Fig. 1). These data indicate that the Julesburg metal formed $\sim$3 Myr after Allende CAIs. This interval is similar to CAI-chondrules formation intervals based on Pb-Pb [9] and Al-Mg systematics [10-13], suggesting that chondrules and ordinary chondrite metal could have formed by the same heating event [1].

The Julesburg metal has a more radiogenic W isotopic composition than magmatic iron meteorites. Given that the $^{182}\text{W}/^{184}\text{W}$ of some magmatic iron meteorites might have been lowered due to the interaction with cosmic rays, W isotopic data for magmatic irons having short exposure times provide the best determination of the W isotopic composition of iron meteorites. The IIAB iron Negrillos has an exposure age of $\sim$45 Myr and a $\varepsilon_W$ value of $-3.42\pm0.08$ (weighted average based on data from [4-6]), which is less radiogenic than the $\varepsilon_W$ value of the Julesburg metal (Fig. 1). If the W isotopic composition of the Julesburg metal has not been modified by parent body processes, then these data indicate that the formation of primitive metal in ordinary chondrites postdated core formation in iron meteorite parent bodies. This is consistent with recent results that suggest that accretion of the parent bodies of iron meteorites [4, 14] and some differentiated achondrites [15] predated the formation of chondrite parent bodies.