HF-W CHRONOMETRY OF AUBRITES AND THE EVOLUTION OF PLANETARY BODIES. M. Petitat[1,2], T. Kleine[1], M. Touboul[1], B. Bourdon[1] and R. Wieler[1], [1]Institute for Isotope Geochemistry and Mineral Resources, ETH Zurich, Clausiusstrasse 25, 8092 Zurich (petitat@mnhn.fr), [2]Laboratoire d'Étude la Matière Extraterrestre, Muséum National d'Histoire Naturelle, 57 rue Cuvier, 75005 Paris, France

Introduction: The formation of aubrites - brecciated igneous meteorites that consist primarily of FeO-free enstatite - probably involved large scale melting and removal of both FeNi-FeS and basaltic melts from their source regions. As a result, aubrites are depleted in a plagioclase component as well as in troilite and metal but nevertheless contain small amounts of metal [1-4]. Aubrites are regolith samples, as is evident from the presence of solar wind noble gases [5, 6] and cosmic-ray induced shifts in the isotopic composition of Sm and Gd [7, 8]. The timescales of metal formation and igneous differentiation in the aubrite parent body can be most effectively studied using ^{182}Hf–^{182}W chronometry [9, 10]. Here we present Hf-W data for the aubrites Norton County, Khor Themiki, Peña Blanca Spring, the anomalous aubrite Mount Egerton, and for Shallowater. In addition, the W isotope composition of Horse Creek, an ungrouped iron meteorite that may be related to aubrites [11], was determined.

Analytical methods: Samples were cleaned with abrasive paper and by ultrasonication in 0.05 M HNO_3 and ethanol. Metals were separated using steel-free tools and a handmagnet and were further purified by grinding in an agate mortar and ultrasonication in ethanol. The dissolution of the metals and purification of W followed our previously established procedure. Owing to the low W concentration in the silicate fraction of aubrites, ~2 g of material was processed. After dissolution in HF-HNO_3, samples were loaded onto a cation exchange resin and W together with other high field strength elements was eluted using 1 M HCl-0.1 M HF. Separation of W from the high field strength elements was then achieved following the methods described in [12]. For both metals and silicates a ~10% aliquot was spiked with a mixed ^{180}Hf-^{183}W tracer for the determination of Hf and W concentrations by isotope dilution. All isotope measurements were performed using a *Nu Plasma* MC-ICPMS at ETH Zurich. The ^{182}W/^{184}W ratios of the samples were determined relative to the value obtained for a terrestrial standard and are expressed in ε^{182}W, which is the 0.01% deviation of the ^{182}W/^{184}W ratio from the terrestrial standard value.

Results: Metals from the aubrites Khor Temiki, Norton County, and Peña Blanca Spring have radiogenic ε^{182}W of ~3.3, ~5.5 and ~8.0, respectively. Likewise, metal from Mount Egerton and the ungrouped iron meteorite Horse Creek have elevated ε^{182}W values of ~0.5. In contrast, metal from Shallowater has an ε^{182}W of ~-3.0, similar to metal from ordinary chondrites. The silicate-rich fractions from Khor Temiki and Norton County have high ^{180}Hf/^{184}W ratios and radiogenic ε^{182}W of ~30 and ~11, respectively (Fig. 1). If one assumes that metal and silicates define isochrons, then the initial ^{182}Hf/^{180}Hf ratios for Khor Temiki and Norton County are ~5.2×10^{-5} and ~2.3×10^{-5} (Fig. 1).

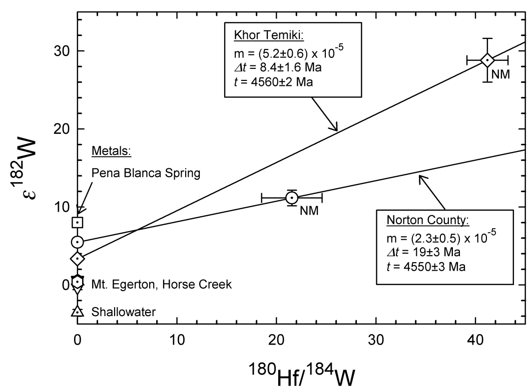

Fig. 1: Hf-W data for aubrites and related samples. Δt refers to the time after formation of CAIs, t is the absolute age calculated relative to the angrites D'Orbigny and Sahara 99555. The ^{182}W/^{184}W of the non-magnetic fractions were corrected for cosmogenically produced ^{182}W using their Ta/W and correction equations. The corrections were ~2.5 ε^{182}W for Khor Themiki and ~1 ε^{182}W for Norton County.

Discussion: *Evolution of the aubrite parent body.* All aubrite metals investigated here as well as the ungrouped iron meteorite Horse Creek have ^{182}W/^{184}W ratios well above the chondritic value. These radiogenic W isotope compositions reveal at least two distinct stages in the evolution of aubrites. The aubrite source(s) must have had high Hf/W ratios and must have had evolved to radiogenic ^{182}W/^{184}W prior to metal formation. The high Hf/W in the aubrite source(s) was most likely established as a result of core formation but later partial melting may have further fractionated Hf and W. There are two endmember models that can account for the radiogenic W isotope composition of the metals: (1) the metals are magmatic and are radiogenic in ^{182}W/^{184}W because they precipitiated from the aubrite melt; (2) postcrystallization heating caused diffusion of radiogenic W from the enstatite crystals into the metals. As shown below, the chronological interpretation of the Hf-W data critically depends on which of these interpretations is correct.

Chronology of the aubrite parent body. The initial $^{182}Hf/^{180}Hf$ ratios inferred for Khor Temiki and Norton County correspond to absolute ages of ~4560 Ma and ~4550 Ma. The Hf-W age for Norton County is consistent with a ^{53}Mn-^{53}Cr age of 4554.5±4.4 Ma (calculated relative to the angrite D'Orbigny). Similar young ^{53}Mn-^{53}Cr [13, 14] and ^{129}I-^{129}Xe [15] ages were reported for the aubrite Bishopville. Khor Temiki has yet not been dated with other chronometers, but its Hf-W age of ~4560 Ma is similar to a ^{53}Mn-^{53}Cr age of 4562.9±2.2 Ma (calculated relative to the angrite D'Orbigny) for Peña Blanca Spring, which is also consistent with its ^{129}I-^{129}Xe age. Therefore, all the available chronological data combined suggest that there might be two age groups among the aubrites. The first group has ages of ~4560 Ma and is represented by Khor Temiki and Peña Blanca Spring, wherease the second group has ages of ~4550 Ma and is represented by Norton County and Bishopville. However, metals from Peña Blanca Spring has Hf/W~0 and the most radiogenic W isotope composition of all the aubrite metals investigated here (Fig. 1), which might be difficult to reconcile with an old Hf-W age for this meteorite. Clearly, more Hf-W data are needed to firmly establish whether aubrites can be subdivided into two age groups.

Moreover, it is unclear whether the apparent Hf-W isochrons for Khor Temiki and Norton County provide meaningful ages. To define an isochron, the different fractions of one meteorite must once have been in isotopic equilibrium, i.e., any pre-existing isotope heterogeneity must have been erased by the event that is being dated. If the metals are magmatic, then this probably was the case because the metals formed from a melt with homogenous W isotope composition. However, if the metals formed by postcrystallization heating, the temperature increase might have been insufficient to completely erase any initial W isotope heterogeneity. In this case the age obtained from the apparent metal-silicate isochrons would be too old.

The closure temperature of the Hf-W system in a pyroxene-metal system has been estimated to be ~900 °C for H6 chondrites (for an assumed initial temperature of 1000°C) [20]. In aubrites, the closure temperature might be different because the metal fraction is lower (which tends to decrease the closure temperature), the grain sizes of the pyroxenes is larger (which would increase the closure temperature), and the initial temperature might have been different. Although the exact closure temperature of the Hf-W system in aubrites is still unknown, diffusion of radiogenic W from pyroxenes into metals certainly requires high temperatures because the grain sizes of the pyroxenes are so large. Therefore, postcrystallization heating might not have been sufficient to completely homogenize the W isotopes. This issue can be addressed by analyzing W isotopes in metal grains having different sizes, which is currently under way. Note that the similarity of the Hf-W and Mn-Cr ages for Norton County suggest that these ages might be meaningful.

If the Hf-W ages are indeed meaningful, this raises the question as to what process might have caused heating to such high temperatures as late as ~20 Ma after CAI formation. It seems unlikely that such late processes are related to magmatic activity on an asteroid-sized body but it might be possible that the Hf-W ages reflect slow cooling of a deeply buried area. However, given that all aubrites are regolith samples, the currently most straightforward interpretation appears to be that impacts on the surface of the aubrite parent body caused heating that was sufficient to at least partially reset the Hf-W system. The heat might have been provided by the impact itself or by excavating hot material from the interior of the aubrite parent body.

Relationship between Horse Creek, Shallowater, and aubrites. Based on similar elevated Si concentrations in aubrite metals and Horse Creek, it has been suggested that Horse Creek represents aubrite metal [11]. The W isotope data presented here are consistent with this interpretation because no other iron meteorite is known to have such a radiogenic W isotope composition [e.g. 17, 18]. Likewise, it was proposed that Shallowater derives from a parent body that is distinct from that of the other aubrites [19]. Again, the W isotope data support this view because the metal from Shallowater is the only metal that has an unradiogenic W isotope composition, similar to ordinary chondrites [9]. Therefore, the late processes that are responsible for the radiogenic $^{182}W/^{184}W$ of the aubrite metals, did not affect Shallowater.

Acknowledgements: We thank J. Nauber (Zürich), T. McCoy (Smithsonian Institution, Washington), I. Leya (Bern), A. Bischoff (Münster), and C. Smith (Natural History Museum London) for providing the samples for this study.

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