Hf-W SYSTEMATICS OF CUMULATE EUCRITES AND THE CHRONOLOGY OF THE EUCRITE PARENT BODY. M. Touboul[1], T. Kleine[1], B. Bourdon[1], [1]Institute for Isotope Geology and Mineral Resources, ETH Zürich, 8092 Zürich, Switzerland (touboul@erdw.ethz.ch).

Introduction: Key issues regarding the early evolution of planetary bodies are the timescales of accretion, core formation, and silicate differentiation. The extinct ^{182}Hf-^{182}W decay system has proven particularly useful as a chronometer for these early planetary processes because Hf-W fractionations occurred during both core formation and melting processes in the silicate mantle. The latter is mainly related to the presence of clinopyroxene and ilmenite that have very high Hf/W ratios. For instance, the crystallization of these minerals in the lunar magma ocean produced large Hf/W variations in the lunar mantle, such that Hf-W chronometry could provide a precise age for the crystallization of the lunar magma ocean [1].

The combined ^{147}Sm-^{143}Nd and ^{176}Lu-^{176}Hf isotope systematics of cumulate eucrites indicate that ilmenite was present in their source regions [2]. Therefore, cumulate eucrites may exhibit highly variable Hf/W ratios and the formation of their source region can potentially be dated using the Hf-W system. Here we present new Hf-W data for five cumulate eucrites (Serra de Mage, Moore County, Talampaya, Moama, and Binda) and use these data to constrain the chronology of core formation and mantle differentiation in the eucrite parent body.

Methods: Samples (~1 g) were finely crushed in an agate mortar and ~400 mg of the whole rock powder were dissolved in Savillex beakers using HF-HNO_3 at 120°C for 72 hours. After drying, the samples are re-dissolved several times in HNO_3-H_2O_2 and finally in 6 M HCl-0.06 M HF. At this stage, complete dissolution is achieved and a ~5% aliquot is spiked with a mixed ^{180}Hf-^{183}W tracer for concentration determination by isotope dilution. The remaining ~95% were first loaded onto cation exchange columns to remove most of the sample matrix. Tungsten together with other high field strength elements (HFSEs) was eluted from this column using 1 M HCl-0.1 M HF. Separation of W from the other HFSEs was achieved using our previously established anion exchange techniques [3]. The anion exchange chemistry was repeated once to ensure complete Ti removal. All measurments were performed using a Nu Plasma MC-ICPMS at ETH Zurich. Tungsten isotope compositions of the samples were determined relative to the ^{182}W/^{184}W obtained for two bracketing measurements of the W standard. In each run 40 ratios were measured and, depending on the W content of the samples, the measurements were performed with ~0.6-1.5V for ^{182}W, resulting in within-run statistics of 0.2-0.4 ε units. The external reproducibility of these measurements is ±0.4-0.8 ε (2σ) for the ^{182}W/^{184}W ratio.

Results: In spite of largely different ^{180}Hf/^{184}W ratios, Moama, Serra de Mage and Talampaya have similar ε^{182}W values of 18.0±0.8, 17.2±0.4, 18.2±0.4, respectively (Fig. 1). Moore County has the highest ^{180}Hf/^{184}W of the cumulate eucrites investigated here but has slightly lower ε^{182}W value of 14.9±0.4. In contrast to the radiogenic ε^{182}W values and low W contents (~4-14 ppb) of these four cumulate eucrites, Binda has much lower ε^{182}W=2.6±0.3 and higher W content (~70 ppb). Compared to basaltic eucrites, the range in ^{180}Hf/^{184}W among the cumulate eucrites is much larger and their ε^{182}W values are lower. Quitté et al. [4] obtained ε^{182}W~0 and ~525 ppb W in their analyses for Serra de Magé, clearly inconsistent with the results presented here.

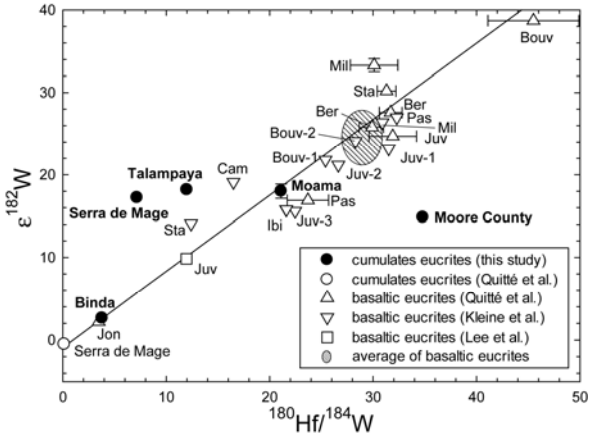

Figure 1: Hf-W isochron diagram for whole rocks of cumulate and basaltic eucrites. ε^{182}W are the deviation of the ^{182}W/^{184}W ratio of a sample relative to the terrestrial standard in part per 10,000.

Discussion: *Chronology of the eucrite parent body.* Quitté et al. [4] argue that the high W content they obtained for Serra de Magé reflects sample heterogeneity, implying the presence of a component with an extreme enrichment of W. Several lines of evidence indicate that this cannot be the case and that the low ε^{182}W and Hf/W obtained for Serra de Mage by Quitte et al. are due to contamination with terrestrial W. First, a linear regression of the Hf-W data presented here and those reported by Quitte et al. [4] yields an initial ^{182}Hf/^{180}Hf that exceeds the solar system initial by a factor of ~2. Second, Quitte et al. reported an ε^{182}W for Serra de Mage that is identical to the terrestrial W isotope composition and a W content that is ~40 times higher than the one obtained here, indicating substan-

tial addition of W having terrestrial isotopic composition. Third, in a plot of $\varepsilon^{182}W$ vs. 1/W, those eucrites that have anomalously high W contents (Serra de Mage and Jonzac [4], Juvinas [5], Binda [this study]) plot on straight lines. This is a characteristic feature of two-component mixtures. Note that the Hf-W data for Binda obtained here plot exactly on the mixing line defined by the Serra de Mage data reported here and by Quitte et al. [4]. Likewise, Jonzac and the Hf-W data point for Juvinas from Yin et al. [5] plot on a straight line defined by the average of basaltic eucrites and terrestrial W.

Therefore, the linear array defined by the basaltic eucrites (+ Serra de Mage as reported by Quitte et al. [4]) in the Hf-W isochron diagram does not represent an isochron but is a mixing line between basaltic eucrites and terrestrial W. If those samples that were clearly contaminated with terrestrial W are excluded from the regression, no statistically meaningful isochron is obtained for the basaltic eucrites. This is because the variation in Hf/W ratios among the remaining basaltic eucrites is too small.

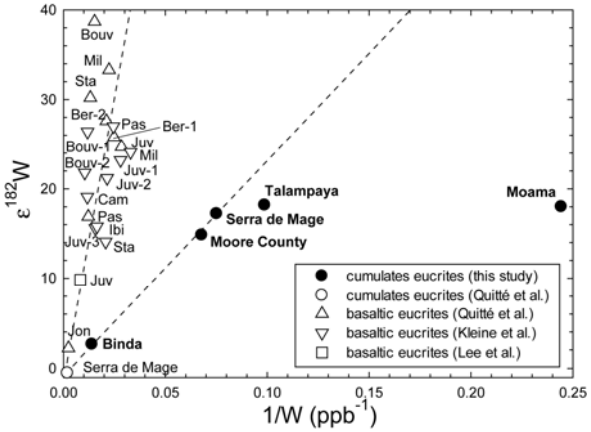

Figure 2: W isotope composition versus 1/W for cumulate and basaltic eucrites. Dashed lines show mixing between terrestrial W and W of cumulate and basaltic eucrite endmembers.

The Hf-W data for basaltic eucrite nevertheless provide important age constraints. The combined ^{147}Sm-^{143}Nd and ^{176}Lu-^{176}Hf isotope systematics of basaltic eucrites indicate that they probably formed as large degree melts from a chondritic source [2]. The lack of substantial variations in $^{176}Hf/^{177}Hf$ ratios among the basaltic eucrites rules out a significant role of ilmenite in their sources. Therefore, only limited fractionation of Hf and W is expected during formation of the basaltic eucrites. This is consistent with the narrow spread in Hf/W ratio and $\varepsilon^{182}W$ values among most basaltic eucrites and indicates that the average $\varepsilon^{182}W$ and Hf/W of basaltic eucrites may provide a good estimate of these parameters in the bulk mantle of the eucrite parent body. If this is correct, these values can be used to constrain the timing of core formation.

Using $^{180}Hf/^{184}W$= 28.8±1.8 and $\varepsilon^{182}W$ = 24.4±3.2 for average basaltic eucrites and assuming a chondritic composition for the bulk eucrite parent body, a two-stage model age for core formation of 2.5±1.2 Ma can be calculated. This corresponds to an absolute age of 4566.1±1.2 Ma (calculated relative to the angrites D'Orbigny and Sahara 99555) and is consistent with the timescales for the differentiation of the eucrite parent body deduced from Al-Mg systematics [6], with a Pb-Pb age of 4566.52±0.33 Ma for cumulate eucrite Asuka 881394 [7], and with the ^{53}Mn-^{53}Cr age of 4566.5±0.6 Ma obtained from a eucrite whole-rock isochron [8] (recalculated relative to the angrite D'Orbigny).

The initial $\varepsilon^{182}W$ calculated from the chondrite-mantle isochron of the eucrite parent body is -3.05 ±0.15, slightly higher than $\varepsilon^{182}W$ values for magmatic iron meteorites. Therefore, core formation in the eucrite parent body appear to have occurred later as in the parent bodies of magmatic iron meteorites.

Origin of cumulate eucrites. One of the key observations of our study is that cumulate eucrites, in spite of widely different $^{180}Hf/^{184}W$ ratios, have homogeneous W isotope composition. The much lower $\varepsilon^{182}W$ value of Binda most likely reflects contamination with terrestrial W and the slightly lower $\varepsilon^{182}W$ ~15 of Moore County compared to the other cumulate eucrites ($\varepsilon^{182}W$ ~18) also is most readily explained by slight terrestrial contamination (Fig. 2). Therefore, cumulate eucrites appear to be characterized by constant $\varepsilon^{182}W$ values of ~18, indicating that their widely different $^{180}Hf/^{184}W$ ratios must have been established after ^{182}Hf became effectively extinct, i.e., later than ~60 Ma after CAI formation. This is consistent with results from ^{147}Sm-^{143}Nd and ^{176}Lu-^{177}Hf whole-rock isochrons corresponding to an age of ~100 Ma after CAI formation [2]. Note, however, that these age constraints are difficult to reconcile with the ~4566.5 Pb-Pb age for cumulate eucrite Asuka 881394 [7].

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