KAIDUN CARBONATES: RE-EXAMINING THE ^{53}Mn-^{53}Cr SYSTEMATICS. M. Petitat[1], M. Gounelle[1], K. McKeegan[2], S. Mostefaoui[1], Y. Marrocchi[1], A. Meibom[1], M. E. Zolensky[3]. [1]Département d'Histoire de la Terre, Laboratoire d'Étude de la Matière Extraterrestre, Muséum National d'Histoire Naturelle, 57 rue Cuvier 75005 Paris, France; [2]Department of Earth and Space Sciences, University of California, Los Angeles, CA 90095, USA; [3]KT NASA Johnson Space Center Houston, TX 77058, USA. E-Mail: petitat@mnhn.fr.

Introduction: The Kaidun meteorite is a complex polymict breccia containing lithic clasts spanning a wide range of chondrite groups, including enstatite, ordinary and carbonaceous chondrites [1]. The latter is represented by the CR, CI and CM lithologies. These lithologies all contain carbonates, derived from aqueous alteration. Given that many other clasts are anhydrous, aqueous alteration probably occurred before compaction. In the first and only ^{53}Mn-^{53}Cr chronological study of Kaidun carbonates, Hutcheon et al. [2] used an ims 3f to analyze several carbonate grains from 3 different lithologies finding a good correlation of δ^{53}Cr with ^{55}Mn/^{52}Cr implying an initial ^{53}Mn/^{55}Mn ratio of ~ 9×10^{-6}. This value is within error of the bulk rock carbonaceous chondrite initial value (^{53}Mn/^{55}Mn = 8.5 ± 1.5) [3,4], a recent estimate of the initial ratio of the solar system. The result of [2] suggests very early, essentially simultaneous aqueous activity on several parent bodies prior to their disruption and the assembly of Kaidun. Such a chronology is surprising given that the onset of aqueous activity overlaps the period inferred for chondrule formation [5,6] and that carbonates in CI chondrites have significantly younger Mn-Cr closure ages. In this work, we used a NanoSims to characterize ^{53}Mn-^{53}Cr internal isochrons on *individual* dolomite grains in Kaidun.

Experimental methods: The mineral chemistry of individual Kaidun carbonates was determined at MNHN and Jussieu by using conventional SEM and EMPA techniques. The NanoSims at MNHN was used for ^{53}Mn–^{53}Cr analysis by rastering a 1-3nA $^{16}O^-$ primary beam over a 5×5 µm^2 area on the polished sample. The secondary ion intensities of $^{52}Cr^+$, $^{53}Cr^+$, and $^{55}Mn^+$ were measured by coupling multi-collection to magnetic peak-switching at high mass resolution sufficient to resolve all molecular ion interferences, including hydrides. The relative sensitivity factor (RSF) for ^{55}Mn/^{52}Cr was determined from the mean of analyses of 4 standards: NBS611 (Mn/Cr = 1.2), San Carlos olivine (Mn/Cr = 7.8), T1-G (Mn/Cr = 50.5) and ATHO-G (Mn/Cr = 130.8). Unfortunately, as with previous ion probe investigations, no carbonate standards were available and thus our Mn/Cr ratios may suffer from a systematic error, but they are still comparable to previous results obtained on carbonates.

Mass fractionation was corrected externally, i.e. ^{53}Cr/^{52}Cr ratios in the Orgueil carbonates were normalized relative to the average value of the ^{53}Cr/^{52}Cr ratios measured for the 4 standards and are reported as δ^{53}Cr, expressed as the deviation, in parts per mil, from the reference ^{53}Cr/^{52}Cr value of 0.113457±0.000001 [7]. Given the magnitude of δ^{53}Cr excesses, possible matrix effects on the mass fractionation correction are negligible.

Samples: Three Kaidun dolomites, embedded in 2 different CI lithic clasts within the Kaidun_3.10.i and Kaidun_cavity mounts, were analysed. Both clasts are similar in mineral composition and size to the one described in [1]. The 3 carbonate grains are fine-grained, range from 20 to 70 µm in diameter, and occur as isolated matrix grains, without any association with other phases (picture 1). They are irregular in shape. The MgO content of these dolomites range from 16.0 to 20.9 wt% and their CaO content can reach 31.1 wt%. They contain significant amounts of iron (between 5.7 and 8.2 wt% FeO) and minor amounts of MnO (below 1.9 wt%).

Picture 1. Kaidun_3.10.i-3 with its three measurement areas. Change of the Cr at the sub-micrometer range makes the ^{55}Mn/^{52}Cr ratios vary.

Results: All 3 carbonates investigated show large enrichments in ^{53}Cr with δ^{53}Cr up to ~ 600‰. Their respective ^{55}Mn/^{52}Cr ratios range up to 15000 and are linearly correlated with δ^{53}Cr constituting strong evidence for in situ ^{53}Mn decay. A best-fit line forced through the origin yields a slope corresponding to initial ^{53}Mn/^{55}Mn ratios at the time of carbonate formation ranging from $(4.27\pm0.43)\times10^{-6}$ to $(5.96\pm1.05)\times10^{-6}$.

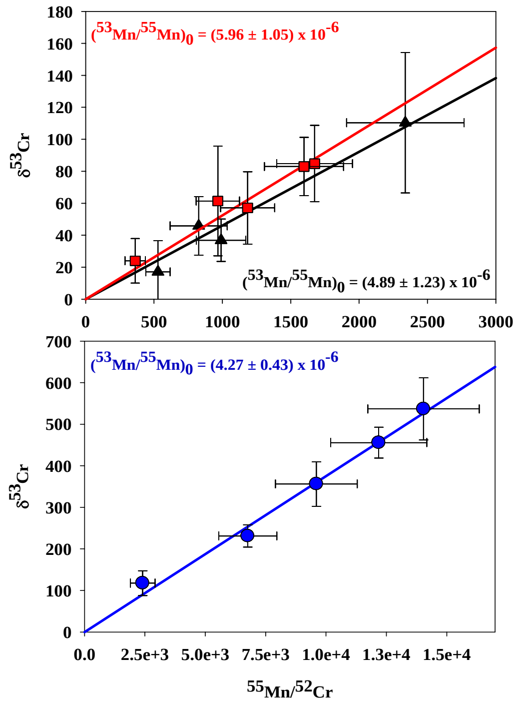

Figure 1. Mn-Cr isochron diagrams for the 3 dolomites from this study. Error bars are 2σ. **red**: Kaidun-cavity_5; **black**: Kaidun-3.10.i_2; **blue**: Kaidun-cavity_3.

Discussion: Apart from grain Kaidun-cavity_5, the initial $^{53}Mn/^{55}Mn$ ratios measured for the Kaidun dolomites from this study are similar within error (Fig. 2) and all overlap the values measured for the CI dolomites in previous studies [8,9], consistent with the derivation of these carbonates from CI lithic clasts. Two of the 3 carbonates have initial $^{53}Mn/^{55}Mn$ ratios plotting below the solar system initial range, represented by the bulk rock carbonaceous chondrites initial value [4,5], with the other grain having a value within error of this range. If ^{53}Mn was homogeneously distributed at the start of the solar system (see [10] for another view), then the dolomite grains Kaidun-3.10.i_2, Kaidun-3.10.i_3 and Kaidun-cavity_5 formed, respectively, 3.0±0.9, 3.7±0.6 and 1.9±0.4 after the start of the solar system, within the time range inferred for formation of chondrules from Semarkona [5] and Chainpur [6].

The average initial $^{53}Mn/^{55}Mn$ ratio, $(5.0 \pm 1.0) \times 10^{-6}$ from this study differs significantly from the value obtained by [2]. This discrepancy might represent sampling of different parts of Kaidun. Note that the isochron from [2] compiles measurements from 3 different lithologies and 2 different carbonate types (calcite and dolomite). The internal isochrons presented here extend the range of already published $^{53}Mn/^{55}Mn$ initial ratios for the Kaidun carbonates. Indeed, if we assume that the Hutcheon *et al.* [2] value and our value are affected equally by systematic uncertainties due to possible matrix effects on the RSF, then a time duration of ~4Ma is still implied. This lower limit would be adequate to permit impact brecciation of several CC parent bodies and reassembly into the Kaidun parent-asteroid. The overlap of Mn-Cr estimates with those of chondrule formation in ordinary chondrites supports other suggestions that aqueous alteration of some parent bodies and chondrule formation were contemporaneous in the solar nebula.

Conclusion: We analyzed 3 dolomite grains from two CI lithic clasts of the Kaidun meteorite, finding identical initial $^{53}Mn/^{55}Mn$ ratios, which diverge from the previous data analysed by [2]. Dolomite formation in these clasts may have initiated very early, spanning from within the first Myr to 2-4 Myr after start of the solar system. This confirms previous ^{53}Mn-^{53}Cr data, suggesting that dolomites in CI formed within the first 4 Myr after the start of the solar system. This study corroborates the fact that aqueous processing started very early in the solar system and, regarding the dolomite carbonate type in CI chondrites, lasted 4 Myr after the start of the solar system.

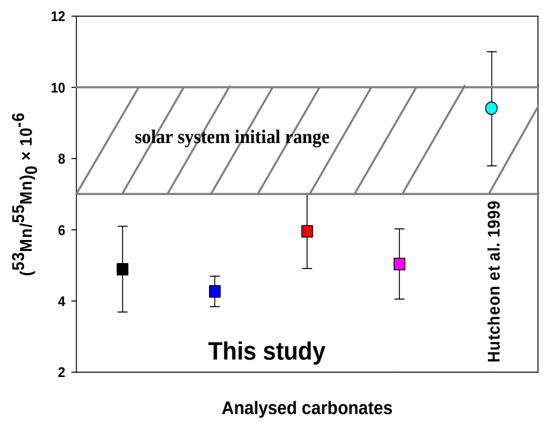

Figure 2. Summary of the initial $^{53}Mn/^{55}Mn$ ratios from this study and their comparison to the initial value from [2]. Error bars are 2σ. Squares: Data from this study: **black:** Kaidun-3.10.i2; **blue**: Kaidun-3.10.i3; **red**: Kaidun-cavity_5; **pink**: averaged value for the 3 dolomite grains in this study.

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