MN-CR SYSTEMATICS FOR THE CM2.1 CHONDRITES QUE 93005 AND ALH 83100: IMPLICATIONS FOR THE TIMING OF AQUEOUS ALTERATION. Simone de Leuw[1], Alan E. Rubin[2], Axel K. Schmitt[1] and John T. Wasson[1,2], [1]Department of Earth and Space Sciences, University of California, Los Angeles, CA 90095-1567, USA (sdeleuw@ucla.edu), [2]Institute of Geophysics and Planetary Physics, University of California, Los Angeles, CA 90095-1567, USA.

Introduction: Aqueous alteration on the CM parent body resulted in the formation of secondary phases such as carbonates, phyllosilicates, sulfides, sulfates, oxides and hydroxides [1,2], but little was known about the timescale of alteration processes. Previous studies using Mn-Cr systematics to determine the onset of carbonate formation on the CM parent body suggested that aqueous activity (and hence, carbonate formation) started within a few million years after CAI formation [3-6]. Alteration products, especially Mn-rich carbonates, could potentially provide a record of the timing of low-temperature aqueous alteration on the CM parent body if the alteration timescale was comparable to the half-life of ^{53}Mn (3.7 Ma). Here we studied two highly aqueously altered CM2.1 chondrites, QUE 93005 and ALH 83100, by ion microprobe and compared our data with previous studies. The results imply that alteration on the CM parent body lasted at least 4 Ma and that the degree of aqueous alteration is roughly correlated with the age of carbonate formation.

Observations: QUE 93005 and ALH 83100 both contain calcite/aragonite ($CaCO_3$) as well as dolomite ($CaMg(CO_3)_2$). Carbonate abundances in these rocks are 2.3 vol.% and 2.8 vol.%, respectively. Electron microprobe analyses of selected carbonate grains showed elevated Mn contents (up to 5.0 wt.% for dolomite in QUE 93005 and 3.8 wt.% for dolomite in ALH 83100), indicating their suitability for Mn-Cr isotopic studies. The Cr contents of the carbonates were below the detection limit (i.e., <0.04 wt.%).

Analytical techniques: Isotopic analyses were carried out on the high-resolution ims 1270 ion microprobe at UCLA with a $^{16}O^-$ primary beam and an accelerating voltage of 12.5 keV. The secondary voltage was set to 10 kV with a 50 eV energy window. The mass resolving power was ~4000 and the beam size was approximately 10 μm. The standard material was San Carlos olivine. $^{55}Mn/^{52}Cr$ ratios were calculated from $^{55}Mn^+/^{52}Cr^+$ using the sensitivity factor determined from San Carlos olivine (Mn/Cr = 10.93 [7]). Deviations in $^{53}Cr/^{52}Cr$ ratios are reported as $\delta^{53}Cr$ (‰).

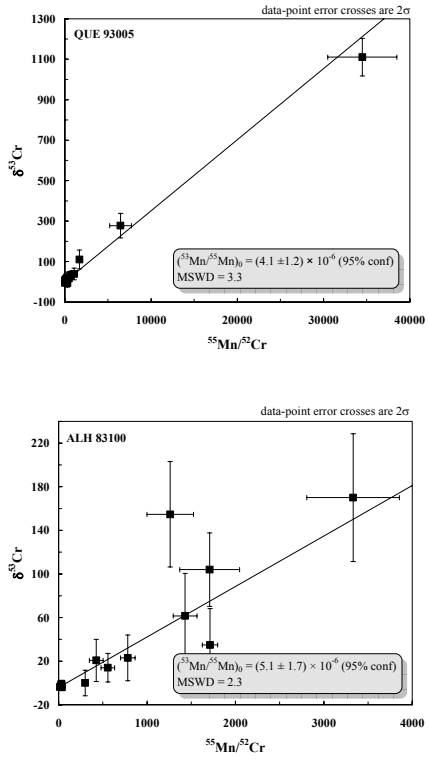

Figure 1: Mn-Cr evolution diagrams for carbonates in QUE 93005 and ALH 83100. Deviations from the terrestrial $^{53}Cr/^{52}Cr$ ratio are plotted as δ values in ‰.

Results: We determined Mn-Cr systematics on 11 carbonate grains from the CM chondrite QUE 93005 and on 13 carbonate grains from ALH 83100. We obtained replicate analyses on nine and four carbonate grains, respectively; obtaining a total of 38 measurements (22 for QUE 93005 and 16 for ALH 83100). Ten measurements in QUE 93005 showed excesses in $\delta^{53}Cr$ with the highest excess of ~1100‰, corresponding to a Mn/Cr ratio of more than 30,000. Five measurements in ALH 83100 showed excesses, with the highest $\delta^{53}Cr$ value of ~170‰ and a Mn/Cr ratio of ~3,300. The ^{53}Cr excesses in both samples are linearly correlated with the $^{53}Mn/^{55}Mn$ ratio, indicating the *in situ* decay of ^{53}Mn at the time of carbonate formation. The slopes of the correlation lines, determined by a weighted least-squares fit, correspond to initial

$^{53}Mn/^{55}Mn$ ratios of (4.1 ± 1.2) × 10^{-6} for QUE 93005 and (5.1 ± 1.7) × 10^{-6} for ALH 83100 (Fig. 1).

Conclusions: To constrain the timeframe of aqueous alteration on the CM parent body, we need to calculate the age difference between carbonates in highly altered and minimally altered CM chondrite. The studied chondrites QUE 93005 and ALH 83100 represent the highly altered end members. In order to calculate the alteration period, we used the value for a moderately altered CM chondrite Y-791198 (CM2.4), obtained by [8]. Y-791198 was measured using the LLNL ims 3f ion microprobe: the slope of the correlation line corresponds to an initial $^{53}Mn/^{55}Mn$ ratio of (8.7 ± 1.5) × 10^{-6}. Using the standard equation for short-lived radionuclides ($\Delta_{\tau 1\text{-}2} = 1/\lambda\ [(^{53}Mn/^{55}Mn)_2/(^{53}Mn/^{55}Mn)_1]$), the calculated time difference of carbonate formation between QUE 93005 and Y-791198 is 4.18 ± 1.92 Ma; the time difference between ALH 83100 and Y-791198 is 2.97 ± 2.27 Ma. The formal time difference between carbonate formation in the two CM2.1 is 1.21 ± 2.08 Ma. However, this is within the analytical error and we conclude that carbonates in QUE 93005 and ALH 83100 formed at the same time.

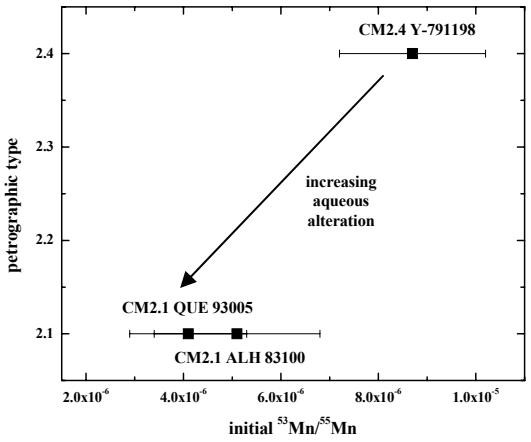

Figure 2: Plot of initial $^{53}Mn/^{55}Mn$ versus petrographic subtype. Initial $^{53}Mn/^{55}Mn$ values decrease with increasing aqueous alteration. Data for Y-791198 taken from [8].

In a plot of initial $^{53}Mn/^{55}Mn$ values versus petrographic subtype (Fig. 2), the more aqueously altered CM chondrites QUE 93005 and ALH 83100 display lower initial $^{53}Mn/^{55}Mn$ values than the more pristine sample Y-791198. This observation implies that the degree of aqueous alteration is correlated with the age of carbonate formation. More data from different CM subtypes are needed to verify this deduction and to constrain the duration of aqueous alteration processes on the CM parent body.

References: [1] Zolensky M. E. and McSween H. Y. (1988) In: *Meteorites and the Early Solar System*, 114-143. [2] Brearley A. J. and Jones R. H. (1998) *Rev. Mineral*., 36, pp 398. [3] Hutcheon I. D. et al. (1999) LPS *XXX*, Abstract #1722. [4] Brearley A. J. et al. (2001) *LPS XXXII,* Abstract #1458. [5] Brearley A. J. and Hutcheon I. D. (2000) *LPS XXXI,* Abstract #1407. [6] de Leuw S. et al. (2007) *Workshop on the Chronology of Meteorites and the Early Solar System*, Abstract #1374. [7] Hoppe P. et al. (2004) *LPS XXXV,* Abstract #1313. [8] Brearley A. J. and Hutcheon I. D. (2002) *Meteorit. Planet. Sci* 37, A23.