MANGANESE-RICH ALTERATION PHASES IN CM CHONDRITES OF DIFFERENT PETROGRAPHIC SUBTYPES: IMPLICATIONS FOR THE TIMING OF AQUEOUS ALTERATION.
Simone de Leuw[1], Alan E. Rubin[2] and John T. Wasson[1,2], [1]Department of Earth and Space Sciences, University of California, Los Angeles, CA 90095-1567, USA, [2]Institute of Geophysics and Planetary Physics, University of California, Los Angeles, CA 90095-1567, USA (sdeleuw@ucla.edu).

We have studied several CM chondrites of different petrographic subtypes by SEM and electron-probe in order to identify manganese-rich alteration phases (silicates as well as carbonates) that are suitable for studying the Mn-Cr systematics on the CAMECA ims 1270 ion microprobe at UCLA.

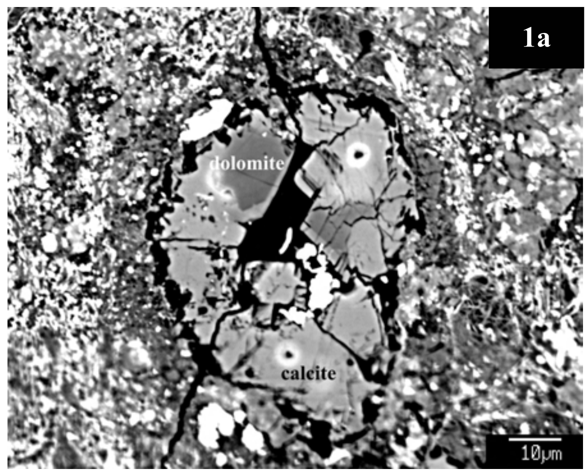
Introduction: A variety of nebular and parent-body processes is recorded in carbonaceous chondrites, especially in CM chondrites. The most important process that affected CM chondrites is aqueous alteration and this resulted in the formation of secondary mineral phases such as carbonates, phyllosilicates, sulfides, sulfates, oxides, and hydroxides [1,2]. Most susceptible to aqueous alteration are metallic Fe-Ni, troilite, and chondrule glass, whereas olivine and low-Ca pyroxene are much more resistant.

Little is known about the timescale and location of these alteration processes. Although most researchers attribute alteration to asteroidal settings [1,3,4], a minority believes that alteration occurred in the solar nebula [5] or in small precursor planetesimals prior to the formation of the CM asteroid [6].

Even if pre-accretionary aqueous alteration played an important role in CM chondrites, it seems likely that these effects were overprinted by alteration processes on the CM parent-body. But there is increasing evidence of a wide range of degrees of CM aqueous alteration. This study will help resolve the differences in the timing of these alteration processes.

Preliminary results: In contrast to similar studies, we use the new alteration scheme for CM chondrites proposed by Rubin et al. [4]. This new alteration sequence correlates with all of the major mineralogic and textural characteristics that change with progressive alteration. Rubin et al. [4] assigned petrologic subtypes ranging from 2.6 for the least-altered samples to 2.0 for the most highly altered CM chondrites. The main criterion for the classification into the different subtypes is the total abundance of metallic Fe-Ni, but several other characteristics also show systematic changes.

For this study, we examined several CM chondrites of different petrographic subtypes (ranging from subtype 2.0 to 2.5) by SEM (EDX element maps) and electron-probe (wavelength-dispersive element maps and quantitative analyses). So far we have examined LAP 02277 (CM2.0), QUE 93005 (CM2.1), Cold Bokkeveld (CM2.2), Murray (CM2.4/2.5), and Murchison (CM2.5). We found several Mn-rich carbonates in QUE 93005 and LAP 02277 as well as Mn-bearing silicates in Murchison. The carbonates are randomly distributed in the thin sections of QUE 93005 and LAP 02277 and they occur in two morphologies: single crystals and irregularly shaped aggregates. The abundance of these secondary carbonates in the two thin sections is relatively high (about 2-3 vol.%).



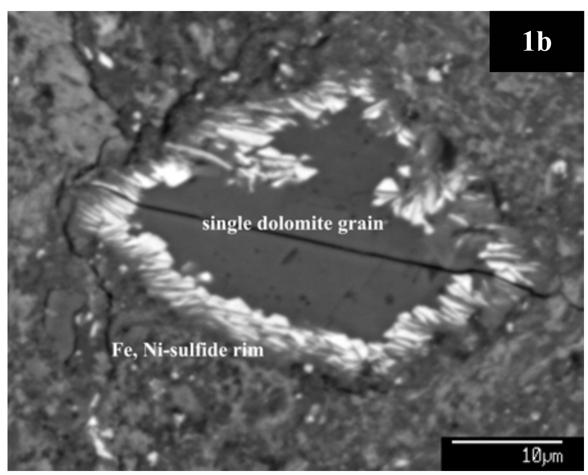


Figure 1: Backscattered images for Ca-carbonate and dolomite grains in QUE 93005. (a) The dolomite grain occurs as a single crystal within a larger calcite grain. (b) Single dolomite grain (~ 30 μm) surrounded by Fe, Ni-sulfide.

QUE 93005 seems to be the most promising sample for Mn-Cr systematics based on the high abundance of large manganese-bearing alteration phases; we conducted electron-probe measurements on more than 20 carbonate phases. The measurements showed that the alteration phases are either calcite and/or aragonite ($CaCO_3$) or dolomite ($CaMg(CO_3)_2$) (Figs. 1a and b).

In general, dolomites are characterized by higher Mn contents than calcites/aragonites (see Table 1). Manganese in dolomites ranges from 1.8 to 4.5 wt.% with an average content of about 3.4 wt.%, whereas in Ca-carbonates the Mn content ranges from 0.05 to 0.86 wt.% with an average of 0.19 wt.%. A prominent feature is that most dolomites occur as single crystals within larger calcite crystals (Fig. 1a); isolated dolomite crystals (Fig. 1b) are rare in QUE 93005. Dolomite grains are smaller than calcite grains with sizes ranging between 10-30 µm, compared to 50-100 µm for the Ca-carbonates.

Conclusions and future work: We will examine the timing of carbonate formation in QUE 93005 by using the UCLA CAMECA ims 1270 ion microprobe to measure Mn and Cr concentrations and Cr isotopic compositions. We will continue to examine additional CM chondrites of different petrographic subtypes to search for Mn-rich phases.

Previous work by Brearley et al. [7-8] and Endress et al [9] has shown that the most altered samples have the lowest $(^{53}Mn/^{55}Mn)_0$ ratios. Their initial $^{53}Mn/^{55}Mn$ ratios vary from $(1.3 \pm 0.6) \times 10^{-5}$ for CM2 Y791198 and $(5.0 \pm 1.5) \times 10^{-6}$ for CM2 ALH84034 to 2×10^{-6} for CI1 Ivuna.

The main purpose of this study is to examine the Mn-Cr systematics of CM chondrites of different petrographic subtypes, ranging from type 2.0 to 2.6. One possibility is that different initial $^{53}Mn/^{55}Mn$ ratios in alteration phases might be present within the same meteorite, implying that alteration processes occurred over a Ma time scale. Another goal is to resolve aqueous alteration processes among differrent subtypes; one would expect that the most recent alteration events occurred in the most altered CM chondrites.

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] McSween H. Y. (1987) *GCA, 51*, 2469-2477. [4] Rubin A. E. et al. (2007), *GCA*, submitted. [5] Ciesla F. J. et al. (2003), *Science, 299*, 549-552. [6] Bischoff A. (1998), *Met. & Planet. Sci., 33*, 1113-1122. [7] Brearley A. J. and Hutcheon I. D. (2000), *LPS XXXI*, Abstract #1407. [8] Brearley A. J. et al. (2001), *LPS XXXII*, Abstract #1458. [9] Endress M. et al. (1994), *Meteoritics, 29*, 463.

Table 1: Electron microprobe data (wt.%) for selected carbonate phases in CM QUE 93005.

	dolomite	**dolomite**	**dolomite**	**dolomite**	**Ca-carbonate**	**Ca-carbonate**	**Ca-carbonate**	**Ca-carbonate**
FeO	6.4	7.1	6.9	4.9	0.70	0.18	0.27	0.17
MnO	3.6	3.5	4.0	4.5	0.86	0.05	0.09	0.20
MgO	10.5	10.8	10.2	10.3	0.33	<0.04	0.20	0.04
CaO	30.1	29.3	29.3	30.8	57.3	55.9	55.6	56.9
SrO	0.43	0.59	0.77	<0.04	0.66	1.4	0.78	0.99
NiO	<0.04	<0.04	0.09	0.05	0.04	0.16	<0.04	0.09
Cr_2O_3	<0.04	<0.04	0.20	0.19	0.12	<0.04	<0.04	<0.04
CO_2	49.0	48.72	48.6	49.3	39.9	42.3	43.1	41.7
Total	100.0	100.0	100.1	100.0	99.9	100.0	100.1	100.1