

IN-SITU C AND O ISOTOPE SYSTEMATICS AND ^{53}Mn - ^{53}Cr AGE DATING OF CALCITE IN CM CHONDRITES. M. Telus¹, C. M. O'D. Alexander², J. Wang² and K. Nagashima³ ¹Earth and Planetary Sciences, University of California Santa Cruz, Santa Cruz, CA 95064 (mtelus@ucsc.edu), ²DTM, Carnegie Institution of Washington, Washington, D.C. 20015, ³HIGP, University of Hawai'i at Mānoa, Honolulu, HI 96822.

Introduction: CM chondrites exhibit a wide range in degrees of aqueous alteration, providing a means to understand the role of fluids in the formation and the early evolution of planetesimals. We recently reported on *in situ* C and O isotope analyses of calcite and dolomite and O isotope analyses of magnetite from the highly altered CM chondrites, ALH 83100, ALH 84034, and MET 01070 [1]. The C and O isotope composition of carbonates in these three samples span the full range of CM bulk values and are consistent with models of calcite precipitation from a fluid in equilibrium with a gas mixture of CO or CH₄ and CO₂ [2]. The petrology is consistent with multiple generations of calcite growth. Here, we present new *in-situ* C and O isotope results for calcite and O isotope analyses of magnetite from CM1/2 chondrite MIL 13005. We also present Mn-Cr systematics for calcite in MIL 13005 and the CM1 MET 01070.

Samples: We have analyzed calcite and magnetite in a thin section of the CM1/2 MIL 13005 whose weathering grade is Ae [3]. Otherwise, very little work has been done on this meteorite. We decided to study it because calcite and magnetite grains are relatively abundant and potentially provide the opportunity to constrain the temperature of calcite formation. We also analyzed MET 01070, a highly altered CM that has been studied more extensively. Previous work on this sample includes *in situ* C and O [1], bulk D/H and bulk carbonate C and O isotope compositions [4, 5], and bulk chemical and petrographic analyses [6]. Grains were identified and characterized prior to SIMS analyses using a variety of techniques, including SEM EDS and cathodoluminescence imaging and Raman spectroscopy.

C and O isotope analyses: Our C and O analyses were carried out at two facilities: 1) NanoSIMS 50L at DTM, Carnegie and 2) the Cameca ims 1280 at the University of Hawaii at Manoa. With the NanoSIMS, analyses were carried out with a Cs⁺ primary beam of ~150 pA. Negative ions of ¹²C⁻, ¹³C⁻, ¹⁷O⁻, and ¹⁸O⁻ were measured with electron multipliers (EMs), while ¹⁶O⁻ was measured with a Faraday cup (FC). See [1] for more details of our NanoSIMS technique. With the Cameca 1280, we measured O and C isotopes separately. For O, we used the Cs beam with a current of ~15pA rastered over 2 μm × 2 μm region. ¹⁶O was measured on the FC, ¹⁷O on the axial EM and ¹⁸O on the mini-EM. We also monitored ¹⁶OH to correct for possible contribution from OH. For C isotope analyses, we used the Cs beam with a current of ~10 pA rastered over 2 μm × 2 μm region. ¹²C and ¹³C were measured on mini-EMs and we

also monitored ¹²CH. Analyses of areas with cracks, etc., were discarded. Sample-standard bracketing with terrestrial carbonate and magnetite standards was used to correct for drift in the EMs and instrumental mass fractionation (IMF). The uncertainties in the isotope ratios include errors from the IMF corrections and counting statistics. There were no systematic differences between the NanoSIMS and Cameca-1280 data.

The C and O isotope data for all the analyses are shown in Figure 1. The reported uncertainties are 2σ. Our *preliminary* results for MIL 13005 (yellow symbols) are consistent with previous results, showing a wide range in C and O isotope compositions and they overlap significantly, despite their different petrologic types. The Δ¹⁷O values for magnetite and calcite in MIL 13005 indicate low-temperature disequilibrium conditions (Fig. 2).

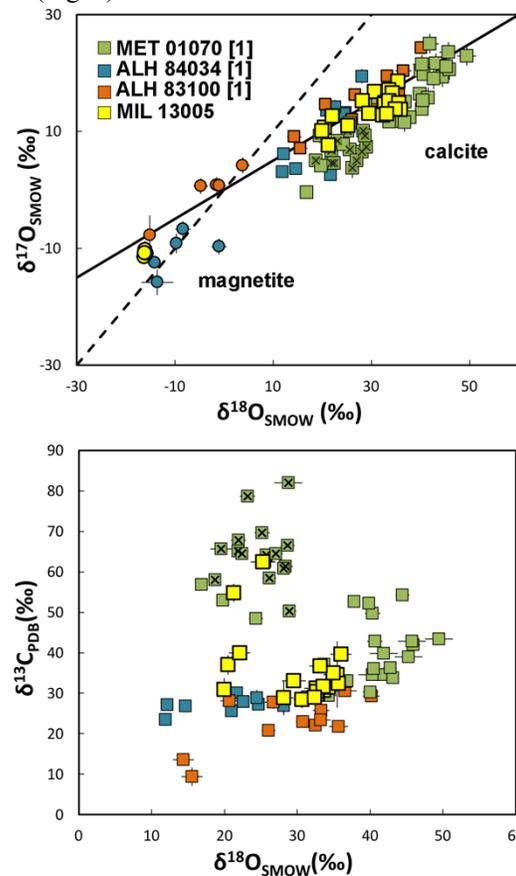


Figure 1. Three O-isotope plot (top) and $\delta^{13}\text{C}$ vs. $\delta^{18}\text{O}$ for individual calcite grains from MET 01070 (green), ALH 84034 (red), and MIL 13005 (yellow).

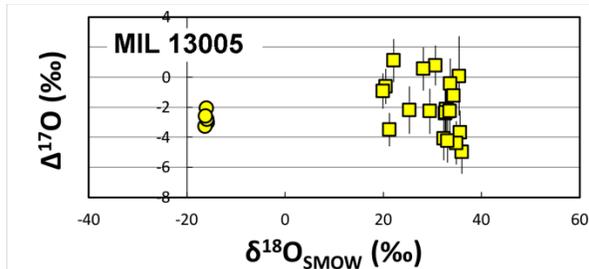


Figure 2. The $\Delta^{17}\text{O}$ values for calcite (squares) and magnetite (circles) from MIL 13005.

Mn-Cr isotope analyses: After the C and O isotope analyses, we analyzed the Mn-Cr systematics of calcite in the CM1/2 MIL 13005 and CM1 MET01070. The Mn-Cr results for MET 01070 were reported previously [7]. These analyses were carried out at UH Manoa using the Cameca ims 1280. Here, we used the Hyperion O beam at 500 pA focused to ~ 10 μm . We measured ^{53}Cr on the axial EM, ^{52}Cr on the mini-EM and switched the magnetic field to measure ^{55}Mn on the mono-EM. We determined the relative sensitivity factor using a matrix-matched calcite standard from [8].

We measured 7 calcite grains in MET 01070 and 6 grains in MIL 13005. The grains in both meteorites exhibit clear correlations between excess ^{53}Cr and the Mn/Cr ratio (Fig. 3). The inferred initial $^{53}\text{Mn}/^{55}\text{Mn}$ ratio of $(4.2 \pm 0.8) \times 10^{-6}$ for MET 01070 is consistent with previous results from [7]. The inferred initial for MIL 13005, $(3.7 \pm 0.7) \times 10^{-6}$ (2σ), has an MSWD of 4.3 due to the data point with the very high Mn/Cr ratio. Without this point, the initial is $(4.6 \pm 1.2) \times 10^{-6}$ (2σ) with an MSWD of 1.9, but there is currently no reason to remove this point. The initial ratios are consistent with calcite formation around $3.5^{+0.9}_{-1.1}$ Ma after CAIs for MIL 13005 and $2.8^{+0.9}_{-1.1}$ Ma after CAIs for MET 01070, assuming an initial Solar System value of 7.1×10^{-6} inferred from the D'Orbigny Mn-Cr initial [8]. Overall, these results are consistent with previous Mn-Cr analyses of carbonates from CM chondrites [e.g., 7, 9, 10].

Conclusions: We present *preliminary* SIMS C and O isotope data for calcite, O isotope data for magnetite in MIL 13005 and *preliminary* results for Mn-Cr systematics of calcite in MIL 13005 and MET 01070. The C and O isotope data indicate that the Mn-rich calcite used to constrain the Mn-Cr ages are those that plot in the group with high $\delta^{13}\text{C}$ values (>45 ‰, Fig. 1). Petrographic evidence from [1] suggests that these carbonate grains formed after those with low $\delta^{13}\text{C}$ values, indicating that the Mn-Cr calcite ages may be recording relatively late-stage carbonate formation in the parent body. More detailed petrologic analyses are necessary to fully interpret these geochemical signatures.

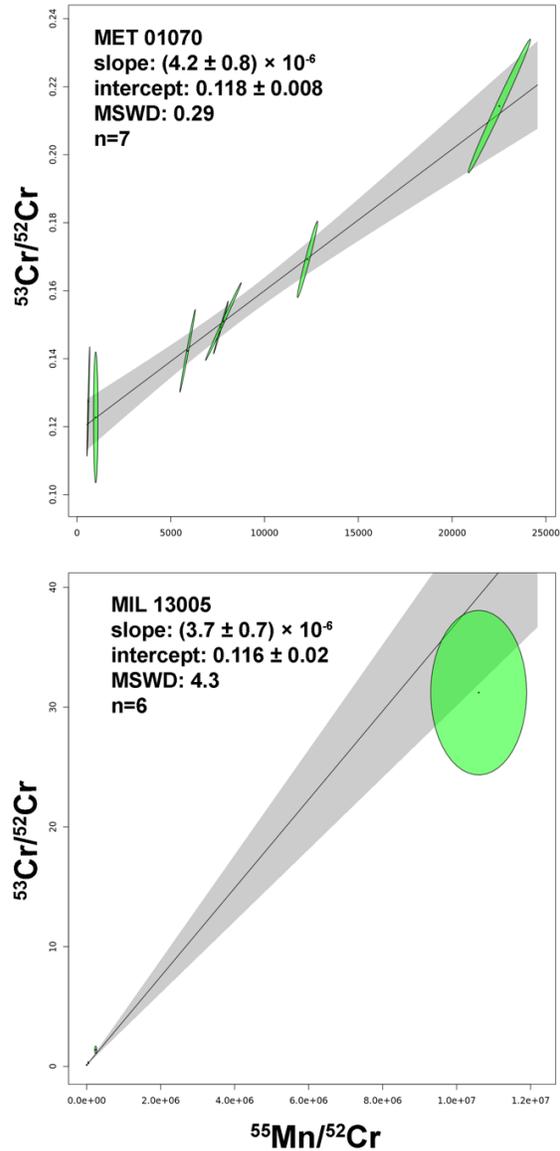


Figure 3. $^{53}\text{Cr}/^{52}\text{Cr}$ vs. $^{55}\text{Mn}/^{52}\text{Cr}$ for calcite grains from MET 01070 (top) and MIL 13005 (bottom).

Acknowledgments: Samples were provided by ANSMET. NASA grant 80NSSC18K0498 to MT.

References: [1] Telus M. et al., 2019. *Geochim. Cosmochim. Acta*, 260: 275-291. [2] Alexander C. M. O'D. et al., 2015. *Meteorit. Planet. Sci.*, 50: 810-833. [3] <https://www.lpi.usra.edu/meteor/metbull.php> [4] Alexander C. M. O'D. et al. 2013. *Geochim. Cosmochim. Acta*, 123, 244-260. [5] Alexander C. M. O'D. 2015. *Meteorit. Planet. Sci.*, 50: 810-833. [6] Rubin A. E., et al. (2007) *Geochim. Cosmochim. Acta* **71**, 2361-2382. [7] Donohue P. H. (2019) *LPSC L Abstract* #1949. [8] Donohue P. H. (2019) *LPSC L Abstract* #1959. [9] Fujiya W. et al. (2012) *Nat. Comm.* **3**, 627. [10] Jilly C. E. et al. (2014) *Meteorit. Planet. Sci.* **49**, 2104-2117.