

IN SITU CARBON AND OXYGEN ISOTOPE ANALYSES OF CALCITE IN CM1 CHONDRITES

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Introduction: CM chondrites exhibit a wide range in degrees of aqueous alteration. They provide constraints on the role of fluids in the formation and evolution of early planetesimals. The bulk $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ values of CM carbonates range from 25-75‰ and 15-35‰, respectively [1], consistent with precipitation from a fluid dominated by H_2O and CO and/or CH_4 at temperatures between 0 and 130°C. Isotopic heterogeneity within individual chondrites has been reported [1], indicating that the bulk analyses do not tell the whole story. The internal heterogeneity of carbonates has been attributed to terrestrial weathering, variations in carbonate abundances between bulk sample aliquots, different generations of carbonate precipitation and/or brecciation [e.g., 1-3]. In situ analyses can provide clues to the causes of the variations in bulk analyses and provide insight into the evolution of aqueous fluids in chondrite parent bodies [e.g., 2-3]. Here, we present preliminary results from in situ C and O isotope analyses of calcite from CM1 chondrites.

Samples: Based on elemental maps and BSE imaging, our ALH 83100 (CM 1.1) section is composed of one lithology, and contains abundant dolomite and calcite grains $\leq 100 \mu\text{m}$ across that are mostly inclusion-free. Our MET01070 (CM 1.2) section has two lithologies. Both lithologies contain abundant calcite, but no obvious dolomite. There are inclusion-free calcite grains in MET 01070, but most are mottled in texture.

Isotope Analyses: In situ C and O isotope analyses of carbonates were carried out using Carnegie's NanoSIMS 50L with a Cs^+ primary beam of ~ 70 -100 pA. Negative ions of $^{12}\text{C}^-$, $^{13}\text{C}^-$, $^{17}\text{O}^-$, and $^{18}\text{O}^-$ were measured with electron multipliers (EMs), while $^{16}\text{O}^-$ was measured with a Faraday cup. A mass resolving power of 9000-10,000 was used to separate interferences from the peaks of interest (e.g., $^{16}\text{OH}^-$ from $^{17}\text{O}^-$). The electron gun was used for charge compensation. The primary beam was rastered over $5 \times 5 \mu\text{m}$ for presputter, then reduced to $3 \times 3 \mu\text{m}$ for the analysis. Real-time images were checked before and after each analysis to ensure that cracks or multiple phases were not included in the analyzed areas. We analyzed 10 calcite grains from ALH 83100. Three grains were large enough to analyzed multiple times to evaluate intragrain isotopic variations. Several dolomite grains were also analyzed, but are not discussed here. We also analyzed 36 calcite grains from both lithologies in MET 01070. Sample-standard bracketing with terrestrial carbonate standards was used to monitor drift in the EMs and instrumental mass fractionation (IMF). Uncertainties on the isotope ratios include errors propagated from the IMF corrections.

Results: There is a positive correlation between the $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ compositions of calcite from ALH 83100 (Fig. 1), with ranges of 5-30‰ and 10-30‰, respectively. The average $\Delta^{17}\text{O}$ for ALH 83100 is $-1.4 \pm 1.9\text{‰}$ (2SD). For MET 01070, the calcite compositions are bimodal: one population has high $\delta^{13}\text{C}$ (60-70‰) and low $\delta^{18}\text{O}$ (20-30‰), and the other has low $\delta^{13}\text{C}$ (30-40‰) and high $\delta^{18}\text{O}$ (40-50‰). On average, the O-isotopic compositions between the two lithologies in MET 01070 are slightly different but the number of analyses is small. The average $\Delta^{17}\text{O}$ for MET 01070 is $-6.1 \pm 3.7\text{‰}$ (2SD). Variations within single calcite grains were not observed. The bulk compositions for these meteorites are not entirely consistent with the in situ analyses, as also reported by [3], but this may be due to a sampling bias for SIMS analyses.

Discussion: A bimodal distribution of $\delta^{13}\text{C}$ in calcite, have been attributed to calcite precipitation in fluid with changing concentration of CO and/or CH_4 [1]. However, if calcite precipitation was from a single fluid, a more gradual change in $\delta^{13}\text{C}$ would be expected. Detailed petrological analyses and additional SIMS analyses are necessary to further evaluate the possible sources for these large variations in the C and O isotopic compositions of calcite on such small spatial scales.

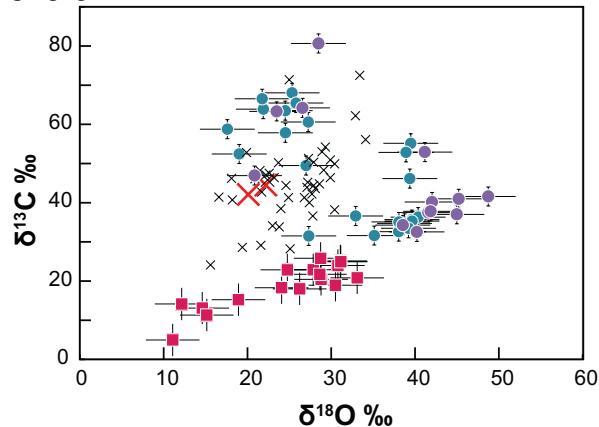


Figure 1. The $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ composition of calcite from ALH83100 (pink squares) and MET01070 (blue and purple circles are for the different lithogies). Bulk CM data (crosses) are from [1], and the red crosses are for the meteorites analyzed in this study.

References: [1] Alexander C. M. O'D. 2015. Meteoritics & Planetary Science 50: 810-833. [2] Lee M. R. et al. 2013. Geochimica et Cosmochimica Acta. 121: 452-466. [3] Tyra M. A. et al. 2015. Geochimica et Cosmochimica Acta. 175: 195-207.

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