MEASUREMENTS OF CARBON AND OXYGEN ISOTOPES IN ALLAN HILLS 84034 CARBONATES

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Introduction: The CM chondrites represent a wide range of fluid-rock alteration products spanning weakly to highly altered samples. Stable isotope measurements of carbonate minerals which precipitated from aqueous solution can be used to constrain the temperatures, fluid sources, and chemical reactions proceeding in these varied samples. Lightly altered samples contain carbonate populations consisting mostly of calcite, and more extensively altered samples contain complex assemblages of dolomite in addition to calcite. The complex petrology and small size of carbonate grains require in-situ study. While in-situ stable isotope measurements by ion probe of calcites are reliable, dolomite grains in highly-altered CM chondrites contain 3-12 mol% Fe, presenting an analytical challenge to accurately quantify the matrix effect during the analysis. Here we present C and O stable isotopic measurements of calcites and dolomites in the highly altered CM chondrite Allan Hills 84034, performed with matrix-matched standards.

Methods: δ¹⁸O and Δ¹⁷O. We used a 700 pA Cs+ beam in the UCLA ims 1290 ion microprobe to analyze δ¹⁸O and Δ¹⁷O in ~6 μm diameter spots at mass resolution of 7000.

δ¹³C. Analyses of δ¹³C were also performed with the UCLA ims 1290 with a 1 nA Cs+ beam, corresponding to a spot size of ~10 μm, at mass resolution of 5500.

Correction for the matrix effect. EPMA data collected at UNM and SEM/EDS data collected at UCLA, as well as previously-described matrix-matched dolomite standards [1] were used to correct for the matrix effect caused by variations in Fe content in the target carbonates. Measurements of δ¹³C, δ¹⁷O, and δ¹⁸O were all corrected using methods outlined in [2,3].

Results: Calcite in ALH 84034 is similar in oxygen isotopic composition to Murchison calcites (black ’x’ symbols in Figure 1), a more weakly altered meteorite. The dolomites fall along an approximately mass-dependent line which passes slightly below the bulk O isotopic value for the paired sample Allan Hills 83100. The calcite and dolomite are not in isotopic equilibrium, as the calcite grains have higher Δ¹⁷O values and appear to define a mixing line of significantly steeper slope than do the dolomites. The correction for the matrix effect is critical to the interpretation of these carbonate data; reducing the data using only a calcite or a single dolomite standard would cause dolomite analyses to appear collinear with the calcite which could create a misleading steep slope for the calcite-dolomite assemblage. Values of δ¹⁸O and δ¹³C both decrease as the iron content of the dolomite increases, suggesting the coevolution of water chemistry and carbon isotopic composition. The δ¹³C of the carbonates ranges from +20 to +80 ‰.

Figure 1. Oxygen isotope compositions of ALH 84034 carbonates. Filled and open circles represent analyses of calcite and dolomite, respectively. Error bars represent 2σ. Small x symbols represent Murchison calcites [4,5]. The star symbol represents the bulk O isotopic value of ALH 83100 [6] which is paired with ALH 84034. The CCAM (Carbonaceous Chondrite Anhydrous Mineral) and Y&R (Young and Russell 99) ’slope-1’ lines are plotted in black as a reference. Blue dashed line represents mass-dependent fractionation from the bulk meteorite oxygen isotopic composition.