Introduction: During early solar system history, some chondritic materials were subject varying degrees of fluid alteration that changed once primitive olivine/pyroxene mineralogies into a varied host of phyllosilicates, carbonates, sulfates, and other phases associated with alteration. Fluid alteration of chondritic materials is one of the earliest known geologic processes, thought to have occurred in the first 20-50 My after the formation of the solar system [1]. While some work has been done to understand the physio-chemical properties of these early alteration fluids [2][3], they remain poorly constrained. Understanding these properties is critical for tracing the evolution of chondritic materials and their parent bodies.

Methods:

Raman Spectroscopy. We used confocal micro-Raman spectroscopy to identify and gather spectral parameters from organic materials and carbonate phases contained within each chondrite thin-section sample. We used a WiTEC alpha300R confocal Raman imaging system coupled with a 532 nm (Nd:YAG) green laser. We collected three intensity distribution maps from seven samples, for each pixel has an associated Raman spectrum. Each of these images has dimensions 100 μm x 100 μm and is composed of 22,500 pixels. A laser spot size of ~0.8 μm results from using a 50x (0.80 NA) objective lens during imaging. We used a laser power of 1.3 mW during our measurements to avoid thermal oxidation of the samples. Initially, map spectra represent a range of ~0-3500 cm$^{-1}$. We cropped these spectra to new dimensions of 1000-1200 cm$^{-1}$ and 900-2000 cm$^{-1}$ for carbonates and organic phases respectively. We then applied a linear background subtraction to each spectrum. A second-order Savitzky-Golay smoothing filter was then applied to the raw spectra. We then fit each raw spectrum with a Lorentzian band (carbonates) or two Lorentzian bands (organics) to extract a fit spectrum and spectral parameters. We discard all fit spectra with R$^2 < 0.95$.

Carbonate Clumped Isotope Geochemistry. Clumped isotope analysis is conducted on CO$_2$ gas released during the dissolution of carbonate phases within a given sample. Approximately 10 mg of carbonate are required to conduct a measurement. As such, depending on the carbonate abundance in a given sample, 200-400 mg of powdered chondrite are loaded into a reaction vessel with 10 ml of anhydrous phosphoric acid. The dissolution reaction occurred at a temperature of ~90 °C. CO$_2$ samples were transferred to a Thermo Scientific MAT 253 Plus gas sourced isotope ratio mass spectrometer. The MAT 253 Plus has been configured to simultaneously measure the CO$_2$ isotopologues of mass 44, 45, 46, 47, 48, and 49 amu. The ratio of the observed voltages for masses 47 and 44 yields the quantity R$^{47}$, which is simply the ratio of $^{47}$CO$_2$ to $^{44}$CO$_2$. The quantity used to report the abundance of mass 47 isotopologues is $\Delta^{47}$, which is defined as the difference per mil between the measured R$^{47}$ value and that of the stochastic or random distribution. $\Delta^{47}$ has been shown to be dependent on the temperature of formation of the carbonate mineral(s) [5].

Samples: LAP 03865, LON 94102, MET 01077, ALH 84042, ALH 85013, MIL 07700 and Murray.

Results: We report an initial carbonate precipitation temperature of 10°C for the chondrite Murray. Using Raman spectral parameters collected from intensity distribution maps we are able to estimate the peak metamorphic temperature (PMT) experienced by each individual chondrite sample. We use the spectral curvature thermometer of [4] to generate PMT values. We report the PMTs for each chondrite sample: 223°C (Murray), 253°C (ALH 84042), 234°C (ALH 85013), 224°C (LAP 03865), 267°C (LON 94102), 355°C (MET 01077).

Discussion: Both carbonate clumped isotope measurements and Raman spectral parameters suggest that CM chondrites were altered under low temperature conditions. However there is disagreement between the temperatures extracted from each method. Our initial carbonate clumped isotope analysis has yielded a temperature of ~10°C for bulk carbonate precipitation in the chondrite Murray. In contrast, Raman spectroscopic measurements suggest that the PMT of the chondrites analyzed is in the range of 223-355°C. This disparity may suggests that bulk carbonate formation occurred after the chondrite parent body had undergone significant cooling from its thermal maximum.