Probing Aqueous Alteration of Carbonaceous Chondrites via Carbonate Clumped Isotope and Raman Carbon Thermometry

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Rationale

- Assess the conditions of carbonaceous chondrite parent body alteration processes.
- Examine the alteration history of carbonaceous chondrites and their parent body.

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- Develop a methodology for understanding parent body processes via the study of returned samples from Bennu and Ryugu.

Background

- Aqueous alteration of carbonaceous chondrites is one of the earliest geologic processes.
- Carbonaceous chondrites contain organic carbon and carbonate minerals precipitated from alteration fluids.
- The structural properties of organic carbon and the isotopic composition of carbonates can help us better understand the thermal conditions of alteration.

Raman Spectroscopy

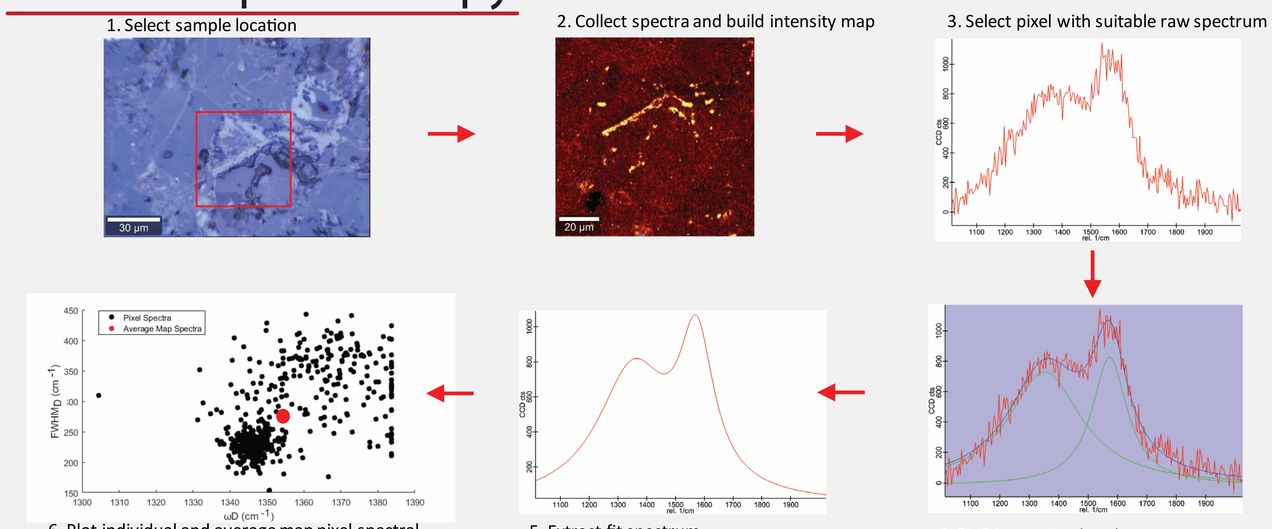

Figure 1. Workflow for Raman spectroscopic analysis.

Carbonate Clumped Isotopes

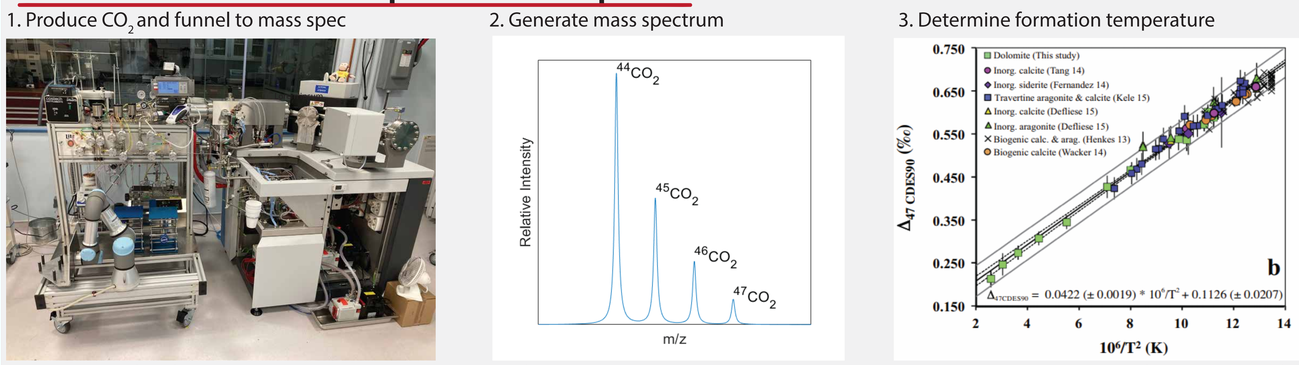

Figure 1. Workflow for Carbonate Clumped Isotope Analysis. (left-inset) Sample is digested in phosphoric acid at 90 °C. Generated CO_2 is purified via a series of cryo traps and funneled to a MAT 253 plus GS-IRMS (center-inset) Sample gas generates a mass spectrum for analysis (right-inset) Temperture of carbonate formation can be determined via Δ_{47}, which is defined as the difference per mil between the measured R_{47} value and that of the stochastic distriubtion (Bonifacie et al 2017)

Results

- Peak metamorphic temperatures estimated by Raman spectroscopic measurements are mainly in the range of 223-267 °C .
- One outlier to this temperature estimate range is MET 01077, which shows a PMT of 355 °C. This is possibly a product of MET 01077's status as a highly weathered meteorite find.
- Peak metamorphic temperature estimates calculated using the spectral curvature thermometer of Young et al. (in-review)
- Initial carbonate clumped isotope analysis for the CM2 chondrite Murray suggests a carbonate formation temperature of 10 °C
- This reported temperature greatly contrasts with the reported value of 30°C for Murray by Eiler and Guo (2007)
- Disparity between carbonate formation temperature and Raman PMT may suggest that bulk carbonate formation occurred after the chondrite parent body had undergone significant cooling from its thermalmaximum.

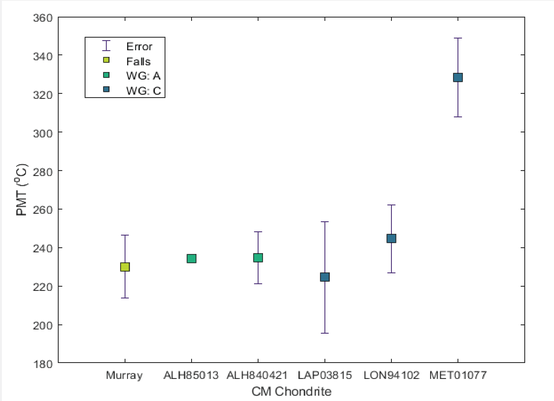

Figure 3. Chondrite peak metamorphic temperature plot. Temperatures gathered via Raman spectroscopic analyses. Sample data points colored by fall/find status: Yellow - Falls, Green - Finds with weathering grade A, and Blue - Finds with weathering grade C.

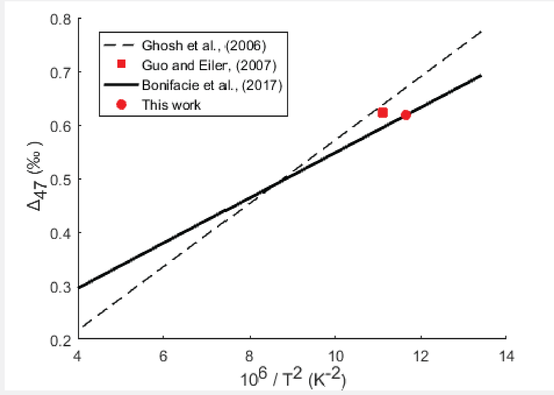

Figure 3. Δ_{47} vs $1/T^2$ plot. Data points shown are for the CM2 chondrite Murray; The Red square show the reported value of Guo and Eiler (2007) using the calibrated thermomter of Ghosh et al (2006). The red circle show the reported value of this work in tandem with the universal calibration of Bonifacie et al. (2017)

Acknowledgements

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