Determination of Petrologic Subtypes of CV3 Chondrites By Raman Spectroscopy and Chondritic Olivine Chromium Concentrations

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Introduction

- CV chondrites are among the most primitive meteorites in the solar system (petrologic type 3) [1], contain organic matter and are not aqueously altered [2].
- They are more pristine than CI and CM chondrites which contain complex organic matter and are aqueously altered [3].
- The current classification scheme for petrologic types (1-6) is a relative scale and little calculation is involved [4].
- Knowing the petrologic subtype (e.g. 3.x) of a primitive meteorite can give us a snapshot of what the solar system contained right when it first condensed.
- Measuring degree of thermal alteration of carbon in the matrix, and measuring trace elemental concentrations in chondritic silicates are two methods of measuring degrees of thermal metamorphism [5, 6].
- Unlike CO and CK, little work have been done on subtyping CV chondrites.
- We want to understand subtle differences in evolution amongst CV chondrites that record the earliest stages of the solar system by looking at the geochemistry of major phases.
- This study is the first time both of these methods have been tested on the same suite of 10 NWA and 11 Antarctic CV chondrite samples.

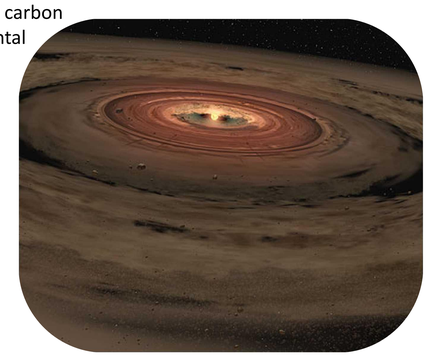

Figure 1: Concept image of a proto-planetary disk swirling around a newly formed star (NASA) [7].

Samples

- A suite of 21 CV group carbonaceous chondrites were used: 10 North West Africa (NWA) samples from the Royal Ontario Museum (ROM) in Toronto Canada and 11 Antarctic samples from the National Institute of Polar Research (NIPR) in Tokyo, Japan.

Figure 2: Image of one of the samples LM58160 (ROM) (left) which was analyzed using the two methods. The 7.3 cm sample is pending classification approval. The right image shows all 21 samples analyzed in this study. Left photo by Brian Boyle (ROM).

Methods

- A Horiba LabRAM ARAMIS micro-Raman spectrometer was used at the Royal Ontario Museum (Toronto, Canada) to measure the degree of alteration in carbonaceous matter in the matrix of all samples.
- A JEOL JXA8230 5-WDS Electron Probe Micro Analyzer (EPMA) located at the University of Toronto, Department of Earth Sciences (Toronto, Canada) was used to measure trace elemental concentrations in chondritic olivine.
- A Nu Wave UP-213 laser ablation microscope was also used in conjunction with the Thermo VG PQ ExCell Inductively Coupled Plasma Mass Spectrometer (LA-ICP-MS) at the University of Toronto to measure trace elemental concentrations in chondritic olivine to compare to the results of the EPMA.

Results (Raman)

- The relationship between FWHM-D and I_D/I_G is similar to that of [2] where FWHM-D is negatively correlated to I_D/I_G.
- The FWHM-D is linked to the degree of thermal alteration and thus Petrologic Type (PT).
- Allende plots closely to that of [2].

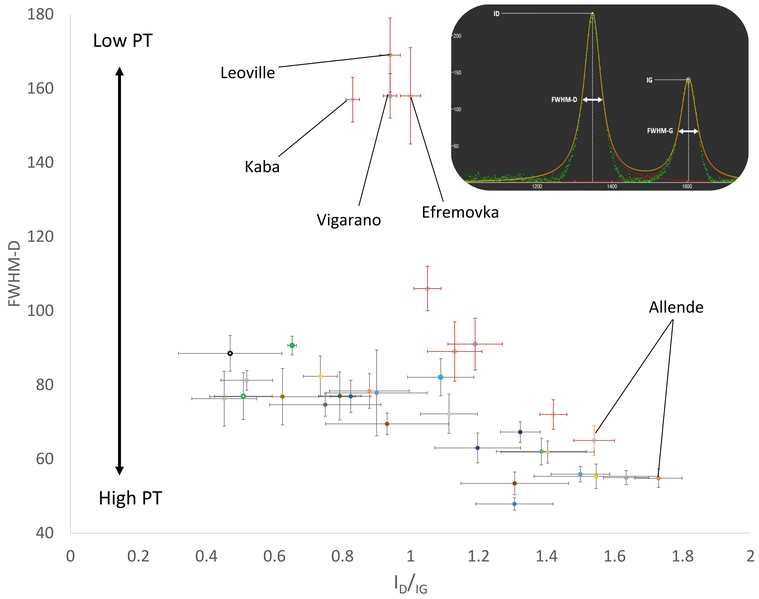

Figure 3: Relationship between FWHM-D and I_D/I_G of CV chondrites. Each plot represents the average value of one sample. Sample from previous studies [2] are marked with red error bars. Leoville, Kaba, Vigarano and EfremovkaInset all plot with relatively high FWHM-D reflecting a more primitive petrologic subtype. Inset of typical Raman spectra showing D and G bands.

Results (EPMA & LA-ICP-MS)

- No relationship to petrologic type can be seen from either EPMA nor LA-ICP-MS data for CV chondrites.
- Compared to previous studies [6], we find no correlation between petrological subtype and Cr concentration with either EPMA or LA-ICP-MS.
- Low Cr concentrations in CV chondrites prevents statistically viable analysis by EPMA.

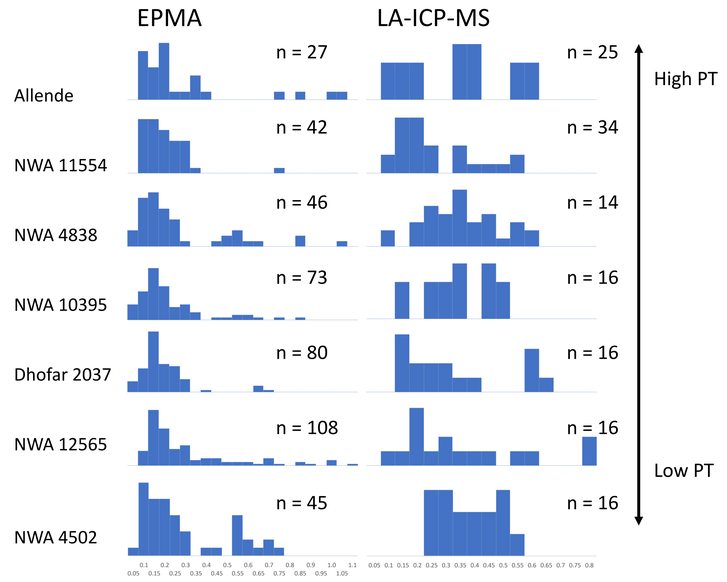

Figure 4: Histogram comparison between EPMA (left) and LA-ICP-MS (right) for Cr_2O_3. Histograms are stacked in the order of Petrologic Type (PT) from top (high PT) to bottom (low PT). Units are shown in mass %.

Conclusions

- Trace elemental concentrations show no clear trend for subtyping CV3's.
- The non-destructive usage of EPMA cannot be implemented for subtype classification of CV's.
- This is the first time LA-ICP-MS has been used to attempt a link between trace element concentration and petrologic type.
- Carbon in CV chondrites is far more susceptible to heat than chondritic olivine.
- Further subtype classification of CV3's is recommended using Raman spectroscopy on carbon phases.

About the Author

Sean is a young scientist who is aiming to pursue a career in meteoritics. He is interested in new methods on how to classify meteorites as well as the origin of organic matter in chondritic bodies. Sean likes to compete in lumberjack competitions in his spare time🪓.

Acknowledgments

Huge thanks to the technician Ian Nicklin at the Royal Ontario Museum. We appreciate the technical support from Yanan Liu for using the EPMA, Colin Bray and Mike Gorton for using the LA-ICP-MS at the University of Toronto, Department of Earth Sciences. We also acknowledge Dr. Akira Yamaguchi at NIPR for kindly loaning us the Japanese Antarctic samples for this study.

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