

**RARE EARTH ELEMENTS IN CV CARBONACEOUS CHONDRITE COMPONENTS.** E. J. Crapster-Pregont ([ellencp@ldeo.columbia.edu](mailto:ellencp@ldeo.columbia.edu))<sup>1,2,3</sup>, M. E. Gemma<sup>1,2,3</sup>, D. S. Ebel<sup>2,1,3</sup>, <sup>1</sup>Dept. of Earth and Environmental Science, Columbia University, New York, NY, <sup>2</sup>Dept. of Earth and Planetary Science, American Museum of Natural History (AMNH), New York, NY, 10024, USA. <sup>3</sup>Lamont-Doherty Earth Observatory (LDEO), Columbia University, Palisades, NY 10964.

**Introduction:** In any particular meteorite, the major element composition of the matrix is complementary to that of the chondrules [1]. Though the compositions of different objects (chondrules, CAIs, AOAs, and matrix) within each meteorite vary, the bulk meteorites all contain near-solar ratios of refractory elements [1]. The chemical compositions and abundances of inclusions within meteorites limit theories of chondrule formation and chondrite accretion, two major unexplained processes in cosmochemistry [2].

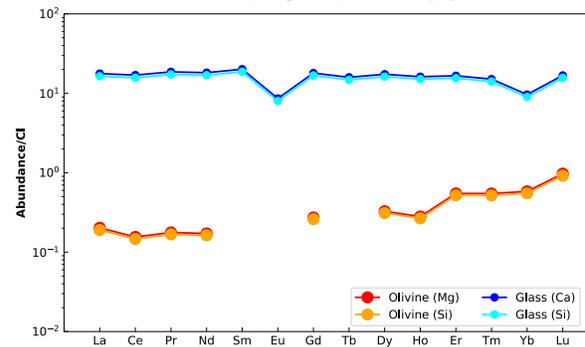
This study examines the chemical composition of Vigarano-type (CV) carbonaceous chondrites, which are known for their high abundance of matrix, CAIs, and AOAs, as well as their large chondrules [3]. We specifically address the distributions of rare earth elements (REE) among these components, and whether complementarity, and its constraints on pre-accretionary processes in chondrites, might hold for the REE. The major element bulk chemistry of meteorites indicates single source reservoirs [1, 4, 5], but how REE elements partition between chondrite components is less clear. Therefore, analysis of trace elemental abundances in chondrite components can provide critical evidence for theories of chondrule formation and chondrite accretion.

**Methods:** Eight polished thick sections of four different CV3 chondrites were analyzed (Allende Axtell, Vigarano, and Leoville). X-ray element maps were obtained for regions that included a variety of chondrite components (35 chondrule, 17 CAI, 7 AOA, and 16 matrix regions) using a Cameca SX100 electron probe microanalyzer (EPMA) with five wavelength dispersive spectrometers (WDS) at the AMNH.

Element maps were used to guide site selection for laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS), and to calibrate element concentrations for laser spots, using concentrations calculated from calibration curves determined using maps of EMPA standards, and to calculate the phase abundances of the inclusions of interest.

The CV sections were then taken to LDEO for LA-ICP-MS to obtain abundances of the REE among other trace and major elements. Both backgrounds and samples were measured in counts per second for 60s for a collection of elements. Laser spot sizes varied from 25 to 75  $\mu\text{m}$ , depending on the size of the target area. Using LasyBoy377 software, desired sections of output were chosen for analysis, using Ca, Mg, and Si

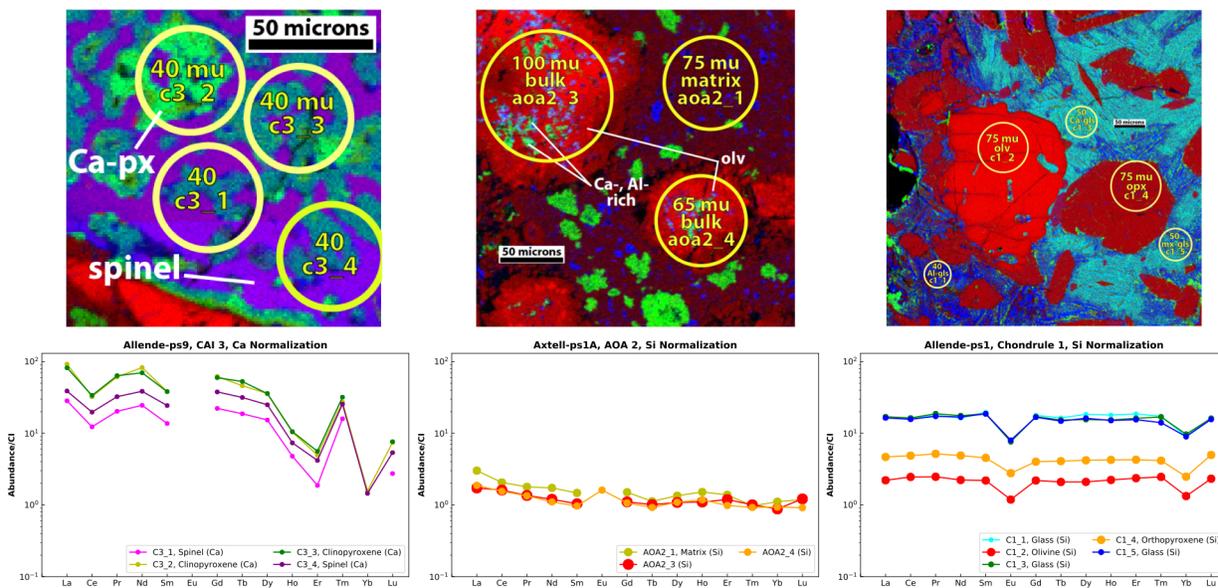
as calibration elements. The REE abundances were then normalized to CI (Orgueil) values [6].



**Figure 1:** CI-normalized REE abundance patterns comparing normalization element for a typical inclusion (Ca and Si for glass/clinopyroxene or Mg and Si for olivine/pyroxene). For a given chondrule, the resulting REE abundance pattern and relative enrichment is independent from the element used for calibration of the LA-ICP-MS data.

**Results/Discussion:** A total of 224 points in 59 inclusions and matrix (126 in chondrule minerals and glass including isolated olivine, 53 in CAIs, and 29 in AOAs) were analyzed. Two different calibration elements were compared for chondrule mesostasis (Ca and Si) and minerals (Mg and Si). Figure 1 demonstrates the consistency of using either of these pairs for calibrating the LA-ICP-MS data. This is helpful as major element presence, *i.e.* minerals, often varies requiring the use of one or the other calibration elements.

Figure 2 depicts representative inclusions, with LA-ICP-MS spot locations, and their corresponding analyses. Refractory inclusions in the CV chondrites of this study exhibit an overall enrichment in REE, with a variety of REE abundance patterns [e.g. 7]. A range of chondrule types was analyzed for REE in both the mesostasis and mineral phases. Generally, chondrule mesostasis is enriched  $\sim 10\times$  CI with a flat pattern, while chondrule minerals (olivine and pyroxene) have a sub-CI to CI abundance of REE. Some variation in the REE abundance patterns is observed in these chondrule components but the average pattern is flat favoring neither the light-REE nor the heavy-REE. These observations are independent of chondrule textural type, chemical type, and apparent abundance of glass or Mg-silicates.



**Figure 2:** Red-green-blue (Mg-Ca-Al) composite x-ray intensity maps (above) with olivine (olv), Ca-poor pyroxene (opx), Ca-rich pyroxene (cpx), matrix, and Ca-, Al-rich AOA material and glass (Ca-gls, Al-gls) indicated. LA-ICP-MS spot sizes are indicated in maps, and by point size in plots. CI-normalized REE abundance patterns are shown (below) for point analyses.

REE within the various chondrite components have been investigated previously in CV chondrites [e.g. AOA in 8; chondrules in 9]. As in other chondrite groups, the refractory inclusions in this study exhibit significant enrichment in REE compared to CI with a range of REE abundance patterns [e.g. 8, 10]. Jacquet et al. [9] observed a ~15x enrichment of REE in chondrule glass with chondrule minerals having an enrichment close to, or less than, CI. The CV chondrules of this study parallel the findings of [9], and those of [11] for ordinary chondrite chondrules. Further investigation of this CV dataset could reveal whether significant differences of REE abundances exist between the different types of CAIs or types of chondrules as implied by previous work [9, 11].

This study is part of a larger endeavor to understand the distribution of REE within chondrites. Work on CO chondrite components [12, 13] has revealed comparable distributions and further work is ongoing, on both the CV chondrites and CR chondrites.

At this stage, it is not clear why the distributions of REE are so consistent across many chondrite components. Further analyses are necessary to gain the statistical power to assess the true variance in REE abundances across all chondrite components, in order to assess the possibility that these components exhibit chemical complementarity in these elements.

What is clear from this study so far is that chondrule mesostasis and CAIs are strongly enriched in REE, while matrix analyses are uniformly flat at near-CI values. The CV chondrites in bulk are slightly enriched in refractory elements including REE, with slight bulk enrichment in light REE (Group II pattern,

[14]). How chondrules, matrix, and other components combine to result in flat or nearly flat bulk patterns remains mysterious.

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