COMBINED RAMAN AND EPMA X-RAY MAPPING OF CARBON PHASES IN CR CHONDRITES. P. J. Gasda¹, E. Hellebrand², and G. J. Taylor¹, ¹Hawai‘i Institute for Geophysics and Planetology, ²Dept. of Geology and Geophysics, both at University of Hawai‘i, Mānoa, 1680 East West Road, Honolulu, Hawai‘i 96822. gasda@hawaii.edu

Introduction: The purpose of our study is to understand the distribution of organic compounds in CR carbonaceous chondrites and determine if the distribution and morphology of the carbon phases changes with extent of aqueous alteration on the meteorite parent body. Our work [1] is designed to determine the petrographic relationships between primary and secondary minerals in CR chondrites and the organic compounds with the goal of improving our understanding the evolution of the organics in the Solar System.

Samples & Preparation: Antarctic meteorites GRO 95577 (CR1) and EET 92161 (CR2) provided by JSC Meteorite Curation Lab were dry-polished on one side. A third sample, QUE 99177 (CR3) was provided as a chunk. The CR3 sample is very friable and cannot be cut or polished. No sample was impregnated with epoxy, cut or polished with oil or water. The CR2 and CR1 samples were embedded in indium metal (Indium Corp, 5N) inside a copper jacket. CR3 sample dust particles were pressed into a clean gold foil mount (EPSL,5N, annealed). A graphite sample (Graphitek Corp, 5N) inside a copper jacket. CR3 sample dust particles were pressed into a clean gold foil mount (EPSL,5N, annealed). A graphite sample (Graphitek LLC, >99.9%) was used as an element standard and mounted unto a separate gold foil mount.

Indium and gold mounted meteorite samples, as well as the standards, were simultaneously coated with 25 nm of aluminum (Lesker, 4N) with a FTM-2000 thickness sensor in a Torr International Coater metal evaporation/coating chamber. Rather than using carbon coating, which could contaminate the sample and compromise future isotopic measurements of carbon, we used an Al coating. The Al coating is still conductive in the electron probe because the oxidation layer is on the surface of the Al.

All electron microprobe analysis was performed using JEOL JXA-8500F field emission gun EPMA instrument at the University of Hawai‘i, Mānoa. For every sample measurement, 10 KeV accelerating voltage and 5 nA probe current was used. Typical spot analyses used a beam diameter defocused to 1 to 3 microns. X-Ray images were collected in each sample at high spatial resolution (0.5 micron pixel size and 1024 x 1024 pixels) and low spatial resolution (1 or 2 microns per pixel), using a 20 ms dwell time per pixel. The Kα energies of the elements C, Ca, Mg, Si, and Al, as well as backscattered electron signal (BSE) were collected for each map. We report raw quantitative C in wt% that have not been corrected for by the presence of the Al coating or the other elements in the sample.

We compare results from EPMA maps with previously collected Raman maps [1]. The Raman maps were collected in situ using a WITec alpha300 R confocal Raman microscope. The microscope includes a piezoelectric device driven stage for precise and automatic Raman map collection. All Raman maps were collected using a 532 nm laser with a 15 s exposure time. The laser power was kept at ≤ 50 μW using neutral density filters. Low laser power prevents damage to the sample by laser-induced heating. All map data were reanalyzed using our newly developed Savitzky-Golay Second Derivative fitting routine, which is designed to suppress intense fluorescence backgrounds in in situ Raman spectra of carbonaceous chondrites [2]. A Monte Carlo technique is used during data interpretation to estimate uncertainties of the Raman spectral parameters derived from the fit of the Raman peaks.

Results: Coatings. Under the conditions used in our EPMA experiments, but using a 5 micron beam size, pure graphite has ~10,000 X-ray counts per second (cps). With a 25 nm layer of Al, the cps is cut by ~22%, and with a 50 nm layer, the count rate is halved. On the flat graphite standard, the Al coating is homogeneous, with no imperfections at the level of electron probe image spatial resolution. Silver coating (Lesker, 4N) was also attempted. but the Ag had imperfections on a scale large enough to be seen by the EPMA. Notably, there are 1 micron ‘islands’ of higher backscatter, possibly due to the slow passivation of the silver layer. (Silver passivates at a much slower pace than Al).

Samples. Quantitative analyses, X-ray images, and BSE images were obtained for all three samples. Other X-ray images were obtained for areas outside the original Raman study areas. Quantitative analysis of spots of the samples that have nominally zero carbon (e.g. olivine chondrules) determine that the background level of carbon in the electron microprobe is 0.65 wt%.

X-Ray imaging of the CR chondrites reveals three distinct carbon phases: high carbon phases (HCPs), carbonates, and matrix carbon (MC).

HCPs are characterized by very low backscatter and indistinct edges and very high carbon in quantitative analysis (up to 58 wt%). Many of these high carbon phases are small and appear to be draped onto the surface of the surrounding silicates. Carbon’s low density...
and the small size of many HCPs (~1 micron), EPMA analysis can easily measure the surrounding silicates or the silicates beneath a high carbon phase. Thus, we suspect that these phases are close to pure carbon. HCPs are seen throughout the CR3 chondrite (appear red in Fig. 1) and CR1 chondrite. In the latter chondrite, the HCPs are much more diffuse and are almost always associated with calcite-magnetite assemblages (see Fig. 3 as an example; magnetite appears black). Bright red areas of Fig. 2 are likely due to diamond contamination as a result of polishing this sample, and dark red spots are associated with areas of high backscatter but likely not high in carbon.

Carbonates, is a phase associated with aqueous alteration of a meteorite on its parent body asteroid [3], are present in each meteorite. In each Fig., calcite grains are seen as purple.

Many matrix areas of the samples contain detectable carbon at the 1–6.5 wt% level in the CR3 and CR2 samples and up to 3.5 wt% in the CR1 sample. Matrix areas are darker green in the Figures. The MC is associated with the fine grained matrix silicates. The MC is extremely fine grained and has fine-scale heterogeneities. Other areas of the matrix may contain C below the detection limit. Terrestrial weathering veins (seen as silicate free areas in Fig. 2, also seem to contain carbon. But whether the brightness of the carbon in these areas is due to the high backscatter in these phases or truly due to higher carbon has not been determined.

Comparison to previous Raman image studies. Raman imaging was performed in the matrix areas of EET 92161 shown in Fig. 2 [1], and maps of spectral properties were created by fitting the D- and G-bands in each spectrum. The presence of the D- and G-bands (two broad peaks at ~1350 and ~1600 wavenumbers) in a Raman spectrum, is consistent with the detection of macromolecular carbon (MMC) [4]. Raman mapping and EPMA of the same areas of the CR2 and CR1 chondrites reveal that the MC is MMC.

Conclusions: Quantitative EPMA measurements of carbon in CR1–3 chondrites coated with 25 nm Al show that carbon is ubiquitous in the fine grained matrix of these meteorites. In all samples, carbon appears to be concentrated in large, possibly pure, carbon phases we call HCPs. Generally, most carbon is detected as very small (<1 micron) HCPs or as extremely fine grained MC.

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