

**THE DISTRIBUTION OF ORGANIC CARBON IN CR2 CHONDRITE EET 92161.** P. J. Gasda and G. J. Taylor, Hawai'i Institute of Geophysics and Planetology, University of Hawai'i, Mānoa, 1680 East-West Road, Honolulu, Hawai'i 96822; pgasda@hawaii.edu

**Introduction:** The purpose of our study is to understand the distribution of organic compounds in carbonaceous chondrites (beginning with CRs) and how these compounds are affected by aqueous alteration on meteorite parent bodies. Recent work [1], shows that CR1-3 chondrites have substantial concentrations of organic compounds, including amino acids, and that the mix of amino acids in them changes with the extent of aqueous alteration. In addition, despite the differences in composition among the carbonaceous meteorites, and the differences in their secondary mineralogy, [1] has shown that CR, CM, and CI chondrites undergo seemingly similar changes in their organic chemistry as they are aqueously altered. Our work is designed to shed light on the petrographic relationships between primary and secondary minerals in CR chondrites and the organic compounds with the goal of understanding the evolution of the organics and their relation processes on the early, pre-biotic Earth.

Raman spectroscopy has been used extensively in the initial stage of this project. The Raman technique is an established method to study the nature of the 'kerogen-like' insoluble organic material (IOM) present in organic-bearing rocks both on Earth and in meteorites [2], [3]. Fundamentally, Raman spectroscopy measures the energy of vibration of chemical bonds. This is typically accomplished exciting the sample with a laser beam, and then measuring the difference between the laser light wavelength and the scattered light. When paired with a confocal optical microscope, Raman becomes a powerful tool for studying mineral grains in rocks. Both the inorganic and organic phases can be identified. The instruments are capable of 1  $\mu\text{m}$  pixel resolution at 100x optical magnification.

To date, most of what is understood about the organic molecule inventory of meteorites comes from destructive bulk analysis of meteorites [4]. These techniques typically use hydrochloric and hydrofluoric acids to demineralize samples and to separate out the individual organic molecules. Raman spectroscopy complements these techniques. It cannot characterize individual organic species present in the meteorite, but it can detect the presence of organic chemicals in relation to the mineral phases. Thus, it is ideal for *in situ* detection of carbon in a rock, and general trends of the carbon can be reported. There have been recent studies that combine bulk analysis techniques with Raman spectroscopy. The general trends reported in these studies (e.g. [3]) may be misleading due the use of

chemical treatments. More importantly, the dissolution techniques erase the petrographic context we are trying to elucidate through *in situ* Raman microscopy.

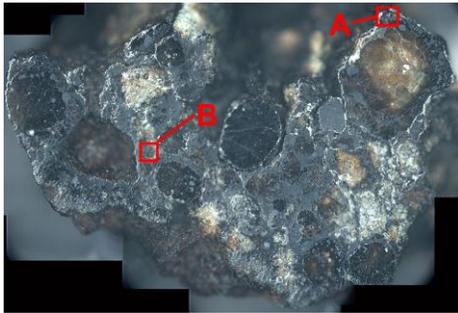
**Samples:** We have been allocated specially prepared samples of CR Antarctic meteorites that include the CR2 EET 92161 (a sample paired with meteorite EET 92042 previously studied by Glavin et al.) by the Johnson Space Center Meteorite Curation Laboratory. The sample is a 1.200 g chip that has been carefully polished on one side. Using a large chip – rather than a thin section – has two major advantages. First, Raman lasers will penetrate transparent materials and can accidentally measure the underlying substrate and mounting material of a thin section. Hence, the samples must be thick enough to be opaque to visible light. Second, most rock samples are impregnated with epoxy before mounting on a glass slide, which can severely hamper our analyses of the distribution of organic compounds. Furthermore to prevent contamination or alteration of the organic and minerals, no oil or water were used while cutting and polishing the sample.

**Methodology:** *Micro-Raman spectroscopic mapping.* Raman maps have been collected 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 presented here were collected using a 532 nm laser with a 15 s exposure time. The laser power is kept at  $\leq 50 \mu\text{W}$  using neutral density filters. Low laser power prevents damage to the sample by laser-induced heating.

*Data analysis.* Data reduction is performed using the IDL 8.0 programming language. The program, a modified version of the code used by Lydie Bonal [5], simultaneously fits Lorentz and Breit-Wigner-Fano (BWF) functions to the D and G bands of the carbon Raman spectra, respectively. The Lorentz function is ideal for fitting spectral peaks and the BWF function is a modified version of the Lorentz function that can account for asymmetric peaks. The output of the program provides information such as the peak center, FWHM, intensity, etc. that may all be used to interpret the nature of the carbon detected in the sample.

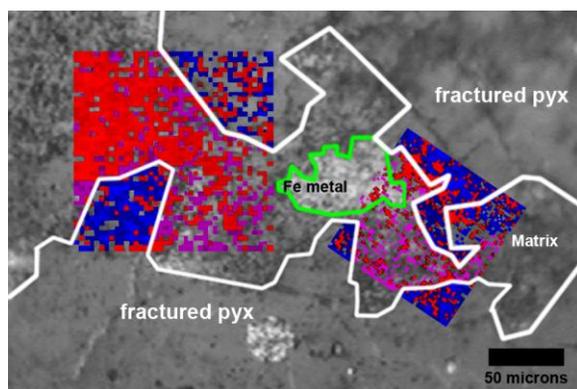
**Discussion of Results:** A 5x magnification reflect-light photomicrograph (Figure 1) of the one polished side EET 92161 shows that the meteorite sample, despite being classified as CR2 (moderately aqueously altered), still contains many primary minerals, chondrules, and metal grains. Between the chondrules there

exists a fine-grained matrix interspersed with larger clasts of primary and secondary minerals. At close inspection, the chondrules have begun to show signs of aqueous alteration. The two chosen areas for examination by Raman spectroscopy are in the fine grained matrix because the IOM is expected to be present there.



**Figure 1**

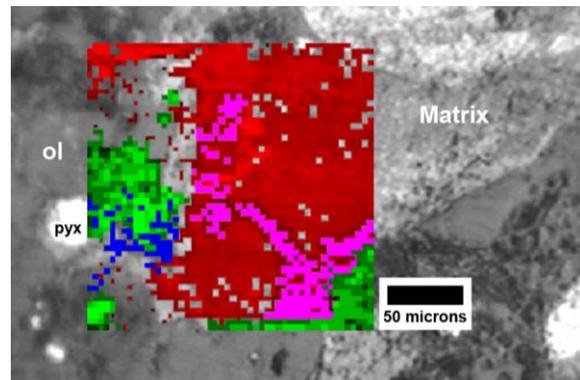
Figure 2 is a B&W photomicrograph of an area of the matrix (labeled 'A' in Figure 1) near a large pyroxene chondrule. Overlaid on the photo are two Raman maps of areas that include the matrix, grains of pyroxene, and weathering veins that course through the pyroxene. The pyroxene is depicted in the Raman map as blue and the presence of carbon is shown in red. Other matrix silicates and sulfides could not be identified individually at this time are seen in purple. Based on their Raman spectra, this unknown material is likely a mixture of phyllosilicates and Fe-sulfides. As predicted, the organic carbon is present primarily in the lighter colored fine-grained matrix, and it is occasionally associated with the dark inclusions in the matrix. The carbon is also transported into the pyroxene via weathering veins.



**Figure 2**

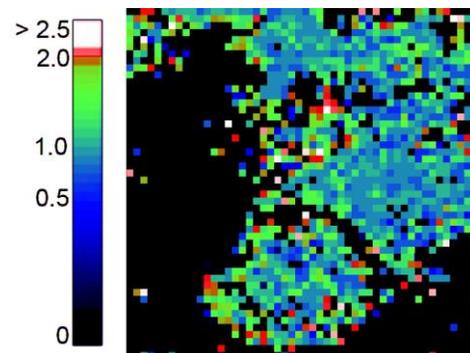
Figure 3 is a B&W photomicrograph of an area of the matrix (labeled 'B' in Figure 1) near a large olivine chondrule that appears to be aqueously altered. Overlaid on the photo is a Raman map of areas that include the matrix, grains of olivine (green), unknown phase

(purple), pyroxene (blue), and weathering veins that stem from a small pyroxene grain. Again, the carbon is found predominantly in the matrix and it is associated with the weathering of the surrounding mineral grains.



**Figure 3**

In general, the carbon found in EET92161,1 analyzed thus far are fairly disordered. The G band, which indicates the presence of graphitic carbon, is generally less intense than the D band. This suggests very disordered carbon has been detected. More analysis is needed, but it appears that carbon in area B is distinctly different, (i.e., less disordered) as well as in higher abundance compared to region A. Figure 4 shows a map of the intensity ratio of the D and G bands of the carbon spectra for the carbon found in region B. The green regions indicate ordered or graphitic carbon, and blue regions indicate disordered carbon. The carbon appears to be less disordered when it is adjacent to the olivine.



**Figure 4:** The D and G band intensity ratio map of the same area shown in Figure 3.

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**References:** [1] Glavin et al. (2011) *MAPS*, 45, 1948–1972 [2] Wopenka, B., and J. D. Pasteris (1993), *Amer. Mineral.*, 78, 533–557. [3] Busemann, H., et al. (2007) *MAPS*, 42, 1387–1416 [4] Sephton, M. A. (2002), *Nat. Prod. Rep.*, 19, 292–311. [5] Bonal, L., E. et al. (2006), *Geochim. Cosmochim. Acta*, 70, 1849–1863.