CARBONACEOUS CHONDRITE GROUPS DISCERNED USING RAMAN SPECTRAL PARAMETERS.

M. Fries[1] R. Bhartia[2] and A. Steele[3]. [1]Planetary Science Institute, Tucson, AZ, fries@psi.edu [2]NASA Jet Propulsion Laboratory, Pasadena, CA. [3]Geophysical Laboratory, Carnegie Institution of Washington.

Introduction: The carbonaceous components of carbonaceous chondrites originally precipitated from a carbon-rich gas then accreted into parent bodies, and then were exposed to thermal and aqueous parent body alteration. A record of those formation and alteration processes is recorded in the chemistry and fine structure of the carbonaceous materials [e.g.1,2]. Raman spectroscopy is sensitive to carbon structure on a sub-micron scale and trends in Raman spectral parameters can be used to differentiate between carbonaceous chondrite types. This is useful for a few reasons: 1) variations within meteorite groups or within individual meteorites can be measured to discern individual histories, 2) carbonaceous clasts can be assigned a meteorite type affinity even in the absence of mineral phases and even if they are optically indistinct from surrounding material, and 3) potential group affinities in ungrouped carbonaceous chondrites can be investigated. Also, Raman analyses are non-destructive and can be performed on very small amounts of material. This approach provides information on meteorite formation and alteration histories in a complementary manner to petrographic studies, electron probe analysis and other techniques. It is worth noting that this information can be applied to both laboratory studies and spaceflight missions featuring Raman spectroscopy, especially for missions to carbonaceous bodies.

We present initial Raman analyses of the carbonaceous components of a suite of carbonaceous chondrites from falls to define spectral feature trends. While similar work has been presented by Busemann et al [3], that work utilized carbonaceous extracts obtained from whole-rock dissolution of meteorites. The spectra presented here were collected from fresh fracture surfaces. This is an improvement in two ways: 1) samples are examined free of laboratory chemical alteration, and 2) the procedures defined here can be utilized on practically any meteorite sample with minimal disruption of the sample.

Procedures: *Sample preparation:* Small (sub-gram) samples were selected from carbonaceous chondrite, representing falls in the CI, CO, CR, CV, and CM groups. These samples were obtained on loan from the Smithsonian Institution. A fresh fracture micro-surface was prepared on each by touching a sterile, pointed-tip scalpel to the surface of each fragment and striking the scalpel to spall a ~mm-sized fragment free.

Raman Analysis: A grid of Raman spectra was collected in the fresh fracture surface using a Horiba LabRam Raman instrument using a 532 nm-wavelength excitation laser. Each spectrum was auto-focused and features multiple iterations per spectrum to improve signal/noise. Background subtraction was performed using the baseline subtraction function in Igor Pro 6.04 software, utilizing a spline fit with Raman modes excluded from the fit. The Igor multipeak fitting routine was used to obtain Gaussian fits of the D and G bands.
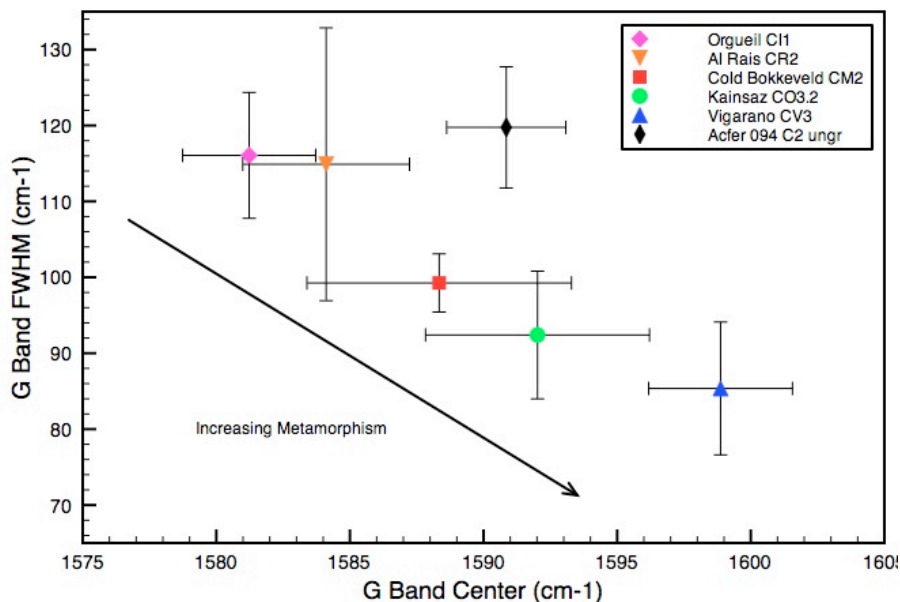

Figure 1: Raman carbon G band parameters for a range of meteorite falls. Peak width correlates to the range of crystallite domain sizes while peak center is a function of the vibrational energy of a particular domain. Metamorphism drives the growth of larger crystallite domains with a narrower size distribution, driving G band parameters toward the lower right in this graph with time and temperature. A preliminary trend line is seen: CI<CR<CM<CO<CV with Acfer 094's position off of the trend line possibly due to N substitution defects.

Results: Raman spectral analysis shows a distinct trend in G band features versus meteorite type (Figure 1). The axes of this graph relate to specific physical features of the carbonaceous material examined. G band position is a function of the fundamental vibrational energy of in-plane graphitic lattices within the excitation laser spot. Peak width (full width at half-maximum, or FWHM) is a function of the range of crystallite sizes within the excitation laser spot. With thermal metamorphism, the range of crystallite sizes becomes smaller and their average size increases, driving Raman spectral parameters towards the lower right on this graph. When and if a hypothetical carbonaceous material crystallizes into graphite, its position on this graph returns to a low value of nearly 1580 cm^{-1} and a low FWHM defined by the Raman instrument optical parameters. A single instance of graphite was noted in Vigarano but was not included in the data shown in Figure 1. Acfer 094 (C2-ungr) was analyzed to examine the hypothesis that this technique can be used to assign group affinities to ungrouped carbonaceous chondrites. Acfer 094's position on the graph is consistent with its status as ungrouped. Its position off of the trend line may be explained by the presence of a large number of nitrogen substitution defects, which affect the fundamental vibrational energy of graphitic crystallite lattices. This is consistent with the very high bulk nitrogen abundance of Acfer 094 [4].

While the trend shown in Figure 1 makes innate sense since it defines an increasing Raman parameter trend with increasing petrologic type, it will benefit from elaboration with additional analyses. Future work will include expanding the number of analyses both in terms of additional falls from the meteorite types noted here, as well as from additional meteorite types.

References: [1] Tuinstra F. and Koenig J. (1970) *J. Chem. Phys. 53*, 1126-1130. [2] Wopenka B. and Pasteris J. (1993) *Am. Min. 78,* 533-557. [3] Buseman H., Alexander C.M.O'D., Nittler L. (2007) *Meteoritics & Planet. Sci., 42* 1387-1416. [4] Newton J., Bischoff A., Arden J., Franchi I., Geiger T., Greshake A., Pillinger C. (1995) *Meteoritics*, *30*, 47-56.