MICROSPECTROSCOPY OF METEORITES: SEARCH FOR ORGANIC-MINERAL CORRELATIONS.

M. Yesiltas[1], M. Unger[2,3], J. Sedlmair[2], C. J. Hirschmugl[3], T. N. Brusentsova[1], J. Arnold[1], R. E. Peale[1], [1]Dept. of Physics, University of Central Florida, 4000 Central Florida Blvd. PS 430, Orlando, FL, 32816, (myesiltas@knights.ucf.edu), [2]Synchrotron Radiation Center, University of Wisconsin-Madison, Stoughton, WI, 53589, [3]Dept. of Physics, University of Wisconsin-Milwaukee, Milwaukee, WI, 53211.

Introduction: Organic molecules in meteorites can be created by catalytic reaction of carbon with oxygen, hydrogen, and nitrogen on individual grains that comprise inhomogeneous meteorites. The amount and type of such molecules created may depend on the mineral species. Processing may alter the chemistry in ways that also depend on the host mineralogy. To investigate these hypotheses, we assessed correlations between concentrations of organic species and mineral species in meteorites. Infrared and Raman microspectroscopy are used to determine relative concentrations of specific minerals and physically associated organic compounds with micron spatial resolution. More than 50 meteorites from broad classes have been studied including carbonaceous chondrites (CI, CM, CR, CO, CV, CK), ordinary chondrites (H, L, LL), enstatite chondrites (EH, EL), achondrites (Howardites, Eucrites, Diogenites, Urelites), and Martian (Shergottites, Nakhlites, Chassignites) meteorites. These samples were obtained from the NASA Antarctic Meteorite Collection, and private sources.

Background: Little is known about the spatial distribution and mineralogical relationships of organic molecules in meteorites. These may have been created by reaction of carbon with simple precursors catalyzed on individual ISM grains that coalesced to form meteorite source objects. The amount and type of such molecules may depend on the mineral species and processing, although correlation between organic compounds and specific minerals is poorly understood. Carbon has been identified preferentially at the surface of metal and troilite grains in ordinary chondrites [1]. Organic material was found in association with clays in CI and CM chondrites [2]. These preliminary studies support the hypothesis for at least partial processing of organic molecules among specific minerals in heterogeneous meteorites, which motivates this investigation.

Experimental: In this study, mineral and organic components of meteorites are identified by infrared micro-spectroscopy with high spatial resolution, and the strengths of organic infrared absorption lines for individual meteorite grains are correlated with the oxide, carbonate, and hydration absorption bands of those grains. Meteorites are ground to fine powder with individual particle spectra measured simultaneously using the Infrared Environmental Imaging (IRENI) beamline at the Synchrotron Radiation Center (SRC) at University of Wisconsin-Madison. This achieves ~1 micron spatial resolution and 4 cm^{-1} spectral resolution over the spectral range 850-3800 cm^{-1}. The experimental setup at SRC is comprised of a Bruker Vertex 70 spectrometer with a Bruker Hyperion infrared microscope and a Focal Plane Array (FPA) detector. The effective pixel size of 0.54 x 0.54 μm^2 allows spatial oversampling for all wavelengths, providing spatially resolved images that are diffraction-limited at all wavelengths. The single shot FPA image covers an area of up to ~50 × 50 μm^2 (96×96 pixels) in the transmission mode with automated mosaic collection for rapid coverage of larger areas.

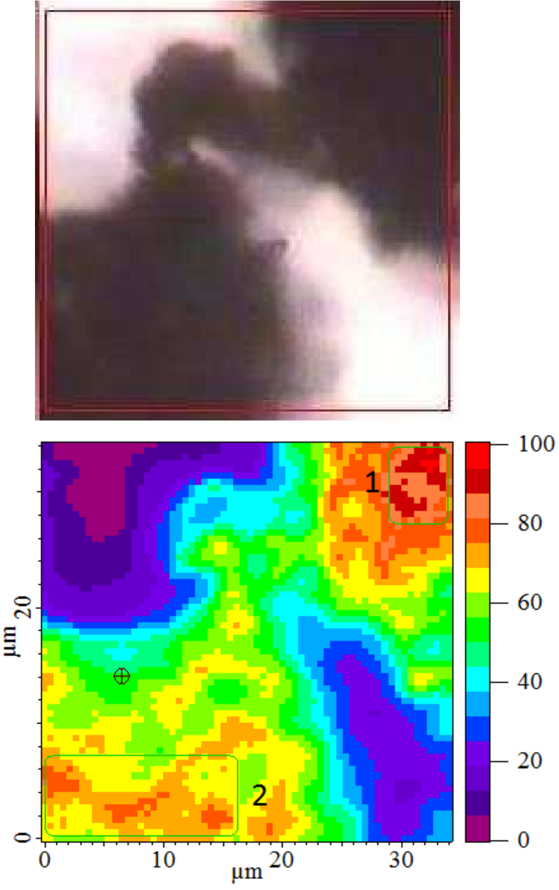

Figure 1. Visible (top) and infrared (bottom) images of Murchison at 2850 cm^{-1}.

This procedure provides information on the lateral sample heterogeneity and correlations between different spectral features [3]. Micro-Raman spectra that complement the infrared absorption data are collected at the Material Characterization Facility of University of Central Florida with a Renishaw RM 1000 micro-Raman spectrometer coupled to a CCD detector and Ar-514nm excitation unit.

Results: Initial results for Allende, Murchison, and Tagish Lake show significant differences in relative line strengths compared with previously reports [4]. Figure 1 presents visible and infrared micrographs of Murchison grains. The infrared image gives absorbance at 2850 cm^{-1}. We spectrally compared two different grain regions that are rich in minerals and organics, and have high infrared absorption. These regions are labeled as “1” and “2” in the infrared image, shown in Figure 1 (bottom).

Infrared absorbance spectra of these Murchison grains are presented in Figure 2. In addition to silicate bands near 1000 cm^{-1} and a broad water of hydration band in the range 3300 - 3400 cm^{-1}, absorption features due to organics are identified. The region between 2800 and 3000 cm^{-1} consists of aliphatic C-H stretching bands. The broad band in the 1500 - 1700 cm^{-1} region is due partially to C=O stretching (aldehyde and ketone), and partially to H-O-H bending (water). A small feature at 1450 cm^{-1} can be attributed to carbonates. As apparent in Figure 2, the different spectral features have different relative strengths in the two regions.

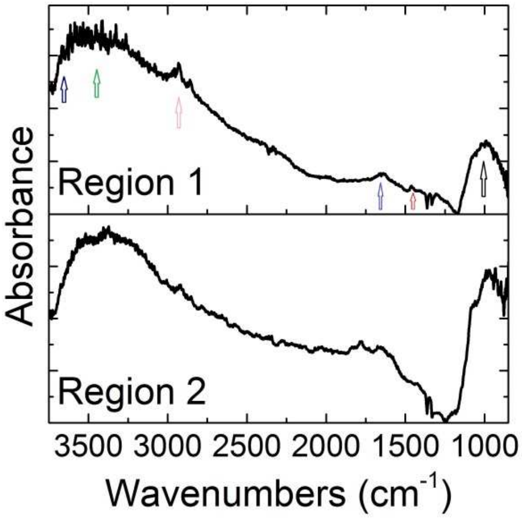

Figure 2. Infrared absorption spectra of Murchison at two different grain regions.

Figure 3 compares integrated absorbance of different bands based on baseline corrected line Lorentzian fits. Integrated absorbance is proportional to the product of concentration and sample thickness, i.e. it is a measure of the number of molecules that interact with the beam. The absorbance decreases by a factor of between 1.5 and 2 for CH_3 aldehyde, ketone, phyllosilicates, and carbonates in going from region 1 to region 2. In contrast, the absorbance of silicates and hydration increase by about 1.5 times. Thus, the quantity of organics (CH_3, aldehyde and ketone) appears to be correlated with carbonates phyllosilicates decrease, but not with silicate and hydration bands.

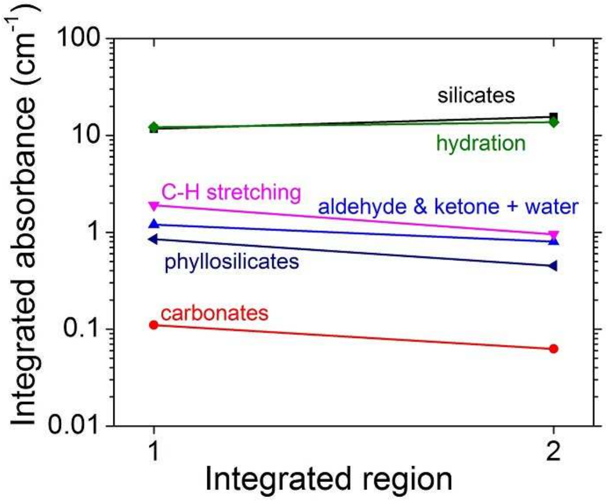

Figure 3. Comparison of integrated absorbance for different IR bands in Murchison.

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