

NEW INSIGHTS INTO CARBONACEOUS CHONDRITE MINERALOGIES OBTAINED FROM MICROSCOPIC MINERAL MAPPING. V. E. Hamilton¹, N. M. Abreu², P. A. Bland³, H. C. Connolly, Jr.^{4,5}, D. S. Lauretta⁵, and J. M. Bayron⁴, ¹Southwest Research Institute, 1050 Walnut St. #300, Boulder, CO 80302 USA (hamilton@boulder.swri.edu), ²Earth Science Program, Penn State - DuBois, ³Dept. of Applied Geology, Curtin University, Perth, Australia, ⁴Earth and Planetary Sciences & The Graduate Center, City University of New York, NY, ⁵Lunar and Planetary Institute, University of Arizona, Tucson, AZ.

Introduction: We have acquired mineral maps of two dozen carbonaceous chondrites (CCs) spanning all groups (plus two C2-ungrouped) and petrologic types using FTIR microspectroscopy. These data complement chemical maps by enabling determination of modal mineralogy (including solid solution), characterization of hydration state, analysis of petrologic relationships, identification of mineral orientation, and assessment of the structural state of meteorite phases, all in petrographic context. Here we discuss two examples of how in situ microscopic mapping provides new insights into CC mineralogy: spatial variations in hydration and the identification of distinct populations of olivine in a CR2 that have not been reported previously. In addition to in situ studies, obtaining phase-specific spectra will be beneficial for augmenting spectral libraries used to interpret meteorite or remote sensing spectra.

Background: Previous thermal infrared (TIR) spectral studies of CCs have focused on powdered whole rock samples [e.g., 1-4], or isolated matrix material and other individual phases/compounds [e.g., 5, 6]. Our work expands on existing studies by measuring whole rock meteorite mineralogy in such a way that petrologic context is retained and we are able to produce spectra of individual phases and the bulk rock.

Samples and Data: To date, we have measured 24 CC meteorites from all groups (CI, CM, CO, CV, CK, CR, CH, and CB, plus two C2-ungrouped) and representing all petrologic types (1-6). Our μ -FTIR reflectance data (plotted here as emissivity, $E=1-R$) span the range 4000 - 400 cm^{-1} (2.5 - 25 μm) and are acquired from standard petrologic thin- or thick sections. Data in this abstract were acquired at a relatively low spatial resolution of 300 $\mu\text{m}/\text{pixel}$ at a spectral sampling of 2 cm^{-1} , typically over an area of about 6 mm^2 , yielding ~400 spectra per meteorite. Higher spatial resolutions of 25 $\mu\text{m}/\text{pixel}$ (the diffraction limit) are possible for studies of small features such as rims, and spatial oversampling can be used to extract spectral features of phases smaller than the observation area. We take advantage of linear mixing in the TIR [e.g., 7, 8] to obtain the whole rock spectrum of a meteorite by averaging the individual spectra in a given μ -FTIR map.

Variations in Hydration: Variations in the shape and strength of the structural OH⁻ absorption at ~3685 cm^{-1} (2.71 μm) are discernible in our spectra, which is useful because the location of hydrogen atoms is not

readily discerned by many conventional chemical techniques or X-ray diffraction. Mapping the distribution of water in the sample may help elucidate differences in the aqueous alteration and impact histories of distinct portions of individual CC meteorites.

OH⁻ in whole rock spectra. As in previous studies, the strength of the structural OH⁻ feature generally diminishes with increasing petrologic type in our whole rock spectra. Our CI1, CR1, CM2, and one C2-ungrouped (Bells) meteorites all exhibit a sharp OH⁻ peak, with variations in the surrounding band shape attributable to the Mg-Fe solid solution composition of phyllosilicates [e.g., 3, 4]. Our CR2s and other C2-ungrouped (Acfer 094) exhibit only a broad feature from ~3760 - 3280 cm^{-1} , which is generally attributed to the presence of adsorbed water. Meteorites of petrologic type ≥ 3.0 contain few hydrous phases, and hydration features are weak or absent in such meteorites, excepting instances of terrestrial weathering phases.

OH⁻ in spatially resolved map spectra. Our mineral maps reveal spatial variations in the structural OH⁻ feature within individual meteorites. Some of this variation is attributable to differences in mineralogy (e.g., phyllosilicates vs. sulfides), but some of the variation occurs within different examples of a particular phase within a meteorite. For example, all of the map spectra of Moapa Valley (CM1) appear to be remarkably similar phyllosilicates [Fig. 1], with the exception of some spectra that also exhibit carbonate bands. But the strength of the ~3685 cm^{-1} feature varies across the map area [Fig. 2-3], and this corresponds to subtle, but real variations in the shape of the fundamental bands of the phyllosilicates [Fig. 4]. We are examining these variations for correlation with elemental chemistry and structure to determine their origins and what they may tell us about aqueous alteration processes.

Identification of Two Populations of Olivine in Graves Nunataks (GRA) 06100 (CR2): GRA 06100 has been interpreted to have experienced high temperature impact metamorphism [9]. The number of silicate bands and their positions in the whole rock spectrum of GRA 06100 is consistent with other CR2s, except that the emissivity in the ~920-860 cm^{-1} region is lower. This characteristic leads GRA 06100 to resemble Kainsaz (CO3.2) and other type ≥ 3.0 meteorites (CO, CV, CK), following a trend of decreasing emissivity in this part of the spectrum as olivine abundance increases.

Individual spectra in the GRA 06100 map allow detailed examination of olivine signatures. Interestingly, the olivine signatures distinguish two populations — one with spectra that resemble that of terrestrial forsterite in band positions and shape and another that resembles in band position but not shape, terrestrial fayalite [e.g., 10]. These spectral shapes are not consistent with crystallographic orientation effects and thus appear to represent two different olivine compositions, and a possible distortion of the fayalite structure. To our knowledge, this is the first report of two types of olivine in GRA 06100. This is a recent discovery in our study and we will confirm it with TEM and chemical imaging to better develop our understanding of the origin of these two phases.

If the detection of two olivines in GRA 06100 reflects a low degree of equilibration rather than impact processing, increasingly equilibrated meteorites (except CVs, with distinct matrix and chondrule olivine) should exhibit more homogeneous olivine spectra, a hypothesis we are currently testing with our dataset.

Summary: Our studies are just beginning, but using μ -FTIR mineral mapping we have discovered variations in the spatial distribution of OH⁻ within individ-

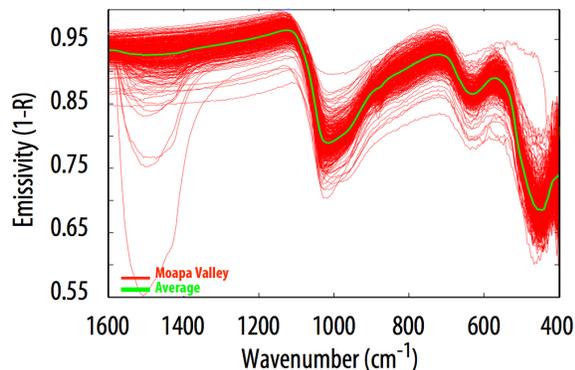


Fig. 1. 400 individual map spectra (red) and average (green) of Moapa Valley (CM1) showing the seeming homogeneity of silicate phases. (Broad feature at ~ 1500 cm^{-1} and narrow feature at 880 cm^{-1} are due to carbonate.)

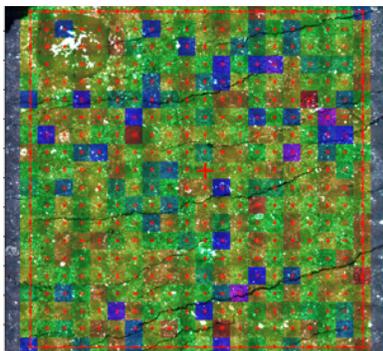


Fig. 2. Map of ~ 3685 cm^{-1} band strength overlaid on a reflected light image of Moapa Valley. Warmer colors indicate greater band strength. Colored pixels are $300 \mu\text{m}^2$.

ual meteorites and two previously undistinguished populations of olivine in a metamorphosed CR2; these (and other) trends are subject to ongoing study by our group, including correlation with chemical/structural datasets (e.g. EMPA, TEM).

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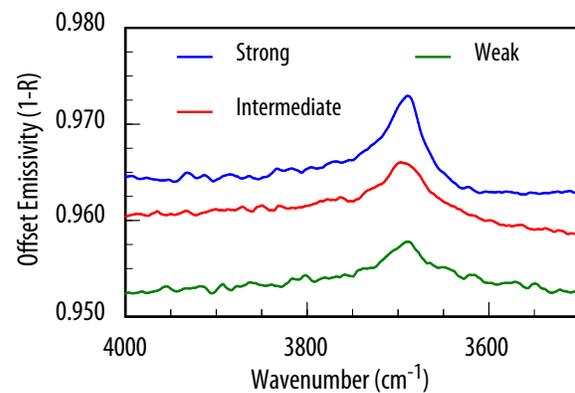


Fig. 3. Spectra of phyllosilicates from Moapa Valley map showing the hydration band at 3685 cm^{-1} , defined as strong, intermediate, and weak based on the index shown in Fig. 2. Spectra offset for clarity.

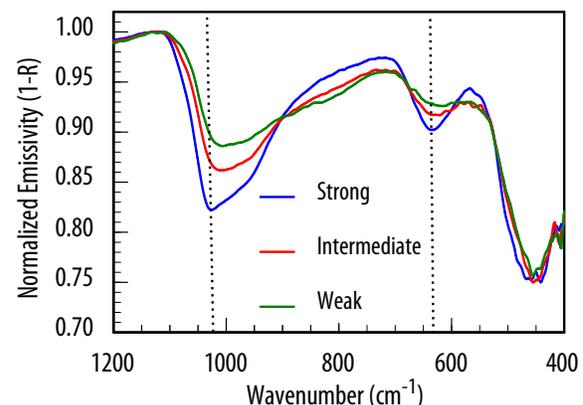


Fig. 4. Silicate fundamental region of phyllosilicate spectra in Fig. 3. Band shapes vary, band minima shift to lower wavenumber, and relative band depths differ with decreasing OH band strength. These trends indicate structural and/or chemical variations within the phyllosilicates; such trends have not been described in previous studies.