HOW VARIABLE ARE HYDRATION SIGNATURES OF CM2 CHONDRITES? – COMPARING SPECTRA OF METEORITE CHIPS ACROSS MULTIPLE SPATIAL SCALES.

C. D. Schultz[1], B. A. Anzures[2,3], R. E. Milliken[1], T. Hiroi[1] and K. Robertson[1], [1]Department of Earth, Environmental, and Planetary Sciences, Brown University, Providence, RI 02912, [2]Lunar and Planetary Institute/USRA, Houston, TX, [3]ARES, NASA Johnson Space Center, Houston, TX. (cody_schultz@brown.edu)

Introduction: Primitive C-complex asteroids have been found to exhibit absorption features in the 2.7–4 µm wavelength region in their reflectance spectra (referred to as the “3 µm feature”) that are diagnostic of OH and/or H_2O in the form of hydrated minerals [e.g., 1–3]. The potential diagnostic capacity of the 3 µm absorption feature in determining the extent of aqueous alteration has motivated workers to propose taxonomical schemes to organize meteorites and asteroids based on the wavelength position and shape of the absorption feature [4]. However, these measurements and others like them were performed on powdered meteorites, which by their nature are homogenized bulk mixtures that have lost all textural petrologic information. Consequently, spectra collected on these powders represent an average spectrum of the bulk material in which the spectrally dominant component(s) may not be the volumetrically dominant component(s). With this in mind, the goals of this study are to: (1) assess the sub-mm spatial heterogeneity of the 3 µm absorption feature within individual C chondrite chips, and (2) to determine the extent to which bulk spectroscopic measurements might belie important information about the 3 µm feature below the spatial scale of individual components.

Methods: We measured and mapped the sub-mm spatial scale reflectance spectra of individual CM2 chips from 1–16 µm with 4 cm^{-1} spectral resolution under dry air (dewpoint of -70°C) using a Bruker LUMOS microscope FTIR (µFTIR) spectrometer with spot sizes of 125 µm x 125 µm. These spectra were then compared to “bulk” IR spectra collected on the same meteorites using a NEXUS 870 FTIR with a spot size of 1–2 mm. Bulk modal mineralogy of separate powdered aliquots of the samples were modeled via Rietveld refinement of powder X-ray diffraction (XRD) patterns acquired with a Bruker D2 Phaser XRD. The meteorites selected for this study include Allan Hills (ALH) 84031, ALH 84048, Elephant Moraine (EET) 83226, EET 83389, Meteorite Hills (MET) 00630, MET 00639, and Queen Alexandra Range (QUE) 97077.

Results & Discussion: The position of the 3 µm band minimum was calculated on the continuum-removed spectrum for each spot for every meteorite for comparison to the organizational scheme proposed by [4]. From these data we identify two apparent groups based on the variability of the position of the 3 µm feature: the spectrally homogeneous group (ALH 84031, ALH 84048, MET 00630) and the spectrally heterogeneous group (EET 83226, EET 83389, QUE 97077). The spectrally homogeneous group is characterized by 3 µm features with band minima positioned at shorter wavelengths that show much less variance in position. When considering statistical outliers, the range in 3 µm band positions for the spectrally homogeneous group extends from ~2.71–2.80 µm, which overlaps Groups 1, 2, and 3 from [4]. In other words, the 3 µm band positions found within individual meteorites spans the entire range of previously proposed taxonomic groups. The spectrally heterogeneous group is characterized by 3 µm band minima positioned at longer wavelengths that also span all three groups and show much more variability in position. Comparing the distribution of 3 µm band positions to the total abundance of phyllosilicates supports the relationship observed by [4] that spectra of the least altered C chodnrites (lower abundance of phyllosilicates) have 3 µm band features centered at longer wavelengths whereas spectra of the most altered samples exhibit 3 µm band positions at the shortest wavelengths. We also observe that the least altered meteorites (those with less phyllosilicates) exhibit the widest range of 3 µm band positions whereas those for the most altered show much less variance in band minimum position.

Implications: The range of 3 µm features calculated for the most phyllosilicate-rich meteorites is relatively narrow and consistent in position with the bulk spectrum, which implies that the bulk reflectance spectrum is representative of the entire meteorite. This may be due to progressive aqueous alteration homogeneizing the mineralogy and chemistry of the meteorites at this spatial scale. However, CM chondrites are brecciated at all scales and may host multiple lithologies that have been aqueously altered to variable extents [5]. A larger survey of C chondrites would be needed to understand how genomict and polymict breccias influence spectra at sub-mm and bulk-scales. Alternatively, the least altered meteorite exhibit a wider range of 3 µm band minimums, which implies that the absorption feature calculated from the bulk reflectance spectrum may not necessarily be representative of the meteorite as a whole but is instead an average. By extension, asteroids exhibiting 3 µm absorption features in their reflectance spectra consistent with those measured here may be interpreted in a similar framework in which the spectrum of the least altered asteroids represents an average that belies the true diversity of mineralogy and chemistry of the body.

References: [1] Takir, D. and Emery, J. P. (2012) Icarus, 219(2), 641–654. [2] Rivkin, A. S. et al. (2015) Asteroids IV, 65–87. [3] Hamilton, V. E. et al. (2019) Nature Astronomy, 3(4), 332–340. [4] Takir D. et al. (2013) Meteoritics & Planetary science, 48, Nr 9, 1618-1637. [5] Lentfort et al., (2021) Meteoritcs & Planetary science, 56, Nr 1, 127-147.