CORRELATED ANALYSES OF CM CHONDRITE NORTHWEST AFRICA 12748 FROM COARSE SCALE TO FINE SPATIAL SCALES. L. Flores[1], T. D. Gotch[1], P. Northrup[2], and Y. Du[2], [1]Dept. of Geosciences, Stony Brook Uni-versity, Stony Brook, NY, leonard.flores@stonybrook.edu, [2]NSLS-II, Brookhaven National Laboratory, Upton, NY.

Introduction: CM meteorites are the most abundant of the carbonaceous chondrites and likely share similar-ities with the samples that will be returned from the near-Earth asteroid Bennu by NASA's OSIRIS-REx mission [1]. As such, these types of meteorites can be used as analogs for material found on asteroids like Bennu. Asteroids such as Bennu can provide significant information about the early ingredients of our Solar Sys-tem. In this work, we described correlated mineralogic and geochemical measurements of a CM2 chondrite with multiple instruments at various spatial scales to de-velop a methodology for analyses of samples returned from Bennu and similar asteroids.

Background: The meteorite we used for this study is NWA 12748 which is a CM2 chondrite. CM2 chon-drites are the most common type of CM meteorites [2]. These CM chondrites are petrographically type 2 ac-cording to Van Schmus and Woods' petrographic scale [3]. These type 2 CM chondrites consist of chondrules, a fine-grained matrix, and hydrated minerals. CM2 chondrites contain anhydrous Fe,Mg silicates including olivine and pyroxene. Phyllosilicates such as Mg-rich serpentine are present and small amounts of magnetite, calcite, and sulfide may be present [4]. We expect to see these phases in our analysis.

Methods: In this study, we use multiple instruments to analyze a thin section of NWA 12748. Our initial analyses included petrographic imaging in reflected plane light of the whole thin section at 4X magnifica-tion. We also acquired a hyperspectral infrared map of the sample at 25 µm/pixel spatial scales using a Nicolet iN10MX micro-FTIR. With this dataset, we can visual-ize the spectral differences between the different com-ponents in the sample through principal components analysis (PCA) [5] and spectral index mapping [6].

With these relatively coarse spatial resolution data, we acquired synchrotron X-ray fluorescence (XRF) maps and X-ray absorption fine structure (XAFS) spec-tra using the Tender Energy Spectroscopy beamline (8-BM) at NSLS-II at Brookhaven National Laboratory. Using our coarser scale infrared and reflected light im-ages for guidance, we mapped element abundances (S, P, Mg, Ca, Al, Si, K, Cl, U) at spatial scales from ~2-10 µm/pixel and acquired XANES spectra to determine the speciation of sulfur and phosphorus.

We additionally identified locations on the sample that interest us to further investigate at a finer spatial scales. We acquired Raman maps of several locations on the sample at ~0.5 µm/pixel using a WiTEC al-pha300R confocal Raman microscope system.
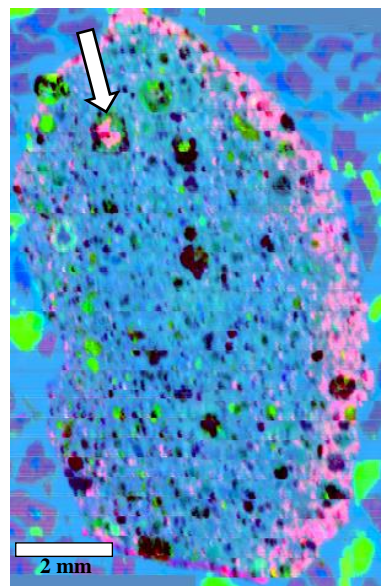

Fig. 1. PCA image of NWA 12748. Red, green and blue correspond to principal components 5, 4, and 3, respectively.

Finally, using our previous measurements, we fur-ther identified areas of interest for nano-IR imaging and spectroscopy at a much finer scale (30 nm/pixel) using a neaspec neaSNOM near-field infrared system.

Results: Figure 1 shows a false color RGB map of the NWA 12748 thin section using the results of our
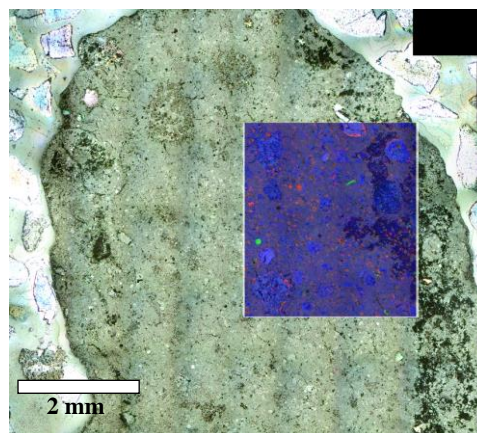

Fig. 2. An element abundance map for overlaid on top of a petrographic image of NWA 12748 using reflected light. Red, green, and blue correspond to P, Al, and Si, respectively.

PCA. The colors seen in Figure 1 do not directly corre-spond to the composition of the sample, but instead in-dicate which portions of the sample are spectrally
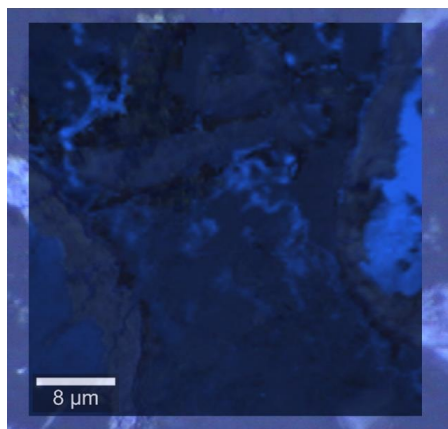
Fig. 3. Raman carbonate map overlayed on a visible image of the inside of a carbon-bearing chondrule on NWA 12748.

different or similar. Using different derived principal components to create different RGB images helps us visualize the variability between materials in the sample.

Mineralogical measurements of NWA 12748 from micro-FTIR measurements are complemented by chemical maps at various spatial scales acquired at the TES beamline (Figure 2). In this image, red corresponds to
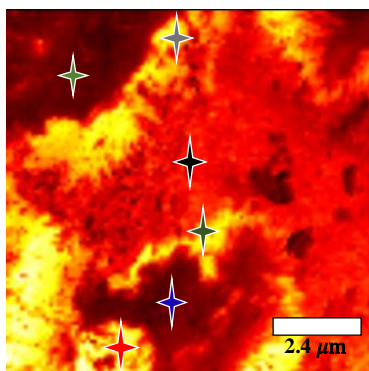

Fig. 4. Near-field IR amplitude image of a chondrule's rim in NWA 12748. Bright regions correspond to high IR amplitude (reflectance) and darker regions correspond to low IR amplitude. The colored stars correspond to the spectra in Figure 5.

P, green corresponds to Al, and blue corresponds to Si. We can additionally map the other elements describes above to search for geochemical and mineralogical correlations.

Inspection of Figure 1 and 2 reveals areas of interest to examine at finer scales, including the large chondrule near the top of Figure 1 (white arrow). Figure 3 shows a Raman map of a region inside the chondrule, displaying the distributions of carbonates.

Finally we acquired broadband nano-IR images (Figure 4) and spectra (Figure 5) to investigate the mineralogy and organic speciation in the sample at ~ 30

nm/pixel spatial scales. The field of view for this image is 5 μm across, demonstrating sample heterogeneity at sub-100 nm scales. Mineralogic and organic heterogeneity in the sample is further confirmed by nano-IR spectra from individual points (Figure 5), which show substantial variation in the silicate Reststrahlen band region and likely carbonates in the black spectrum.

Conclusions: NWA 12748 has varying spectral features at all spatial scales. When observing the whole sample using the false color RGB map, we can see that there is spectral heterogeneity throughout the entire sample by observing all the different colors present on the map. When taking a closer look with the element abundance maps, we can identify which elements are causing this heterogeneity.

When we zoom in with the Raman maps, we observe that the sample is still spectrally heterogenous by using various maps that focus on different distributions. Finally, when we observe NWA 12748 using nano-IR images, we still see heterogeneity at a sub-100 nm spatial scale. This method of observation gives us insight into how complex the composition of such meteorites can be from coarse to fine spatial scales. Future work will include investigations of more analog meteorites. This process can be very useful to observe the spectral differences of the samples and identify what makes elements are making it heterogeneous at various spatial scales.

References: [1] Laurette, D. S. et al. (2019) *Nature, 568*, 55-60. [2] Weisberg, M. K., McCoy, T. J., and Krot, A. N. (2006) *Meteorites and the Early Solar System II*, University of Arizona Press, 33. [3] Van Schmus, W. R. and Wood, J. A. (1967) *Geochimica et Cosmochimica Acta, 31*, 747-754. [4] Howard, K. T. et al. (2011) *Geochimica et Cosmochimica Acta, 75*, 2737. [5] Le Maitre, R. W. (1982) *Numerical Petrology: Statistical Interpretation of Geochemical Data.* Elsevier, Amsterdam, 106-121. [6] Viviano, C. E. et al. (2014) *JGR Planets, 119*, 1403-1431.
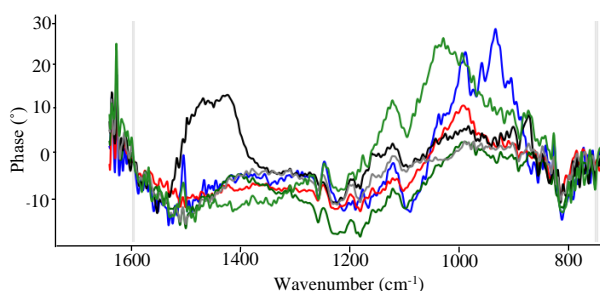

Fig. 5. Spectra of locations found in Figure 4.