THE EFFECTS OF FINE PARTICULATES ON THERMAL INFRARED EMISSIVITY SPECTRA. K. L. Donaldson Hanna[1,2] and N. E. Bowles[2], [1]Department of Physics, University of Central Florida, Orlando, FL, USA (Kerri.DonaldsonHanna@ucf.edu), [2]Atmospheric, Oceanic and Planetary Physics, University of Oxford, Oxford, UK.

Introduction: NASA's Origins, Spectral Interpretation, Resource Identification, and Security–Regolith Explorer (OSIRIS-REx) mission successfully launched on September 8th, 2016 and arrived at near-Earth asteroid (101955) Bennu December 3rd, 2018. Since its arrival at Bennu, OSIRIS-REx has been characterizing the asteroid's physical, mineralogical, and chemical properties using a suite of instruments in an effort to globally map the properties of a primitive carbonaceous asteroid and choose a sampling location [e.g., 1,2]. Spectral measurements are being collected across the visible to near infrared (VNIR) and thermal infrared (TIR) wavelengths using the OSIRIS-REx Visible and InfraRed Spectrometer [OVIRS; 3] and the OSIRIS-REx Thermal Emission Spectrometer [OTES; 4]. OVIRS and OTES observations made just before and after their arrival at Bennu suggests its surface is composed primarily of CI- or CM-like materials [5]. While the surface is visibly dominated by boulders and coarse particulates [6], TIR observations suggest a combination of fine (< 125 μm) and coarse (< 125 μm) particulate materials may be needed to explain the shape of the average global Bennu spectrum [5].

Here we present thermal infrared emissivity laboratory measurements of (1) a suite of samples that have been ground and sieved to a range of particle size fractions (fine to coarse) and (2) physical mixtures of the finest and coarsest particle size fraction of each sample measured under Earth- and asteroid-like conditions. These laboratory measurements will better enable the interpretation of OSIRIS-REx observations of Bennu [e.g., 5-6], Hayabusa2 observations of Ryugu [e.g., 7-8], and future observations of boulder-dominated asteroid surfaces.

Samples: Samples in this study include San Carlos olivine, Allende (CV3), and Murchison (CM2). While olivine and Allende are not compositional analogs for Bennu, they are samples that have been characterized extensively and are analogs for other primitive carbonaceous asteroids. Each of the samples was crushed and sieved into five particle size fractions: < 45 μm, 45 – 75 μm, 75 – 125 μm, 125 – 250 μm, and 250 – 500 μm. To remove any clinging fine particles (< 45 μm) from the larger particle size fractions, the larger particle size fractions (> 45 μm) were washed with distilled water and then placed in an oven at 60°C to dry out the samples. The washing and drying step was repeated two more times. Spectra were collected for each of the cleaned particle size fractions.

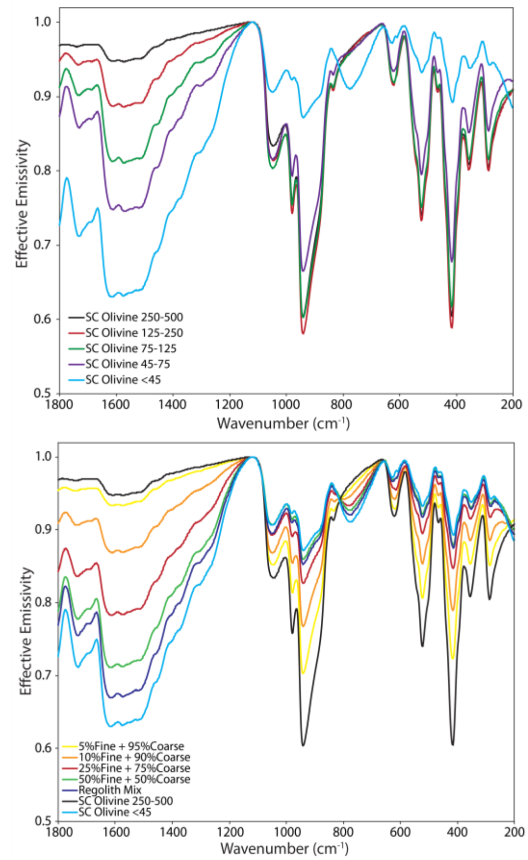

Figure 1. (Top) Ambient spectra of particle size fractions of San Carlos olivine. **(Bottom)** Ambient spectra of physical mixtures of San Carlos olivine.

Physical mixtures of each sample were then made to show the spectral effects from an increasing amount of fines by mixing varying amounts of the finest particle size fraction (< 45 μm; F) and the coarsest (250–500 μm; C). Mixtures include: 5 vol. % F + 95 vol. % C, 10 vol. % F + 90 vol. % C, 25 vol. % F + 75 vol. % C, 50 vol. % F + 50 vol. % C, 75 vol. % F + 25 vol. % C, and 90 vol. % F + 10 vol. % C. A multi-component physical mixture of each sample was made by mixing several particle size fractions: 67 vol. % < 45 μm, 11 vol. % 45 – 75 μm, 11 vol. % 75 – 125 μm, and 11 vol. % 125 – 250 μm. Spectra were then collected for each of the physical mixtures.

Experimental Methods: Thermal infrared (TIR) emissivity measurements were made under Earth-like (ambient) and simulated asteroid environment (SAE) conditions using the Planetary Analogue Surface Chamber for Asteroid and Lunar Environments (PASCALE) within the Planetary Spectroscopy Facility at the University of Oxford. The experimental setup and calibration of SLEC have been previously described by [9]. Under ambient conditions, samples are heated from below to 80°C while the environment chamber is held at ambient pressure (~1000 mbar N_2) and temperature (~28°C). Bennu's near surface environment, in particular the thermal gradient experienced in the upper hundreds of microns in the regolith, is simulated by: (1) removing atmospheric gases from inside the chamber (< 10^{-4} mbar), (2) cooling the interior of the chamber to < –150°C, and (3) heating the samples from below and above until the maximum brightness temperature of the sample is ~75°C. TIR spectra were collected using a Bruker VERTEX 70V Fourier Transform Infrared (FTIR) spectrometer at a resolution of 4 cm^{-1} from ~2000 – 200 cm^{-1} (~5 – 50 μm).

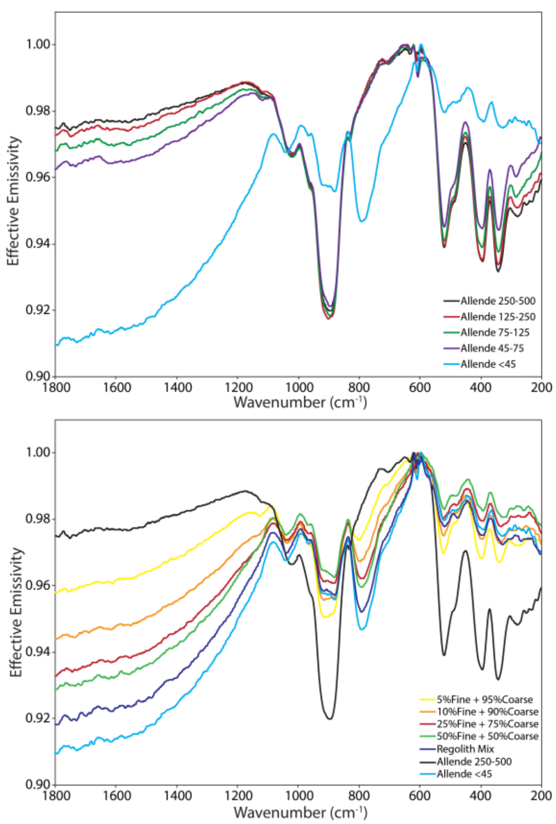

Figure 2. (Top) Ambient spectra of particle size fractions of Allende. **(Bottom)** Ambient spectra of physical mixtures of Allende.

Results: Emissivity spectra in Figs. 1 and 2 show the ambient measurements for the particle size separates (top) and physical mixtures (bottom) of San Carlos olivine and Allende, respectively. The olivine and Allende particle size spectra show similar behavior in that the transparency feature (TF) near 800 cm^{-1} is only observed for the finest particle size fraction (< 45 μm) while the spectral contrast in the transparent region of the spectra (> 1200 cm^{-1}) increases with decreasing particle size. In the olivine particle size spectra, a decrease in spectral contrast is observed in the reststrahlen bands (~1100 – 800 cm^{-1} and ~700 – 200 cm^{-1}), but little to no change is observed in the Allende particle size spectra.

The physical mixture spectra of olivine and Allende suggest that only 5% fine particulates are needed to begin introducing spectral effects commonly associated with fines. These observed changes include: (1) a transparency feature near 800 cm^{-1}, (2) an increase in spectral contrast in the transparent region of the spectra, and (3) a decrease in contrast in the reststrahlen bands. As expected, as the abundance of fine particulates increases the spectra behave more like the fine particle end member (<45 μm) with little spectral behavior from the coarse particle end member (250-500 μm). The multi-component mixture spectra (labeled as regolith mix in Figs. 1 and 2) behave similarly to the fine particle end member spectra.

These lab measurements of olivine and Allende suggest that (1) only the finest fraction (<45 μm) spectra have transparency features and (2) only a small amount of fine particles (on the order of 5%) are needed to introduce spectral behavior associated with fine particulates.

Future Work: Laboratory measurements of the Murchison meteorite will be made to better understand the TIR spectral effects of increasing amounts of fine particulates for Bennu-like materials. The Murchison laboratory measurements will better enable the interpretation of OTES observations of Bennu and will provide direction for future lab studies.

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