PARTICLE SIZE EFFECTS IN PARTICULATE ROCK SAMPLES: IMPLICATIONS FOR THERMAL EMISSION SPECTROMETER (TES) DATA ANALYSIS IN HIGH ALBEDO REGIONS ON MARS. V. E. Hamilton, Arizona State University, Box 871404, Tempe, AZ 85287-1404; hamilton@tes.la.asu.edu.

Introduction: We are evaluating the spectral characteristics of particulate bulk rock samples as potential analogues for surface materials in the high-albedo and border regions on Mars. If distinguishing characteristics as functions of particle size, composition, mixing, texture, and packing can be found, these results will aid in the interpretation of Thermal Emission Spectrometer data.

Spectral absorptions in TES data are attributable to atmospheric CO_2 and dust, water-ice clouds, and surface materials. The surface spectrum that remains after atmospheric removal is indicative of several properties of the surface materials including bulk composition, relative abundances of minerals, and particle size. The easiest surface spectra to interpret are those obtained in the low-albedo, high thermal inertia regions that are dominated by coarse (10's – 100's of μm) sands, regolith, and/or bedrock with little dust. However, the fundamental spectral signatures of most coarse materials and bedrock are likely obscured in higher albedo regions, which contain higher percentages of fine (10's of μm) particles and have low spectral contrast. Because regions of geologic interest include both dark (rocky) and bright (dusty) regions, this study will examine the midinfrared (5 – 50 μm) spectral characteristics of crushed and powdered whole rock samples with the objective of qualitatively establishing the spectral behavior of particulate mixtures at decreasing particle sizes as a function of composition [1].

Background: The effects of particle size on the thermal infrared spectra of minerals have been studied for many years [2-9] because particles having dimensions on the order of the wavelength of light used to observe them display significant variations in their spectra, greatly complicating the analysis of natural surfaces. Commonly discussed variations in emission spectra of minerals as a function of decreasing particle size include: shallowing of reststrahlen bands (reduction of spectral contrast), decreasing emissivity in the transparency regions between the reststrahlen bands, and changes in apparent band shape. The latter two of these effects are most prevalent at particle sizes below ~65 microns. Degree of packing in very small particle size fractions and the presence of clinging fines on larger (>65 microns) particles also influence spectral signatures. Despite the considerable attention devoted to the physics of particle size effects in pure minerals, very little attention has been given to these effects in physical mixtures (e.g. dusts and sands derived from rocks), primarily due to the increased complexity of the physics of light interaction and scattering in mixtures. However, it is still possible to empirically investigate particle size effects in mixtures as a function of bulk composition.

Samples: The samples for this study are dominantly igneous rocks selected to represent a variety of compositions (felsic to ultramafic) as well as intrusive and extrusive textures. Initially, approximately 20-30 samples will be prepared and analyzed. Sample preparation consists of crushing and dry sieving of the sample to the following particle size fractions, in microns: <10, 11-20, 21-30, 31-40, 41-50, 51-62, 63-125, 125-250, 250-500, 500-1000, 710-1000, and >1000 (a solid sample will be retained for spectral analysis as well). After crushing, fractions are washed to remove clinging fines.

Laboratory Data Acquisition: Spectral data are acquired using a Mattson Cygnus 100 interferometric spectrometer, covering 2000 – 400 cm^{-1} (5 – 25 μm), modified to collect emitted sample radiance [10]. Solid sample (rock) spectra are obtained after heating the sample overnight at 80°C (to improve signal to noise during analysis). Particulate samples are poured into copper cups that are painted flat black. These samples are also heated to 80°C, and this temperature is maintained during the spectral analysis. Emission spectra of the particulate sample separates and bulk rock samples are processed using the methods detailed in [10].

Results: The initial phase of this study consists of examining the changes in reststrahlen features as a function of particle size. Pure minerals crushed to particle size fractions like those described above commonly display decreasing spectral contrast (band shallowing) of the reststrahlen bands as the size fraction becomes smaller; this change is observable at particle sizes considerably greater than the ~65 μm size at which the more traditional "particle size effects" (e.g., decreased emissivity in transparency regions) become apparent [4,5]. We want to determine whether or not the same effect is observable in crushed rock samples.

When a rock sample is crushed, the spectrum of the "particulate rock" becomes decreased in its spectral contrast relative to that of the solid sample. [11] demonstrated empirically for a single granitic rock that this decrease was approximately 40% of the solid sample's emissivity across the spectrum (i.e., addition of a 40% blackbody component), when the rock was crushed and sieved to a particle size range of 710-1000 μm. This effect was attributed to the creation, in the particulate sample, of blackbody photon traps between the particles [6]. What remains unknown is if this observation holds true universally. Preliminary results [1] suggest this effect may be similar regardless of composition and texture (at the 710-1000 μm fraction).

Figure 1 shows the spectra of a solid basalt sample

and coarse particulates derived from crushing the sample. The difference between the solid sample spectrum and the 710-1000 μm particulate sample is ~35% emissivity. However, further decreases in the particle size fraction do not exhibit comparably significant, or even regular, decreases in the spectral contrast of reststrahlen features, except at the smallest (<63 μm) size fraction. If we assume that all crushed rocks behave in a similar manner, this observation suggests that on the basis of reststrahlen band depth alone, crushed particles may be distinguished from a solid sample, and that <63 μm particles may be distinguished from coarse particulates, but that size fractions in between are indistinguishable. However, if this observation is found to not be universal, and if an observable percentage decrease in spectral contrast can be determined to be a function of particle size and is independent of composition, this information could be used to determine the approximate, or mean particle size of an observed natural surface, even in materials too coarse to display the typical "particle size effects". Furthermore, particles <~65 μm have been demonstrated to exhibit spectral effects due to volume scattering as well as photon trapping [e.g., 7]. Do particulate fractions <65 μm demonstrate any traceable decrease in spectral contrast as a function of particle size as well? Conversely, we might also determine the minimum decrease in spectral contrast that is observed when a rock is crushed, i.e., do large grains ever appear to be indistinguishable from solid samples?

Ongoing studies: As more samples are prepared, we will continue to examine the effect of particle size on the spectral contrast of reststrahlen bands in rock samples. In addition, we will examine several other characteristics of the particulate samples, including: changes in transparency features as a function of particle size, mixtures of particulate size fractions, textural differences, spectral variation due to packing of powdered samples, and the potential influence of adsorbed water on interpretation of short wavelength features. All data will be convolved to TES 5 and 10 cm^{-1} spectral sampling in order to accurately assess the applicability of these results to TES analysis.

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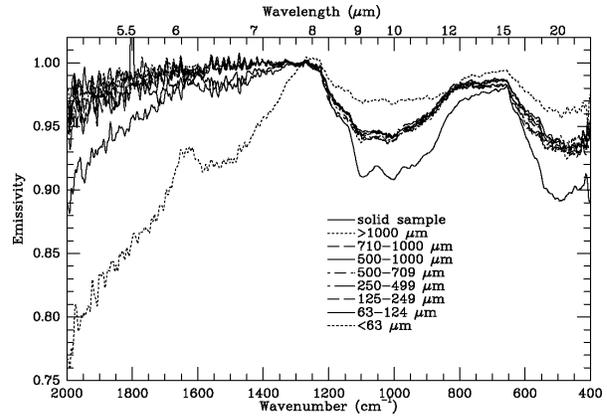
Figure 1. Emissivity spectra of basaltic particulates. Reststrahlen bands (8 – 12 μm and 15 – 25 μm) shallow with decreasing particle size and transparency features (5 – 8 μm and ~12 μm) exhibit decreased emissivity.