EFFECTS OF FINE PARTICLES (<25 μm) ON REFLECTANCE SPECTRA FROM 0.3 TO 25 μm. J. E. Hays and J. F. Mustard, Dept. Geol. Sci., Brown University, Providence RI, 02912

Introduction: One of the significant challenges to the use of visible-infrared spectroscopy for soil compositional analysis is separating the effects of particle size from composition. Weathering processes on most planetary bodies produce particulate surfaces where typical particle size distributions are dominated volumetrically by large particles but numerically by small particles. These fine particles dominate the spectral properties through increases in surface and volume scattering. Although there have been many studies documenting the effects of particle size on spectra (e.g. 1,2), there have been few studies to investigate the effects of very fine particles on reflectance spectra over the extended wavelength range from 0.3 to 25 μm. In this paper, we present the first results of a detailed investigation of the effects of particles <25 μm in size on the reflectance spectra of olivine over the wavelength range of 0.3 to 25 μm. Two fundamental results of this analysis are that the wavelength position of the transparency feature decreases as a function of decreasing particle size, and as the wavelength approaches the dominant particle size of each separate, the spectra exhibit a sharp decline in intensity.

Procedures: The sample used in this study is a fosteritic olivine (Fo 94) from Jackson County, North Carolina. The sample was first disaggregated and then the contaminants were removed by visual inspection. At this stage, many olivine grains possessed a thin rind of serpentine. This was removed through repeated light grinding and sieving until all the particles >100 μm were visually clean. The clean olivine was then ground to a fine powder with a mortar and pestle. A combination of dry and wet (ethanol) sieving procedures were utilized to acquire 18 grams of clean olivine with a particle size <25 μm. The 18 g of sample was professionally sieved by the Gilson Company into five particle size separates at 5 m intervals: 0-5, 5-10, 10-15, 15-20, and 20-25 μm. The actual size distribution for the separates were measured using an Elzone 280 PC Particle Size Analyzer (See Figure 1 for results). The spectra of each size separate was measured at the RELAB Facility at Brown University, from 0.3 to 2.6 μm with RELAB and from 0.9 to 25 μm with a Nicolet 740 FTIR Spectrometer. The Nicolet data was scaled and merged to the RELAB data at 1755 nanometers. These merged data are presented in Figure 2.

Results: The wavelength position of the spectral features related to compositional and structural properties of olivine were found to be largely invariant as a function of particle size. These include crystal field absorptions near 1.0 μm, the Christiansen feature and reststrahlen bands between 8.5 and 12.0 μm, and overtones and combinations of overtones of internal and lattice mode vibrations between 4 and 6 μm. This confirms the invariance of these primary diagnostic spectral features to the very finest particle size used in this analysis.

A small number of spectral features, however, do vary in wavelength as a function of particle size. The most notable of these is the transparency feature (3), near 13 μm. This feature exhibits a systematic shift in the position of the peak reflectance from 13.07 to 12.37 μm as particle size decreases (Figure 3). This shift in position was confirmed through repeated measurements with the biconical attachment on both on-axis and off-axis modes. In addition, the spectral contrast of the transparency feature changes with particle size. Initially, this feature increase in contrast as particle size decreases until a maximum contrast is reached at the 10-15 μm size range, then decreases again to the finest particle sizes (See Figure 2b).

Throughout the spectra shown in Figure 2, exists numerous changes in spectral contrast and intensity as particle size decreases. Most of these can be understood through basic principles of scattering and absorption (1, 2, 4). The two smallest size fractions (0-5 and 5-10 μm), however, exhibit unusual behavior in the near and mid infrared portion of the spectrum. The spectra of the 0-5 μm size fraction is the brightest in the visible and comparable to other spectra in the near infrared, until approximately 4 μm. At this wavelength, the intensity of the spectra begins to dramatically decrease, reaching a minimum shortwards of the Christiansen feature. The same behavior is observed for the 5-10 μm fraction, except the decrease in intensity occurs at a longer wavelength (6.5 μm). As the particle size of a surface becomes comparable to, and smaller than the wavelength of light, changes are expected in how particles and particulate surfaces scatter light. Mie theory provides a tool for determining the wavelength that this should occur for spherical

© Lunar and Planetary Institute • Provided by the NASA Astrophysics Data System

SPECTROSCOPY OF FINE PARTICLES...J. E. Hays and J. F. Mustard

particles. Hapke (1993) calculated with Mie theory that extinction efficiency undergoes a rapid decrease when the parameter (n-1)X decreases to values less than approximately 2 (n is the index of refraction, and $X=(\pi D)/\lambda$, where D is particle diameter and λ is wavelength). Assuming a an index of refraction of 2.0 and the numeric mean for the particle size separates from the lab, we calculated the wavelength predicted by (n-1)X=2. We found that for the 0-5 µm separate, the expected wavelength is 4.4 µm, and for the 5-10 µm separate, the expected wavelength is 7.1 µm. These calculated diameters are comparable to wavelengths where we qualitatively identified the onset of rapid decrease in reflectance.

Conclusions: The narrow particle size separates for particles < 25 µm in size allows us to investigate the effects of decreasing particle size on reflectance spectra from 0.3 to 25 µm. The most useful observation is that the wavelength of the transparency feature is not constant as particle size becomes very small. Therefore the use of the wavelength position of the Christiansen and transparency features as diagnostic indicators of composition (e.g. 5, 7) may not apply to samples and natural systems dominated by small particles. We are continuing these investigations with other materials and to further understand the physical processes occurring in the spectra of very fine particle sizes.

References: (1) Salisbury et al (1992) Infrared (2.1-25 µm) Spectra of Mineral, Johns Hopkins University Press, Baltimore, Maryland; (2) Pieters (1983), JGR, 88, 9534-9544; (3) Salisbury and Wald (1992) Icarus, 96, 121-128; (4) Clark and Roush (1984), JGR, 89, 6329-6340; (5) Salisbury (1993) Remote Geochemical Analysis, Pieters and Englert ed., Cambridge University Press, Cambridge; (6) Hapke (1993), Theory of Reflectance and Emittance Spectroscopy, Cambridge University Press, Cambridge; (7) Salisbury and Walter, (1989) JGR, 94, 9192-9202.

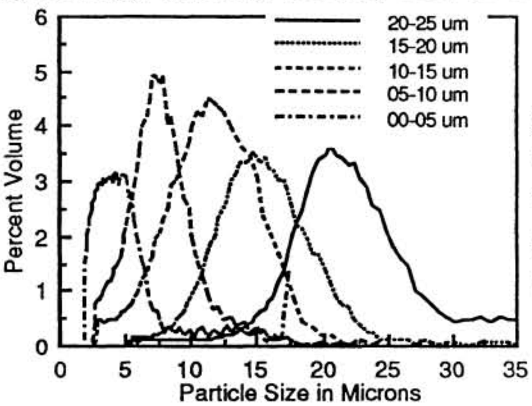

Figure 1. Distribution of particle size based on volumetric measuments.

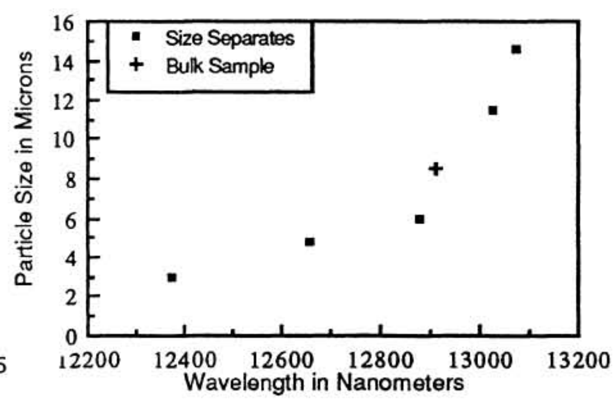

Figure 3. Wavelength position of peak reflectance of the transparency feature as a function of particle size.

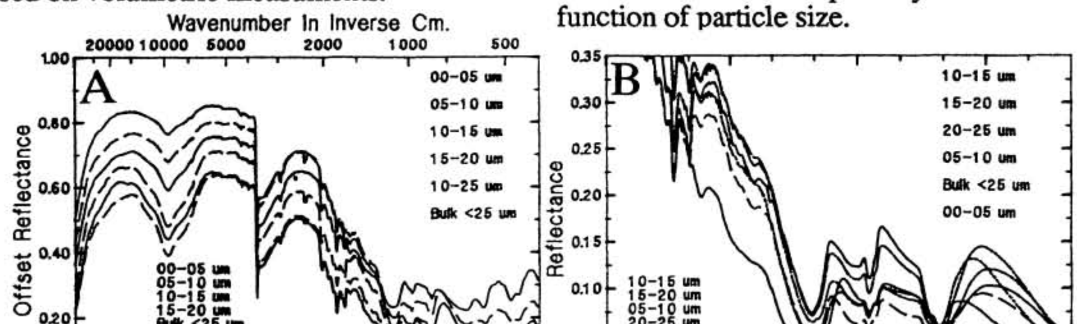

Figure 2. (a) Reflectance spectra of size separates and bulk sample. Spectra offset 5% veritically for clarity. (b) Detail of reflectance spectra in the mid infrared of size separates and bulk sample. Note the shift in postion of the transparency feature near 13µm with decreasing particle size.

© Lunar and Planetary Institute • Provided by the NASA Astrophysics Data System