

THE EFFECTS OF GRAIN SIZE, <45–1000 μm , ON THE REFLECTANCE SPECTRUM OF PLANETARY ANALOGS FROM 0.35–2.5 μm . M. A. Craig¹, E. A. Cloutis¹, and D. T. Bailey¹, ¹Department of Geography, University of Winnipeg, 515 Portage Ave., Winnipeg, MB, Canada R3B 2E9; m.craig@uwinnipeg.ca.

Introduction: There is significant evidence that basalt is widely present on the surfaces of a number of bodies in the inner solar system [1]. The spectral reflectance properties of three common planetary materials are presented here (basalt, olivine, orthopyroxene). Five different grain sizes of each have been spectrally characterized from 0.35 – 2.5 μm .

Experimental Procedure: The samples were gently crushed and dry sieved to obtain 5 different fractions: <45, 45-90, 90-250, 250-500 and 500-1000 μm . Absolute reflectance spectra were acquired with an Analytical Spectral Devices (ASD) FieldSpec Pro HR field portable spectrophotometer from 0.35 to 2.5 μm ; $i=0^\circ$, $e=0^\circ$ afforded via the use of a bifurcated fibre optic probe and illumination was provided by an ASD supplied QTH fibre optic light source. Spectral resolution is fixed at 2-7nm with a 1nm spectral sampling interval and 2000 spectra were averaged to increase the signal-to-noise ratio. Spectra were measured relative to halon and corrected for minor irregularities in halon's reflectance in the 2-2.5 μm range. Spectral measurements were taken with identical viewing geometries and probe to sample distances allowing for overall reflectance to be diagnostically useful. Each sample was placed in an identical aluminum sample cup, lightly tamped and "cut" across its top surface with a glass slide to provide a flat matte surface. The sample cups have a well 10mm in diameter and viewing geometry was maintained such that the 25° field of view of the bifurcated fibre optic probe imaged only sample and none of the sample cup.

Bands depths were derived by straight line fits tangent to the spectrum on either side of an absorption band of interest. For the pyroxene absorption band near 2 microns, the long wavelength side of the tangent was fixed at 2.5 microns. As the ASD spectrometer uses 3 detectors to cover the full wavelength range (0.35-1, 1-1.83 and 1.83-2.5 μm), there are often breaks in the spectra at the junctions (an artifact of the fibre optic assembly – three bundles feeding separate detectors); these breaks are corrected for in the presented spectra by normalizing to the central detector range.

Results: The results are presented in Figures 1-4. The first three figures show the spectra of olivine (OLV003), orthopyroxene (PYX032) and basalt (SA-51). Grain size fractions are as follows, from top to bottom: <45, 45-90, 90-250, 250-500 and 500-1000 μm for each figure respectively. Figure 4 is a scatter plot of band depth (y) vs. grain size (x). From top to

bottom: olivine band I, pyroxene band II, pyroxene band I and basalt (the second band in basalt is too shallow to reliably identify a band minimum). From left to right grain sizes: <45, 45-90, 90-250, 250-500 and 500-1000 μm . The trend-lines in figure 4 are 3rd order polynomial fits of the band depth data.

As expected, with increasing grain size overall reflectance decreases [eg. 1-3], but in each instance the spectra remain readily recognizable as the parent sample. There is however, a slight increase in band depth as grain size increases where it appears to reach a maximum with respect to grain size vs. band depth between <45 and 250 μm , and subsequently decreases as grain size increases further. Band centers are markedly consistent in the first three smaller grain sizes, only shifting subtly to longer wavelengths in the largest two fractions. The bands themselves shallow considerably at larger grain sizes complicating band center determination, likely due to band saturation; this is most evident in the spectrum of the 500-1000 μm fraction of pyroxene. Slopes of the straight line continua across the bands are also remarkably consistent for all grain sizes and samples, only shallowing marginally toward longer wavelengths with the two largest grain sizes in each sample.

The overall NIR slopes, taken from the onset of band I to the extinction of band II, set at 2.3 μm for the olivine and basalt samples and at 2.5 μm for the pyroxene are also remarkably similar. In the pyroxene and olivine samples the NIR slopes are all but identical for the first three fractions and again shallow to longer wavelengths only marginally in the largest fractions. For the basalt sample however, the NIR slope shallows dramatically to become near flat in the largest three fractions. Additionally in the basalt and pyroxene samples the slope of the 0.35-0.8 μm range shallows drastically as grain size increases while the reflectance minima at 0.35 μm remain within 0.07% of one another.

Discussion: Qualitatively assessing the affects of differing grain sizes on their spectra are complicated by three factors: (1) preferred orientation from non-equidimensional grains orienting themselves non-randomly resulting in spectral variation; (2) band saturation in the largest fractions complicating band center determination; (3) contamination by accessory phases is most likely in the smallest grain sizes. Of these three complicating factors, preferred grain orientation seems to not be an issue with these samples. Band saturation and contamination of the smallest fractions is evident.

In the largest fractions of both the olivine and pyroxene samples band saturation is apparent. With the olivine the saturation of the $1\ \mu\text{m}$ Fe^{2+} M2 band both complicates band center determination and obscures the Fe^{2+} M1 site side bands which are well resolved in the first 4 grain sizes [4]. Also apparent in the olivine spectra may be some minor accessory phases present in the two smallest fractions altering the spectral shape of the minor iron features before the onset of band I, although this may be due to other causes. In the largest pyroxene fraction, band II, Fe^{2+} M2 site [5] at $\sim 2\ \mu\text{m}$ is significantly saturated producing a nearly 200nm wide flat interval obscuring the band center.

Looking at figure 4, there would seem to be a consistent correlation between band depth and grain size that is linear up to a grain size of somewhere between <45 and $250\ \mu\text{m}$, which is mineral dependent. This same relationship is apparent in the work of other investigators. Combining their work and ours we find that band depth increases with increasing grain size to some value at which point it flattens out or begins to decline [1, 3].

Conclusion: Determination of the effects of multiple grain sizes is of importance for the remote sensing of planetary bodies and asteroids. Having an assemblage of differing grain sizes and bulk surfaces already spectrally characterized could prove quite useful in identifying mineralogy and aid characterization of the dominant grain size of the regolith. In particular the ability to recognize absorption band saturation would help to prevent spurious mineralogical identifications from being made and would assist in recognizing young planetary surfaces, which would be characterized by larger grain sizes due to the presence of young surfaces and immature regoliths. Acquiring spectra of grain sizes larger than those previously available fills in some of the gaps present between the largest grain sizes previously characterized and the spectra of bulk materials. In furtherance of this study we plan to add several more rocks and minerals, measure spectra of bulk surfaces and reacquire spectra of the three samples presented with a slightly altered viewing geometry and light source to improve the signal-to-noise ratio of the spectra at the highest wavelengths.

References: [1] Harloff J. and Arnold G. (2001)

PSS, 49, 191-211. [2] Hiroi T. and Pieters C. M. (1992) *LPSC*, 22, 313-325. [3] Mustard J. F. and Hays J. E. (1997) *ICARUS*, 125, 145-163. [4] Cloutis E. A. (1997) *JGR*, 102, 25,575-25,580. [5] Cloutis et al. (1986) *JGR*, 91, 11,641-11,653.

Figures 1-3: Grain size fractions from top to bottom: <45 , $45-90$, $90-250$, $250-500$ and $500-1000\ \mu\text{m}$ for olivine (Fig. 1), orthopyroxene (Fig. 2), and basalt (Fig. 3). **Figure 4:** Band depth (y) vs. grain size (x).

From top to bottom: **olivine band I**, **pyroxene band II**, **pyroxene band I** and **basalt**. From left to right grain sizes: <45 , $45-90$, $90-250$, $250-500$ and $500-1000\ \mu\text{m}$.

