

DERIVING FORMULAS FROM HED SPECTRA FOR DETERMINING THE PYROXENE MINERALOGY OF VESTA AND VESTOIDS. T. H. Burbine¹, P. C. Buchanan², and R. P. Binzel³, ¹Department of Astronomy, Mount Holyoke College, South Hadley, MA 02139, USA (tburbine@mtholyoke.edu), ²Museum für Naturkunde, Humboldt-Universität zu Berlin, Invalidenstrasse 43, D-10115 Berlin, Germany, ³Department of Earth, Atmospheric, and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA 02139, USA.

Introduction: Asteroid 4 Vesta is one of the target objects for the upcoming Dawn mission. Reflectance spectra of Vesta in the visible and near-infrared are similar to the spectra of the HED (howardite, eucrite, and diogenite) meteorites. Smaller bodies with reflectance spectra similar to Vesta and HEDs are usually called Vestoids.

HEDs are a clan of achondritic meteorites that have continuous variations in mineralogy and chemistry [1]. Eucrites are composed primarily of anorthitic plagioclase and low-Ca pyroxene with augite exsolution lamellae, while diogenites are predominately magnesian orthopyroxene. Howardites are polymict breccias containing fragments of both lithologies.

Pyroxenes have distinctive absorption features that are centered near 0.9 (Band I) and 1.9 μm (Band II) that are due to Fe^{2+} and are found in the reflectance spectra of Vesta and HEDs. These band positions move to longer wavelengths for increasing contents of Fe^{2+} and/or Ca^{2+} .

Gaffey et al. [2] has previously developed a number of formulas for determining pyroxene chemistries (Fs and Wo contents) from their Band I and Band II centers. Band centers are the band minima for spectra in which the continuum has been divided out. These formulas were derived from the spectra of minerals. This study uses high resolution spectra and detailed compositional analyses of HEDs to derive formulas for determining their average pyroxene mineralogies.

Data: Thirteen HEDs (Bouvante, EETA79005, EET 87503, EET 87542, EET 90020, Johnstown, Juvinas, LEW 87004, Pasamonte, Petersburg, PCA 82502, Stannern, Tatahouine) in the RELAB database had high-resolution reflectance spectra of fine-grained samples [3,4,5,6,7] and EMPA (electron microprobe analysis) data [7,8,9,10] from which the average pyroxene chemistries of the HEDs could be derived. The HEDs included ten eucrites, one howardite, and two diogenites. The spectra were all taken at 0.005 μm intervals for samples with grain sizes of less than 25 μm .

The HED spectra were fit using a smoothing algorithm in Matlab. To determine the Band I center, a linear slope tangent to the peaks near ~ 0.7 and ~ 1.4 μm was divided out of the spectrum. Since Band II usually had no appreciable continuum slope and the Band II extends past 2.5 μm , making it difficult to ac-

tually determine the continuum slope in this wavelength region, no continuum slope was divided out of the spectrum to determine the Band II center. Instead the Band II minimum was determined, which should be similar in value to the Band II center.

Average pyroxene mineralogies and Mg#s for all meteorites except for Johnstown, Juvinas, Pasamonte, and Stannern [8,10] were determined using the Cameca CAMEBAX and SX-100 electron microprobes at NASA Johnson Space Center or the JEOL JXA-8900R electron microprobe at the Natural History Museum at the Smithsonian Institution. For most analyses, instruments were operated at a voltage of 15 keV and a sample current of 20 or 30 nA. Except for Tatahouine, counting times for individual elements in the analyses tended to range from 20 to 40 s for major elements and 30 to 100 s for minor elements. For Tatahouine, six analyses were done for 30 minutes each and should represent the average pyroxene mineralogy since orthopyroxenes in diogenites have very uniform major-element chemistry [1].

The given pyroxene compositions represent average pyroxene mineralogies of the meteorites. Except for Tatahouine, a large number of analyses were done for each meteorite and ranged from 34 analyses on Juvinas to 266 analyses on EET 87503.

Analysis: The Gaffey et al. [2] formulas were tested using band parameters derived from the spectra of the thirteen HEDs with known average pyroxene compositions. The Gaffey et al. [2] formulas correctly predicted within error bars the Wo content of each meteorite and the Fs content in eight of the thirteen meteorites. The largest difference between actual and predicted Fs content was 9.8 mol%. The average difference in the actual content and predicted Wo content was 1.25 mol% while the average difference in the actual and predicted Fs content was 4.40 mol%. Both differences are within given error bars for the measurements. The Gaffey et al. [2] formulas primarily had problems with meteorites with molar contents of Fs greater than 50 and Wo greater than 11.

New formulas (Figures 1-6) with R-squared values were derived for calculating the Fs content, the Wo content, and Mg# from the Band I center and the Band II minimum. The formulas using the Band I center or the Band II minimum both predict the Fs content, the Wo content, and Mg# within similar uncertainties.

Both formulas for predicting the Fs content have average differences of 3.3 mol% between the actual and predicted Fs content. Both formulas for predicting the Wo content have average differences of 1.1 mol% between the actual and predicted Wo content. Both formulas for predicting the Mg# have average differences of 3.8 between the actual and predicted Mg# content.

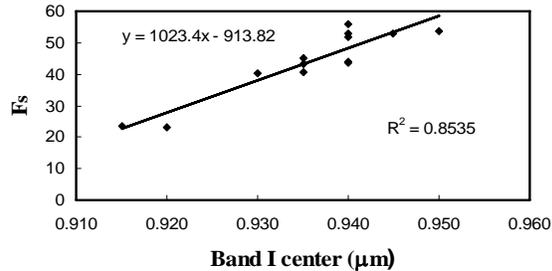


Figure 1. Band I center (μm) versus Fs content for the HEDs.

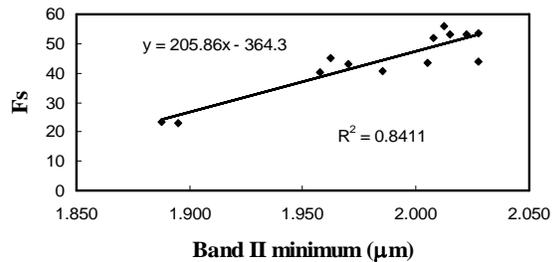


Figure 2. Band II minimum (μm) versus Fs content for the HEDs.

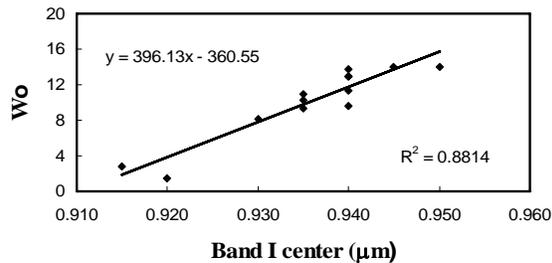


Figure 3. Band I center (μm) versus Wo content for the HEDs.

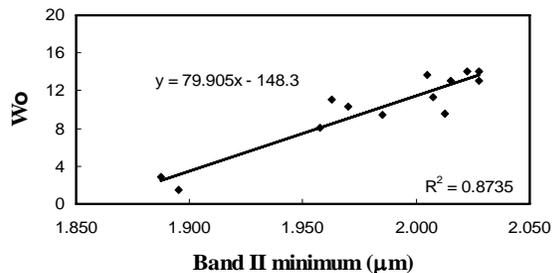


Figure 4. Band II minimum (μm) versus Wo content for the HEDs.

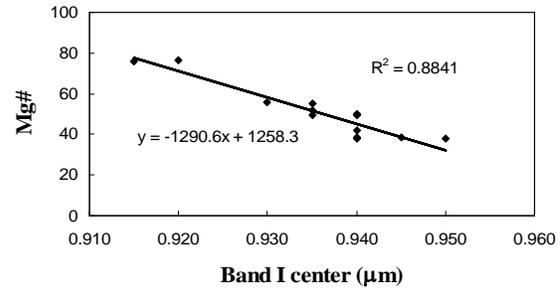


Figure 5. Band I center (μm) versus Mg# for the HEDs.

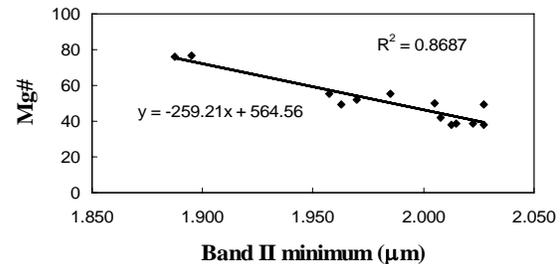


Figure 6. Band II minimum (μm) versus Mg# for the HEDs.

Conclusions: Using HED reflectance spectra, new formulas have been derived for determining the average Fs content, Wo content, and Mg# from the wavelength position of the Band I center and the Band II minimum. These formulas are currently being tested to see how well they predict the average pyroxene mineralogy of unknown assemblages.

References: [1] Mittlefehldt D. W. et al. (1998) *Reviews in Mineralogy, Vol. 36, Planetary Materials*, 4-1-4-195. [2] Gaffey M. J. et al. (2002) *Asteroids III*, 183-204. [3] Hiroi T. et al. (1994) *Meteoritics*, 29, 394-396. [4] Hiroi T. et al. (1995) *Icarus*, 115, 374-386. [5] Hiroi T. et al. (2001) *Earth, Planets and Space*, 53, 1071-1075. [6] Hiroi T. and Pieters C. M. (1998) *Antarctic Meteorite Research*, 11, 165-172. [7] Burbine T. H. et al. (2001) *Meteoritics & Planet. Sci.*, 36, 761-781. [8] Basaltic Volcanism Study Project (1981) *Basaltic Volcanism on the Terrestrial Planets*. [9] Buchanan P. C. (1995) Ph.D. dissertation, University of Houston. [10] Zema M. et al. (1997) *Meteoritics & Planet. Sci.*, 32, 855-862.

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