Supplemental material

Imaging spectroscopy methods and calibration

Imaging spectroscopy measurements of samples shown in examples 1 and 2 were performed at the Headwall Photonics, Inc. (Fitchburg, MA, USA) laboratory using engineering models of their High Efficiency Hyperspec® visible-near infrared (VNIR) E-series and High Efficiency Hyperspec® shortwave infrared (SWIR) X-series pushbroom systems. The VNIR imager covers 0.4 to 1.0 µm with a 1.785 nm sampling interval, 7 nm spectral resolution (the full width at half maximum of the slit intensity image), and 0.382 mrad instantaneous field of view (IFOV). The SWIR imager covers 0.95-2.5 µm with 12.0656 nm sampling, 12 nm spectral resolution, and 1.2 mrad IFOV. Samples were illuminated by a quartz tungsten halogen light source and imaged from nadir while the samples moved below the imager on a computer-controlled motorized scanning table from the Headwall Hyperspec® Starter Kit™. Calibration was done line by line through a dark current subtraction (S_d; image acquired with the lens covered) and then ratioing to an image of a Spectralon® panel (S_s), which is a near perfect reflector. Images were then corrected for known reflectance properties of Spectralon® (R_s) using spectrum HL-JFM-012 of the same material measured in the Reflectance Experiment Laboratory (RELAB, Brown University, Providence, RI, USA) and resampled to the wavelengths of the imagers. Calibration to reflectance (R) was done with the following equation:

$$R = \frac{S_t - S_d}{S_s - S_d} * R_s \ .$$

S_t is the image of the sample. VNIR and SWIR images were joined by warping the SWIR image to the VNIR image using manually selected control points, a first degree polynomial, and nearest neighbor resampling in Exelis Visual Information Systems ENVI®. The images were then

merged into a single image cube using VNIR bands covering wavelengths through 0.997 µm and SWIR bands longward of 0.998 µm and deleting overlapping bands. The SWIR bands were scaled to remove any offset between the VNIR and SWIR detectors using a multiplicative factor assuming that the actual reflectance is constant at each pixel at 0.997 and 0.998 µm.

The imaging spectroscopy data shown in examples 3 and 4 were acquired with the Ultra-Compact Imaging Spectrometer (UCIS) developed by the Jet Propulsion Laboratory (Pasadena, CA, USA) covering wavelengths 0.5-2.5 µm (Van Gorp et al., 2014). Calibration was done following the methods of Van Gorp et al. (2014).

Spectral and mineral indicator parameters

Spectral parameters calculating the depth of absorption features within reflectance spectra are commonly used in remote sensing data to map the likely presence and extent of compositional units (e.g., Clark and Roush, 1984; Pelkey et al., 2007; Viviano-Beck et al., 2014). Here, we calculate traditional spectral parameters mapping single features and then use combinations of those parameters to create mineral indicator parameters. This process allows for more accurate mapping of mineral components. For example, serpentine and calcite both have similar absorption features at 2.33-2.34 µm (e.g., Hunt and Salisbury, 1971; King and Clark, 1989). Calcite, however, also has an absorption feature longward of 2.5 µm (Hunt and Salisbury, 1971) that is expressed in these data as a downturn toward the long wavelength end of the detector at 2.5 µm. Serpentine has a boxy absorption feature at 2.1-2.2 µm (King and Clark, 1989). Calcite is mapped where the 2.34 µm feature and the downturn toward 2.5 µm are both present, and serpentine is mapped where the 2.1 and 2.33 µm features are present. Formulas for spectral parameters used in this paper are given in Supplemental Table 1, and formulas for

mineral indicator parameters are given in Supplemental Table 2. Spectral parameters shown in example 3 were calculated using formulas in Pelkey et al. (2007).

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Supplemental Table 1. Formulas for spectral parameters.

Spectral parameter	Formula	Interpretation
BD450	$1-\frac{2*\sum(Refl\ 0.451\ to\ 0.462)}{\sum(Refl\ 0.429\ to\ 0.440\ )+\ \sum(Refl\ 0.472\ to\ 0.483)}$	Tetrahedral Fe^{3+} in serpentine[1-3]
Positive SWIR slope	$\frac{R1.794+R1.806+R1.818}{R1.154+R1.167+R1.179}$	Related to iron oxidation state and mineralogy
BD1390	$1-\frac{2*(R1.384+R1.396)}{1.62*(R1.345+R1.360)+0.38*(R1.504+R1.516)}$	Mg_3-OH stretching overtone[4]
BD1410	$1-\frac{2*(R1.408+R1.420)}{0.72*(R1.345+R1.360)+1.28*(R1.504+R1.516)}$	Al_2-OH stretching overtone[4]
BD1900	$1-\frac{2*(R1.915+R1.927+R1.939)}{1.34*(R1.843+R1.854+R1.867)+0.66*(R2.036+R2.047+R2.060)}$	H-O-H combination[5]
BD2210	$1-\frac{{}^{4}/_{3}*(R2.20+R2.21+R2.22)}{{}^{13}/_{12}*(R2.15+R2.16)+{}^{11}/_{12}*(R2.27+R2.28)}$	Al-OH or Si-OH combination[5-7]
BD2300	$1-\frac{{}^{4}/_{3}*(R2.289+R2.301+R2.313)}{R2.205+R2.217+R2.386+R2.398}$	Fe/Mg-OH combination[5]
BD2310-20	$1-\frac{2*(R2.31+R2.32)}{{}^{10}/_{21}*(R2.15+R2.16)+{}^{32}/_{21}*(R2.36+R2.37)}$	Fe/Mg-OH combination[5]
BD2340	$1-\frac{2*(R2.337+R2.349)}{0.48*(R2.205+R2.217)+1.52*(R2.386+R2.398)}$	Mg_3-OH combination band or C-O overtone[4,8]
BD2340-50	$1-\frac{2*(R2.34+R2.35)}{{}^{12}/_{25}*(R2.15+R2.16)+{}^{38}/_{25}*(R2.40+R2.41)}$	Mg_3-OH combination band, Fe^{2+}-OH or C-O overtone[4,8]
D2500	$1-\frac{R2.482+R2.494}{R2.410+R2.422}$	C-O combination band[8]

R# = reflectance at # µm
Σ(Refl # to ##) = sum of reflectance of all bands from # to ## µm
References: [1]Burns (1993); [2]Dyar (2002); [3]Cloutis et al. (2011); [4]Bishop et al. (2008); [5]Clark et al. (1990); [6]Aines and Rossman (1984); [7]Goryniuk et al. (2004); [8]Hunt and Salisbury (1971)

Supplemental Table 2. Formulas for mineral indicator parameters.

Mineral	Formula
Calcite	BD2340>0 and D2500>0; Displayed value: BD2340
Fe/Mg-clay	(BD1390 or BD1410)>0, BD1900>0, BD2300>0, and D2500<0.1; Displayed value: BD2300
Serpentine	BD2120>0 and BD2340>0; Displayed value: BD2340