

TESTING THE INCORPORATION OF PORTABLE INFRARED IMAGING INTO A SAMPLING WORKFLOW TO ENHANCE SCIENCE RETURN BY ASTRONAUTS. G. Ito¹, A. D. Rogers¹, K. E. Young², J. E. Bleacher², C.S. Edwards³, and T. D. Glotch¹, ¹Stony Brook University, 255 Earth and Space Sciences Building, Stony Brook, NY 11794-2100 (gen.ito@stonybrook.edu), ²NASA Goddard Space Flight Center, MD, USA, ³USGS Flagstaff, AZ, USA.

Introduction: The sample collection workflow during future human missions to planetary bodies will likely incorporate portable/hand-held geochemical and mineralogical instruments. Rapid, in situ analyses of rocks and soils will allow astronauts to make strategic decisions most fit for the scientific objectives of the mission. Thus, crewmembers can quickly proceed to sample collection and work with the science team to develop and later test new hypotheses. In addition, ground- or rover-based spectral imagers allow for rapid compositional documentation of the site and sample context.

Though portable geochemical and mineralogical instruments are now widely available from commercial sources, there is little documentation about how to efficiently incorporate them into a traditional field geology and sampling process. As part of the RIS⁴E (Remote, In Situ, and Synchrotron Studies for Science and Exploration) SSERVI (Solar System Exploration and Research Virtual Institute) effort, we are testing the performance of candidate instruments and operational procedures through a series of field work expeditions that simulate lunar and asteroid conditions as best as possible on Earth [1-2]. One of the primary objectives is to understand the degree to which instruments, which can have significant operational overhead, can enhance the science return of a planetary field mission. Planned work includes incorporation of NIR and TIR spectral imagers, XRF, and a Raman point spectrometer into sampling decision-making at SSERVI target body analog sites.

For a broader overview of objectives and preliminary results that are part of the RIS⁴E field efforts, see Young et al. and Glotch et al. (this meeting [1-2]). This abstract focuses only on the initial outcomes of using the portable TIR multispectral imager during our first expedition in September 2014.

Location: Volcanic lava fields were chosen as our field site because the landscape and mineralogy represent a reasonable analog to surfaces of the Moon and some differentiated asteroids. Field work took place at Kilauea Volcano, Hawaii. This volcanic field is characterized by glassy basalts containing olivine and plagioclase phenocrysts and ash deposits [3]. Near vents, variations in silica coating thickness cause spectral differences; in ash units away from the vents, spectral differences are caused by increasing presence of opal-

ine silica and iron oxides [4]. Because the mineralogy and surface properties are already reasonably well-characterized, Kilauea Volcano is a well suited field site for testing field instruments and sample collection procedures.

Instrument: Mineralogy of rocks and sands in the field site are inferred from thermal infrared spectroscopy. We use a commercial Forward Looking Infrared (FLIR) T-640 Thermal Imager modified with five custom filters. Custom spectral filters were designed to transmit at 8.3 μm , 8.6 μm , 9.1 μm , 10.3 μm , and 11.3 μm , covering the 8 – 12 μm range of highest terrestrial atmospheric transmittance in the thermal infrared. Ground-based multispectral TIR imaging techniques have been previously described by [5].

Methods: At the field site, we stopped at major areas of interest, such as volcanic vents and sub-unit contacts, to collect samples just as if an astronaut was walking on an extraterrestrial surface. Some stops were pre-decided based on analysis of airborne Thermal Infrared Multispectral Scanner (TIMS) data. The FLIR imager was mounted on a tripod to minimize movement of the instrument during the image acquisition process. By changing the filters, consecutive images of the same scene were acquired in the designated wavelength bands. GPS coordinates were recorded at each stop, and technical data, such as total time of acquisition and number of people involved, were recorded. Because portable data processing was not available, we processed the images at our base camp and returned to the site for sampling the following day.

Post-acquisition image processing included band registration, calibration to radiance, atmospheric correction, and conversion to emissivity. Then, multiband images were reduced for visual evaluation using principle component analysis, decorrelation stretch, or spectral classification. Using the processed data, we returned to the location of image acquisition for sample collection. Rock/soil sample collection was driven by spectral distinctiveness in the previously-acquired images.

Collected samples were brought to the Vibrational Spectroscopy Laboratory at Stony Brook University and thermal emission spectra were acquired. The validity of the instrument spectral analysis was evaluated by comparing spectra acquired from the instrument to those of laboratory.

Results: Eighteen stops were made over the course of two days and corresponding sets of images were acquired. The average image acquisition time was ~5 minutes. A processed image of a sub-unit contact location is displayed in **Figure 1** as an example. In the scene, older, undivided pahoehoe flows, consolidated ash, and loose ash/sand are present. The ground-truth comparison of spectra processed in this particular scene is illustrated in **Figure 2**, where instrument spectra are compared to laboratory spectra from collected samples.

Discussion and Future Work: Preliminary results show relatively strong agreement between laboratory and field acquired spectra. This indicates that multi-spectral TIR imaging can distinguish spectral variations and aid the sample collection process (**Figure 2**). Visible images alone cannot clearly capture mineralogical variations within the scene; the aid from a processed image is a valuable tool for astronauts when scrutinizing the field site to find the most effective sampling locations. Differences between the field and laboratory spectra (**Figure 2**) highlight the need for improved calibration, however.

Presently, our field operation is not satisfactorily efficient, but our initial work allowed us to identify many areas in image acquisition, data processing and field operation techniques that can be improved prior to our next field excursion. For example, one problem encountered was matching the sample of interest on the displayed image to its actual outcrop location. Different unit delineation approaches will be tested in the future. In addition, adjustments to the band registration and calibration process will improve the measurement accuracy and quality of higher level derivative products that are used in the field.

Laboratory spectral, mineralogical and geochemical measurements for all collected samples [1] are presently being acquired. This will allow direct assessment of spectral sensitivity to geochemistry and mineralogy and better definition of thresholds for defining units as distinct or unique. Near-infrared imaging will also be incorporated into future field work.

References: [1] Young, K. E. et al., this meeting [2] Glotch, T. D. et al., this meeting [3] Wright T. L. (1971) *U.S. Geological Survey Prof. Paper*, 735, 40pp. [4] Seelos K. D. et al. (2010) *JGR*, 115, E00D15. [5] Ramsey, M. S. and A. J. L. Harris (2013), *J. Volc. Geo. Res.* 249, 217-233.

Acknowledgement: Work was conducted within the Hawai'i Volcanoes National Park under National Park Service science permit #HAVO-2012-SCI-0025. Funding is from the RIS⁴E SSERVI.

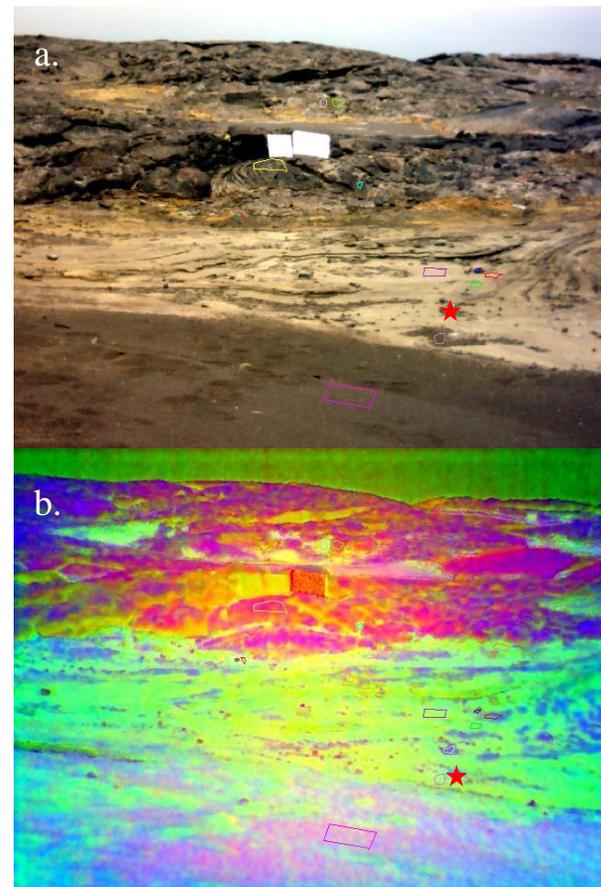


Figure 1. Images of an outcrop with exposed contacts of subunits. a. Visible image. b. Decorrelation stretched image of emissivity of the scene calculated from radiances taken using the five filters. Older undivided flows appear magenta/red, consolidated ash appears green/yellow, and loose ash/sand appears cyan/magenta. Red star indicates the location of sample used to obtain laboratory spectrum shown in Figure 2.

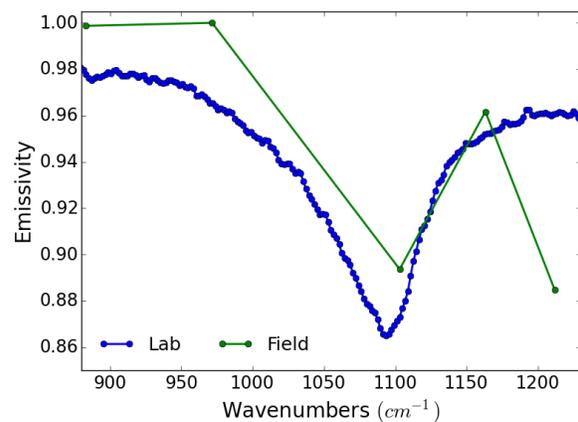


Figure 2. Laboratory spectrum of a collected sample (blue) compared to a spectrum acquired in the field (green). The sample location is indicated by a red star in Figure 1.