Exploration at the Hand Lens Scale: Results from the 2010 ILSO-ISRU Field Test Using the Multispectral Microscopic Imager.

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Introduction: To maximize scientific return, future robotic and human missions to the Moon, or Mars will need to have *in-situ* capabilities to enable the selection of the highest value samples for further analysis. In order to accomplish this task efficiently, samples will need to be characterized using a suite of instruments that can provide information about elemental composition, mineralogy and microtexture. Such spatially-correlated data sets, which place mineralogy into a microtextural context, are considered crucial for correct petrogenetic interpretations.

The Multispectral Microscopic Imager (MMI) combines microscopic imaging with visible/near-infrared reflectance spectroscopy, to obtain mineralogical information within a microtextural context. MMI images require minimal surface preparation and provide data sets that are comparable to what geologists routinely acquire in the field, using a hand lens, and in the lab using thin section petrography. Microtexture and mineralogy provide essential information for interpreting primary formational processes for rocks and soils, as well as secondary (diagenetic) alteration processes. Such obervations also provide "ground truth" for orbital data.

MMI Instrument: The development version of the Multispectral Microscopic Imager (MMI) used in this investigation (Figure 1) captures multispectral, microscale reflectance images of geological samples at 62.5 µm/pixel resolution, where each pixel consists of a spectrum ranging from the visible to the short-wave infrared (463 nm to 1735 nm) [1], [2]. This spectral range enables the discrimination of a wide variety of rock-forming minerals, especially Fe-bearing phases, and enables the detection of hydrated minerals within a microtextural framework [3], [4].

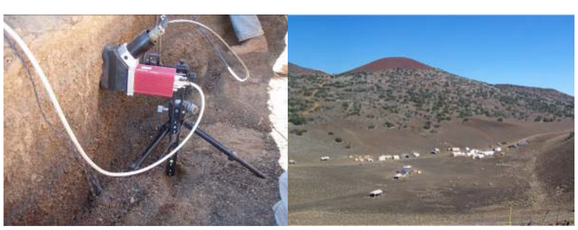

Figure 1. Field deployment of the MMI as part of the 2010 ILSO-ISRU Field Test. Left panel: MMI on tripod imaging a vertical outcrop in volcanic sediments. Right panel: ISRU base camp on the southern slopes of Mauna Kea.

Field Investigations with the MMI: To assess the value of the MMI as a tool for future exploration applications, we deployed a field-portable, tripod-mounted version of the MMI in the field as part of the 2010 International Lunar Surface Operations *In-Situ* Resource Utilization (ILSO-ISRU) Field Test on the slopes of Mauna Kea, Hawaii [5]. The MMI was used to image rocks and soils *in-situ*, in support of ISRU experiments, and to assess the performance of the MMI when operating under daytime illumination and adverse weather conditions, including cold operating temperatures and strong winds (Figure 1).

Results: Figure 2 shows data obtained with the MMI from the natural outcrop shown in Figure 1. The 50 cm high outcrop exposes a layered sequence of pyroclastic beds showing a range of textures and compositions. This deployment provided an opportunity to evaluate the capabilities of the MMI to image a rough, vertical surface under daytime illumination (Figure 1), and to use mechanical positioning of the camera to produce a mosaic of overlapping microscale images covering the entire stratigraphic section (Figure 2A).

The MMI composite images faithfully resolved the microtextural features of rocks and soils in outcrops and samples over a broad range of lithologies and grain sizes (e.g. Figure 2). The application of spectral end-member mapping (using ENVI) revealed the distribution of Fe-bearing mineral phases within samples, including silicates (e.g. olivine and pyroxene), oxides/hydroxides (e.g. hematite, goethite, and ferrihydrite) and plagioclase feldspar. The MMI composite images and spectra also revealed the presence of hydrated minerals in samples (e.g. Figure 2). Our MMI-based petrogenetic interpretations compare favorably with laboratory observations (including XRD).

Conclusions: The utility of the MMI for characterizing the microtexture and mineralogy of rocks and soils has been successfully demonstrated over a broad range of field and laboratory applications, as well as mission simulations [6], including field deployments during the 2010 ILSO-ISRU Field Test on the slopes of Mauna Kea, Hawaii. Ruggedization and packaging of the MMI for remote field and lab deployments has significantly advanced the Technology Readiness of the MMI for future mission opportunities and increased the value of the MMI for astronaut and rover-based exploration of the planetary surfaces.

References: [1] Sellar R. G. et al. (2008) *Joint Ann. Meet. LEAG-ICEUM-SRR*, Abstract #4075. [2] Nuñez J. I. et al. (2009) *LPSC XL*, Abstract #1830. [3] Nuñez J. I. et al. (2010) *LPSC XLI*, Abstract #1581. [4] Farmer J. D. et al. (2011) *LPSC XLII*, Abstract #1544. [5] ten Kate I. L. et al. (2012) *J. Aerospace Eng.*, In Press. [6] Farmer J. D. et al. (2011) *EOS Trans. AGU Fall Meeting*, Abstract #P33B-1767.

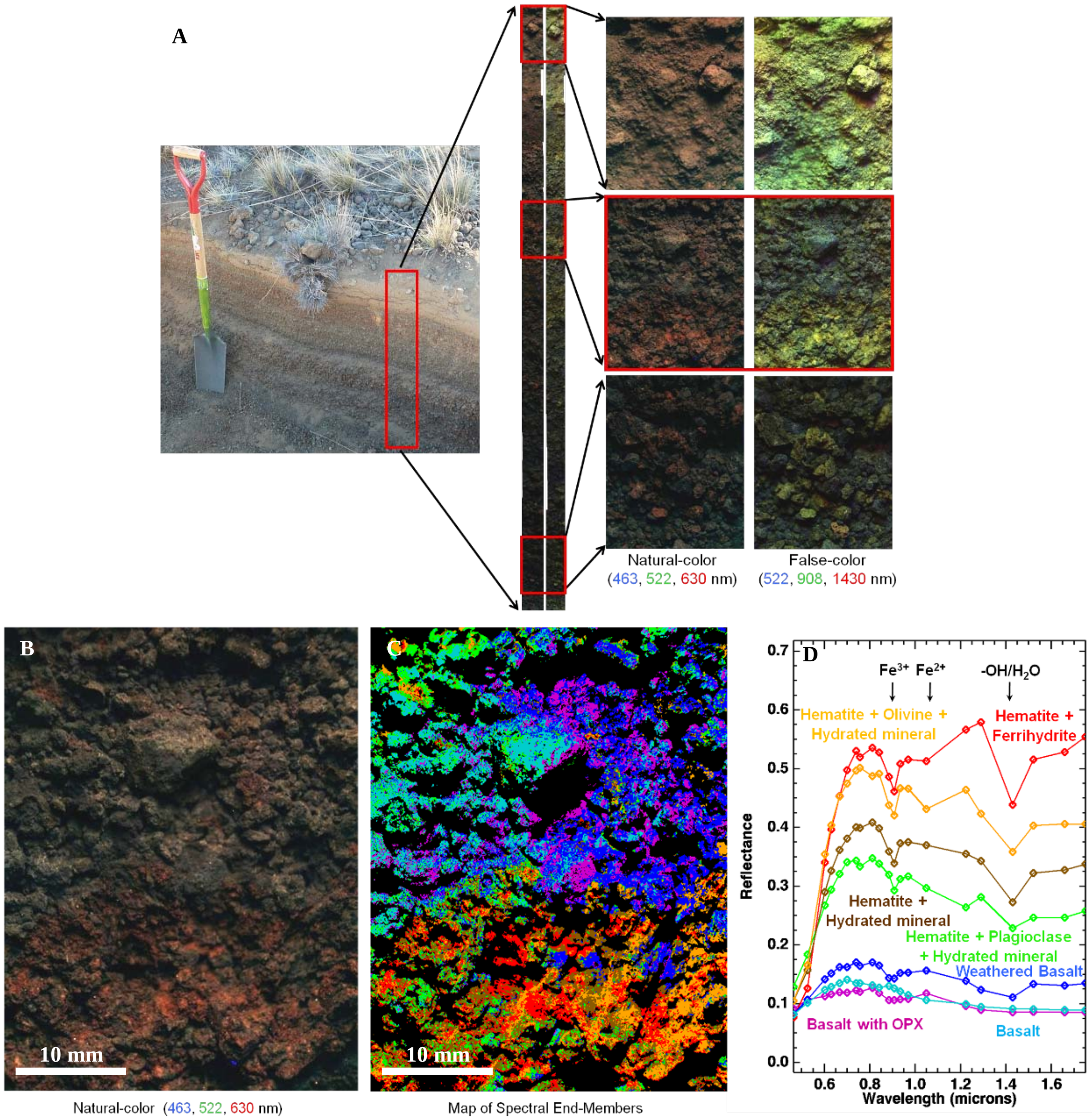

Figure 2. 2A: Mosaic of microscale multispectral reflectance images (center) obtained with the MMI deployed on a 50 cm high outcrop of layered pyroclastic deposits (left). The mosaic is shown in central column and was stitched together from overlapping MMI images obtained along the entire stratigraphic section. Individual frames are shown at higher magnification in the columns to the right. The left images consist of linear stretched visible color bands (RGB = 630, 522, 463 nm), to simulate natural color, while the right column shows linear stretched images in visible and near-infrared bands (RGB = 1430, 908, 522 nm). 2C: Corresponding spectral end-member map produced by processing the spectral data in ENVI. 2D: Plots of spectra representing the spectral end-members mapped in 2C. MMI field-of-view: 40 mm x 32 mm (62.5 μm/pixel).