REMOTE MAPPING OF THE KA'U DESERT, HAWAI'I: SILICA IN A MARS ANALOG TERRAIN.

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Introduction: The Ka'u Desert, a relatively young semiarid terrain located southwest of Kilauea caldera, exhibits a wide variety of lava flows, ash deposits, solfataras, and other volcanic landforms. Active solfataras emit sulfurous gases and steam that deposit silica, native sulfur, and gypsum on the surrounding surfaces. Ash and tephra deposits are being reworked through aeolian activity, in places forming weak silica-cemented duricrusts and partially mantling even the youngest (1971, 1974) pahoehoe flows. These same flows commonly exhibit very thin (<15 μm) silica and titanium-rich coatings. Multiple remote sensing datasets as well as field and laboratory observations were used to evaluate the character of these materials and map their distribution in a manner parallel to what will be possible with current and upcoming Mars datasets. The surprisingly common presence of silica and its influence in the spectral properties of nearly all identified materials has important implications for remote mapping of the Martian surface, both for VISIR reflectance and thermal emission spectroscopy.

Methodology: The 2.5 x 3.5 km study area was examined using three primary remote sensing datasets: Airborne Visible Near-Infrared Imaging Spectrometer (AVIRIS) data, Landsat Thematic Mapper Simulator (NS001) composites, and grayscale airborne panchromatic images. AVIRIS data are hyperspectral with 224 channels distributed throughout the spectral range of ~0.4 to 2.5 μm, and spatial resolution of about 17 m/pixel [1, 2]. After atmospheric correction procedures were applied, AVIRIS data were used to identify spectral endmembers within the study site and deduce dominant mineralogic signatures. Concurrently, examination of the multispectral infrared through thermal NS001 composite images and panchromatic images, with spatial resolutions of ~7 m/pixel and 2 m/pixel, respectively, allowed generation of a geologic materials context map. Previously published geologic maps of the area [e.g. 3] served as a basis for many unit names and relative age estimates.

Detailed laboratory analyses on samples collected in August 2002 were performed in order to better define the mineralogy and physical nature of the materials. Analysis techniques included reflectance spectroscopy, Laser-Raman spectroscopy, X-Ray Diffraction (XRD), and Electron Microprobe.

Geologic Materials: The distribution of geologic materials and landforms identified within the study site is shown in Figure 1.

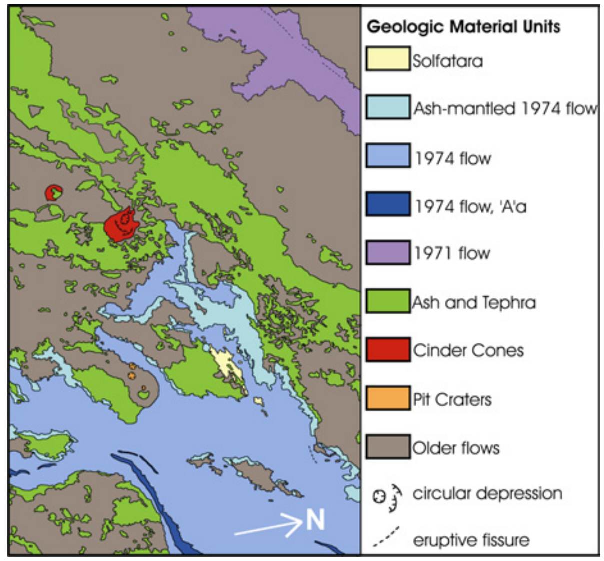

Figure 1. Geologic material map of the Ka'u Desert study area (2.5 x 3.5 km, centered at approx. 19º21'30"N, 155º19'W). Kilauea caldera is ~6 km to the Northeast.

Lava flows. The "basement" material in the study area are lava flows generated from caldera eruptions 500-700 years ago [4]. These older flows exhibit ropey pahoehoe surface textures and are brownish in appearance. In AVIRIS (Figure 2) and laboratory reflectance spectra, OH and Fe^{3+} absorptions are dominant. Raman spectral analyses detected the presence of amorphous silica and hematite along with lesser amounts of olivine and magnetite.

In contrast, the 1971 and 1974 flows from fissure vent eruptions in the upper Ka'u Desert appear fresh and glassy. The surface of these flows often exhibit whitish-blue coatings interpreted by Raman and electron microprobe analyses to consist of a thin (5-10 μm) silica-rich layer overlain by a discontinuous TiO_2-rich layer (<5 μm thick). The reflectance peaks at ~0.5 μm and negative slopes into the infrared observed in the two AVIRIS endmembers (1971,74-A and 1971,74-B) are consistent with glassy coatings on dark substrates [5, 6].

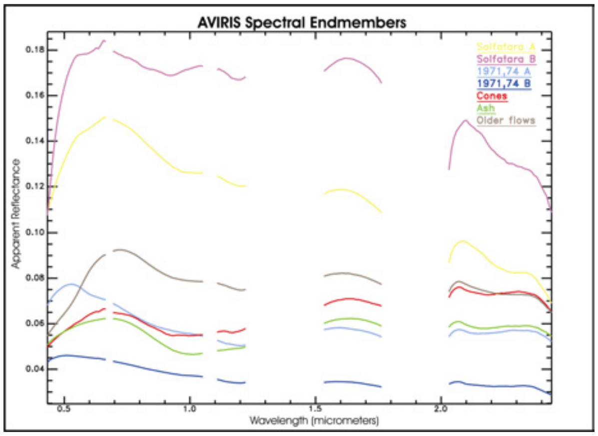

Figure 2. Endmember spectra from analyses of AVIRIS hyperspectral data. Gaps around 1.4 and 1.9 µm correspond to water and CO_2 atmospheric absorptions.

Ash deposits. Lava swales and depressions of the older flows are filled with Keanakako'i ash and tephra deposits. This ash is actively being reworked [7], forming dunes and mantling younger flows in places, but also exhibiting weak surface crusts. Raman and XRD analyses of the ash found plagioclase and pyroxene to be the dominant mineral types, which is consistent with the broad, shallow ~1.0 and ~2.0 µm absorption bands observed in reflectance measurements (Ash endmember spectrum). Areas of duricrust-like materials are comprised of aeolian ash grains held together by amorphous silica cement (Figure 3).

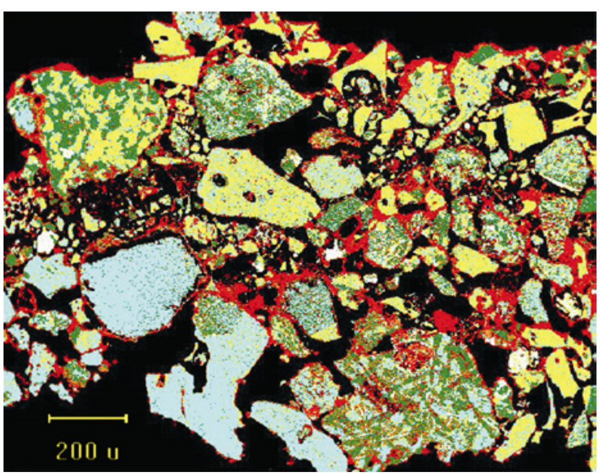

Figure 3. Backscattered electron image of a duricrust profile. The silica cement (shown in red) drapes over and between the aeolian ash grains. Scale bar is 200 µm.

Solfataras. Active solfatara zones consist of bright white and yellow surface incrustations. Reflectance spectra of these materials (Solfatara A and Solfatara B) show relatively strong water and OH absorptions consistent with amorphous silica as well as a sharp drop-off near 0.45 µm indicative of sulfur [8]. Raman and XRD analyses confirmed the presence of these minerals in addition to minor amounts of gypsum. Significant gypsum and native sulfur deposits were observed in the near subsurface at the vent sites.

Discussion: The presence of amorphous silica in nearly all Ka'u Desert materials poses interesting questions regarding geochemical cycles. Coatings, cements, and incrustations may be formed through accretionary processes, although the formation of a TiO_2-rich layer on the 1971 and 1974 flows is less easily explained. These recent flow coatings are observed in even greater abundance closer to Kilauea caldera, perhaps implying that pH-dependent dissolution, aerosol deposition, or leaching processes may be important. Further field and laboratory investigations are planned for summer 2003.

Spectral observations of the diverse array of Ka'u Desert materials hold important implications for Mars remote sensing studies. Upcoming 2003 OMEGA and 2005 CRISM spectrometers have specifications similar to AVIRIS, and will be capable of detecting silica absorption features. Like the Ka'u Desert, abundant silica in a Martian volcanic terrain may be indicative of hydrothermal-related geochemical processes conducive to habitable environments for microbial ecosystems.

Conclusion: The young basaltic Ka'u Desert terrain contains a diverse assemblage of Mars analog materials, including pahoehoe lava flows, ash deposits, and solfataras. The prevalence of amorphous silica as coatings, cement, or incrustations imply geochemical processes which may have been operational within similar Mars volcanic terrains. Upcoming imaging spectrometer missions to Mars are capable of distinguishing these types of materials and may lead to the identification of target sites for further remote or landed exploration.

References: [1] Green R. O. et al. (1998) *Rem. Sens. Env.*, 65, 227-248. [2] Vane G. et al. (1993), *Rem. Sens. Env.*, 44, 127-144. [3] Wolfe E. W. and Morris J. (1996), *USGS MAP I-2524-A*. [4] Holcomb R. T. (1987) USGS Pro. Paper #1350. [5] Bishop J. L. (2002) *LPS XXXIII*, Abstract #1170. [6] Fischer E. K. and Pieters C. M. (1993) *Icarus,* 102, 185-202. [7] Malin et al. (1983) *GSA Bul.* 94, 1148-1158. [8] Hunt G. R. et al. (1971b) *Mod. Geo.,* 3, 1-14.

Acknowledgements: Washington University Pathfinder students contributed to the field and laboratory analyses, including Alex Morel who is studying duricrust materials.