ON THE SPECTRAL REFLECTANCE PROPERTIES OF MATERIALS EXPOSED AT THE VIKING LANDING SITES

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Reflectance data derived from Viking Lander multispectral data were used to characterize the types of soils and blocks exposed at the landing sites and to search for evidence of relatively unaltered igneous rocks. Despite past research efforts [1-5], there has yet to be a comprehensive examination of the multispectral data that combines testing of the Camera radiometric calibrations, explicitly removing the effects of atmospheric attenuation and skylight, and quantitatively comparing the corrected data to reflectance data from laboratory materials. This abstract summarizes our work Guinness et al. [6] which reports such comprehensive efforts. Bi-directional reflectances for blue (0.40-0.52 µm), green (0.50-0.59 µm), and red (0.60-0.74 µm) channels were determined for 31 block and soil exposures at the Viking Landing sites. In order to interpret the mineralogy of the landing site materials, the Lander data were compared to laboratory spectra of selected materials and Earth-based telescopic spectra of Mars after the laboratory and telescopic data were resampled to the Lander bandpasses.

The uncertainty in the Lander reflectance estimates must be well-known in order to compare Lander data acquired by the four different Cameras and to compare Lander reflectance estimates to laboratory reflectance data. Preflight calibrations were tested by analyses of the brightness values obtained from sunlit and shadowed gray patches mounted on the Landers, which have well-defined Lambertian scattering characteristics. Except for Camera 2 on Lander 1, the results were consistent with the combined 8% uncertainty in the radiometric calibrations measured in the preflight tests [7], 3% uncertainty in the analog-to-digital conversion [8], and the uncertainty in the optical depth value. We concluded that the preflight calibrations for the color channels are still valid (with the possible exception of Camera 2 on Lander 1) and that reflectances can be computed with an uncertainty of about $\pm10\%$ due to radiometric calibration and analog-to-digital conversion uncertainties. Partially shadowed RTC images acquired with the three infrared channels suggested that there have been changes in the calibration constants of the infrared channels or wavelength dependent changes in the spectral responsivity functions. Both types of changes were predicted from modeling of neutron induced degradation of the infrared channels [7]. As a result, the infrared channels are poor prospects for extraction of absolute reflectance. More importantly, it is difficult to make comparisons with laboratory samples since we cannot determine the nature of the wavelength dependent changes to the responsivity functions. Thus, we limited our analysis of absolute reflectances to data from the blue, green, and red channels from the 3 Cameras where the preflight calibration data are still valid. However, it was clear from the RTC data that voltage versus RTC gray patch reflectance was still linear for the infrared channels. This suggested that the IR channel detector sensitivities were still linear, although absolute values and IR spectral properties were questionable. Thus, the infrared channels were used to explore relative brightness variations with wavelength, albeit in more qualitative ways than with the blue, green, and red channels.

Laboratory analogs used for this analysis were chosen primarily for their compositional and spectral relevance to Mars, based on the interpretation of, for example, Viking Lander chemical measurements and Earth-based telescopic reflectance spectra [9-11]. Samples included the ferric oxides hematite, goethite, and limonite, two Hawaiian palagonitic soils, hematitically altered

volcanic cinders, and seven mafic igneous rocks (fresh and weathered surfaces of each). Four telescopic spectra were chosen as representative data in the spectral region of interest, including a bright region and a dark region observation from both the 1969 [12] and 1973 [13] oppositions. The comparisons of the Lander reflectance data to laboratory spectral data was primarily based on spectral shape. The blue, green, and red reflectances can be used to characterize spectral shape in terms of spectral curvature and slope. The red/green reflectance ratio divided by the green/blue reflectance ratio was used to measure spectral curvature. We found that this curvature parameter was related to ferric oxide mineral type as well as degree of crystallinity in laboratory samples. Larger values of curvature would, for example, be consistent with greater degrees of ferric iron crystallinity because the green channel is sensitive to the depth of the ferric iron absorption near 0.45-0.54 µm. This measure was also very sensitive to the spectral difference between mineral phases such as hematite and goethite. In addition, we used the ratio of the red and blue reflectances to measure the slope of the spectra. The red/blue ratio will generally increase as the degree of oxidation of iron bearing materials increases [14-15].

The variations in bi-directional reflectance in the visible and relative brightness in the infrared for Lander soils and blocks can best be explained by varying composition (i.e., degree of oxidation, mineralogy, and crystallinity) among the different samples. The darkest, grayest block surfaces are consistent with laboratory reflectance spectra of mafic rocks, thinly coated with ferric iron-rich palagonite. Such a result is consistent with the low relative reflectance for the dark facets determined from images acquired with the infrared channels. More rigorous determination of substrate rock composition (e.g., ultramafic, basalt, or basaltic andesite) requires complete spectral data in the near-infrared region. Most other block surfaces are consistent with thin to optically thick covers of palagonitic material [10]. Limited exposures of soil have blue, green, and red reflectances that are similar to palagonitic material. One soil exposure has a spectral shape that is similar to a sample of hematitically altered volcanic cinder. The bulk of the soils sampled and a few block surfaces have spectra with steeper slopes and larger curvatures than the palagonite analog. In particular, one reasonable interpretation is that the most commonly sampled soil exposed at the landing sites may have a greater degree of ferric iron crystallinity than the palagonite analog. These soils could also be an intimate mixture of palagonitic material and other materials not seen in end-member form. But, if intimate mixing occurs, these other materials would need an even greater slope and curvature than the observed soils, and be presumably even more different from material seen on block surfaces in terms of the degree of ferric iron crystallinity.

The distinctly different spectral shape of most observed soils as opposed to blocks imply that soils at the landing sites have not been produced by local weathering of blocks. Even if mixing occurs between material weathered from blocks and a soil end-member not exposed at the landing site, it implies that soils at the landing sites are not predominantly derived from local weathering of blocks. A more plausible scenario is one where soils are created globally by a number of processes that operated at higher rates earlier in geologic time. For example, Baird and Clark [16] make compelling arguments that soils are derived from mafic to ultramafic source blocks in some isochemical process. Palagonitization of basaltic magmas and basaltic glass have also been proposed as an important mechanism [17-18]. The materials would then be transported and would accumulate at a variety of locations. Once deposited, further erosion would sort the material, and evaporation of fluids would lead to generation of duricrust. At least at the

landing sites, blocks would have been steadily added to the site by impact events and exposed to slow, perhaps steady state weathering generating only a small amount of soil. This scenario implies that the bulk of the soil at the sites carries little information about the local geology.

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