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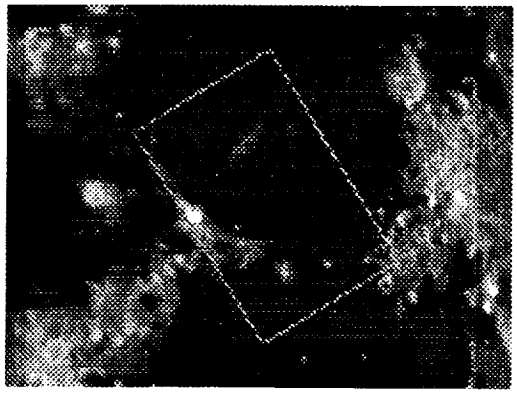
HIGH SPATIAL RESOLUTION TELESCOPIC MULTISPECTRAL IMAGING AND SPECTROSCOPY OF THE MOON: I. THE SERENITATIS/TRANQUILLITATIS BORDER REGION; J.F. Bell III (NRC/NASA Ames Research Center, Moffett Field, CA 94035) and B.R. Hawke (PGD/SOEST, University of Hawaii, Honolulu, HI 96822).

The region of the Moon near the border between Mare Serenitatis and Mare Tranquillitatis is one of the most geologically and compositionally complex areas of the nearside. The geologic history of this region has been shaped by impacts of widely-varying spatial scale and temporal occurrence, by volcanism of variable style and composition with time, and by limited tectonism. We have been studying this region as part of a larger multi-remote-sensing-technique effort to understand the composition, morphology, geology, and stratigraphy of the Moon at spatial scales of 2 km or less [cf. 1, 2]. We have been aided in this effort by the proximity of this area to the Apollo 11, 15, and 17 landing sites and by the occurrence of one of the primary lunar spectroscopic "standard areas" within our scene (MS2). Here, we report some of the findings from the multispectral imaging and spectroscopy part of this effort [3].

The reflectance spectra analyzed here were obtained with the UHPGD near-IR circular variable filter (CVF) spectrometer with a cooled InSb detector. The data were obtained at a spectral resolution of $\Delta\lambda/\lambda \approx 1.25\%$ over the wavelength range 0.65 to 2.6 μm using the University of Hawaii 2.24-m telescope at Mauna Kea Observatory. The CVF was stepped through 112 wavelengths over the course of about 90 seconds, and anywhere from 2 to 6 independent measurements were made of each region. Observations were carried out on October 29 and 30 UT, 1985, at a lunar phase angle of 10° and 20° respectively. The 2.24-m telescope was configured at *f*/35, yielding at spot size of 1.3 km diameter on the Moon using the smallest aperture and assuming 0.65 arcsec seeing. Spectra were obtained of 20 regions in the Serenitatis/Tranquillitatis region [4] as well as of the Apollo 16 landing site.



Telescopic multispectral CCD images of the Serenitatis/Tranquillitatis region were obtained using a 384×576 pixel Photometrics cooled CCD camera. The camera and an uncooled narrowband filter wheel were mounted to the University of Hawaii Planetary Patrol 61-cm telescope at Mauna Kea Observatory. Images were obtained in 8 narrowband transmission filters, chosen to maximize the potential spectral differences between the units in the different regions. Observations were carried out on August 7 1990 UT at a lunar phase angle of 10°. The Planetary Patrol telescope was configured at *f*/13.5, yielding a plate scale of 0.573 arcsec per 23 μm CCD pixel. This translates to a 1.66 km/pixel resolution at the lunar equator and a 200×310 arc sec field of view. The boundaries of our study region are shown in Figure 1.

Multiple independent measurements of the near-IR spectrum of each region were averaged to produce a final "raw" spectrum with associated error bars. The spectra were converted into scaled reflectance units by taking a ratio of each region relative to Apollo 16 and then multiplying by the ratio of Apollo 16 to the Sun derived from spectral studies of returned Apollo 16 lunar samples. For many of these spectra, one or more linear continuua were removed by fitting straight lines to the data at local maxima near 0.8 and 1.5 and 2.6 μm. Spectroscopic analyses include (1) determination of band center positions and band widths using derivative

analysis and polynomial curve fitting; (2) determination of band depth, width, and area using standard methods [5,6]; and (3) calculation of simple linear mixing models [7].

The imaging data reduction process included subtraction of the dark (bias + dark current) values from all images and then division of a normalized (mean = 1.0) flatfield frame from each Moon and sky image at the appropriate wavelength. The sky image was then subtracted from the Moon image for each filter. Finally, the multispectral images are spatially co-registered into an image cube with an estimated registration accuracy of 0.25 pixel. This was achieved using a flux-conserving procedure whereby each image is convolved with a sinc^2 function having a width consistent with the estimated point spread function of our images. A relative calibration is achieved by ratioing all the images to the spectrum of MS2 as observed in the scene. Thus, we can compare spectra extracted from these multispectral images with previously-obtained spectroscopic data sets also presented as spot/MS2 ratios.

Analysis techniques used on these images included (1) generation of simple ratio images between different wavelengths in order to examine spectral slope and absorption band variations; (2) extraction of 6 to 8 channel spectra ("pseudospectra") from the image cube for comparison with other spectroscopic data sets; and (3) creation of simple linear mixing models using a small number of endmembers. We followed the mixing technique of [7] and [2] for spatial mapping of spectral heterogeneity and for the analysis of compositional variations focusing on specific processes (e.g., soil maturation, highlands-mare mixing, etc.).

Major findings to date [3,8] include the observation that the 1-μm band in the 43-km crater Plinius' central peak and NE wall regions is clearly composed of two features: a short-wavelength component centered near 0.92 μm and a longer-wavelength component centered near 1.0 μm. The 0.92 μm feature is weaker than the 1.0 μm band in the NE wall spectrum; however, the two bands have comparable strengths in the central peak. The presence of a 0.92 μm band in these spectra indicates that parts of Plinius are composed of highlands-like materials. This interpretation is confirmed by mixing analyses of the imaging data, which clearly show that the Plinius peak and several regions on the floor have a Haemus-like highlands signature. Also seen in the endmember images is an indication that low-Ti (central Serenitatis) mare exists on several regions of the floor and S-SW crater rim. The implication is that the mare is relatively shallow in this part of the Serenitatis-Tranquillitatis border. It is puzzling, however, that there are no indications of highlands material in the Plinius ejecta. This may be due to inadequate spatial resolution (the highlands component of the ejecta is unresolved) or more likely to the effects of vertical mixing, where the spectral signature of the pre-existing mare materials now completely dominates the mixed highlands-mare signal. The nearby 18-km crater Dawes has little or no highlands signature in its spectra. It registers a very high fraction of immature endmember materials, however, and one interpretation of this is that the brightness of its ejecta blanket is due to maturation rather than compositional effects.

Our study demonstrates the value of both high spatial and spectral resolution observations of geologically and spectroscopically interesting regions of the Moon for extending compositional, stratigraphic, and morphologic interpretations gleaned from previous data sets. While the Clementine mission should obtain spectacular high spatial resolution multispectral views of the Moon, it is important to note that higher spectral resolution observations of these regions will substantially add to our understanding of the Moon at fine spatial scales.

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