SPECTRAL VARIATION WITHIN MARE TRANQUILLITATIS: IMPLICATIONS FOR STRATIGRAPHY AND MIXING MECHANISMS Matthew I. Staid, Carle M. Pieters, James W. Head, Dept. Geol. Sci., Box 1846, Brown University, Providence, RI 02912

Introduction: Galileo's second lunar flyby in 1992 produced low and high phase angle images of the Tranquillitatis and Serenitatis basins with the Solid State Imaging (SSI) system (1). The SSI detector possesses seven channels within the wavelength range of 0.4 - 1.0 µm from which a set of compositionally sensitive ratios have been developed to identify surface units (2). These ratio images show significant spectral variation within the lunar basalts of Mare Tranquillitatis. These variations may result from compositionally distinct flows or the mixing of different highland and mare lithologies. A linear spectral mixing analysis was performed on six channels of a low phase angle (~ 25°) SSI image sequence of the basin in order to identify and map distinct spectral components. Results of this analysis were registered to higher spatial resolution telescopic images obtained at low sun lighting in order to evaluate the distribution of compositional endmembers in their geologic setting and to assess mixing mechanisms.

Data Analyses: Three standard color composite images of the Tranquillitatis region were created from ratios of the SSI data: a UV/VIS ratio (0.41/0.76 µm blue), its complement (red), and a 0.76/0.99 µm ratio (green). The intensity of the blue (0.41/0.76 µm) ratio has been empirically correlated to the titanium content of basaltic materials within the mare (3). The complement of this ratio, or the red intensity, corresponds to less titanium rich mare flows. The green component of this color display is an approximate estimate of the strength of the 1 µm iron absorption band of pyroxenes and olivines. This ratio is greatest for freshly disturbed crater materials because of a relative lack of optical alteration (4). While the color ratio images are fairly homogeneous for Mare Serenitatis, Mare Tranquillitatis shows significant spectral variations across its basin. High spatial resolution mapping of mare UV/VIS ratios in Tranquillitatis using earth-based telescopes have also observed this spectral heterogeneity (5).

A linear spectral mixing analysis was performed on the SSI data to determine what materials could mix to explain observed spectral variations. The mixing technique decomposes the reflectance signal of each pixel into fractions of individual endmember components. A number of fraction images equal to the number of endmembers in the analysis is created from the least squares solution to this mixing problem. Each fraction image displays the relative abundance of one endmember for each pixel in the image (6). Initial endmembers for mixing were selected from within the image after a detailed analysis of the spectra of the mare basalts and surrounding regions. In order to improve the results of the spectral mixing analysis, the SSI data were preprocessed to mask areas of relatively pure highland material to eliminate variations unrelated to the mare region. Sources of spectral variation within the mare, such as mixtures of highland material within the basin and bright mare craters, were preserved in the preprocessed image. The best solution in this spectral mixture analysis required the use of four endmembers: a very blue (high titanium) mare basalt from central Tranquillitatis, a red (low titanium) basalt from Serenitatis, highland material, and material rich in iron-bearing minerals from a bright mare crater in Tranquillitatis (Jansen B 26°40'E,10°50'N). Relative reflectance spectra of these endmembers are plotted in figure 1 and resulting endmember fraction images are shown in figure 2. An important step in the data analysis was registering the ratio images and the results of the mixing analysis to low illumination angle telescopic images of higher spatial resolution. These combined data allowed endmember abundance and spectral variance to be placed in the context of the regional topography of the basin. Of particular interest were the relationships of the endmembers to geologic features such as mare-highland contacts, craters, wrinkle ridges and mare domes.

Discussion: The spectral variation seen in Mare Tranquillitatis can be attributed to compositionally distinct basaltic units as well as to the effects of impact gardening into a shallow and stratigraphically complex basin. Data analysis suggests at least two distinct mare flow types. Stratigraphically younger titanium rich flows are found most abundantly in the central western portion of Tranquillitatis, while less titanium rich flows dominate significant sections of the north-eastern and south-eastern portion of the basin. Photogeologic and crater-count analysis of regions containing the higher titanium basalts indicate that these flows overlay adjacent less blue basalts (5, 9). Depending on location in the mare, impact gardening has caused vertical mixing of both highland and lower titanium underlying basalts into overlying higher titanium flow units. As expected, the mare crater endmember centers around the recent impact structures in the basin. This endmember is insensitive to boundaries between lower and higher titanium units, adding to the spectral variation of flows with similar composition.

Potential sources for the Tranquillitatis basalt flows are being investigated relative to the proximity of mare dome features (7). Since two large domes (21°30'E, 7°40'N and 21°30'E, 6°20'N) north-west of the Lamont feature are found in the titanium poor unit, the domes could be volcanic sources related to these flows. A likely source for the higher titanium basalts is a string of smaller dome features between Arago and Maclear which lie within a region of very high titanium basalts (5). Since the higher titanium flows are interrupted by islands of lower titanium basalts that are not a result of impact mixing, it is likely that the location of the high titanium flows is a result of both source location and the topography of the basin when they were extruded.

The distribution and mechanisms of highland mixing allows evaluation of the depth of the mare units and the proximity of the underlying basin highland topography. The highland endmember fraction image shows a notable association with mare/highland boundaries although mixing of the highland endmember is more prevalent in the southwestern portion of Tranquillitatis than at the eastern mare-highland contact. In the southwestern portion of the basin, craters such as Sabine and Ritter which have been previously hypothesized as volcanic structures (8) can clearly be seen as impact features excavating shallow highland material. The highland endmember has been excavated by the large crater Arago and also maps abundantly along protruding peaks of highland northeast of that area. South of Arago, a significant portion of the highland endmember occurs on the eastern side of a set of wrinkle ridges east of the Lamont feature. High resolution Lunar Orbiter images do not show any evidence of significant impact events in this region. It is possible that these compressional wrinkle ridge features are upthrusting highland material from short distances below to mix with the surface mare. However, thrusting is not a necessary mechanism since shallow underlying highland topography along with minor impact gardening may be solely responsible for this highland component. The distribution of the highland endmember along with structural features indicate that the underlying highland topography lies unusually close to the surface below these regions. This distribution of highland material supports the existence of shallow sub-mare basin topography, perhaps relating to the proposed inner ring of Procellarum which has been mapped through the center of the basin from its southwestern edge up to the northeast portion of the basin just east of southern Serenitatis (9).

Figure 2: Endmember fraction images of the Tranquillitatis region

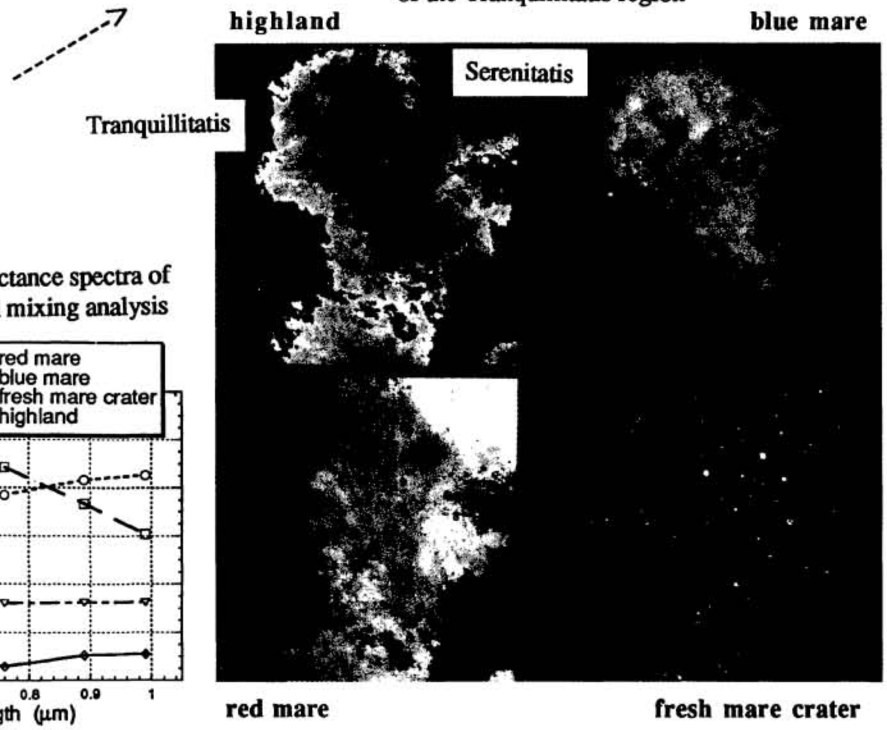
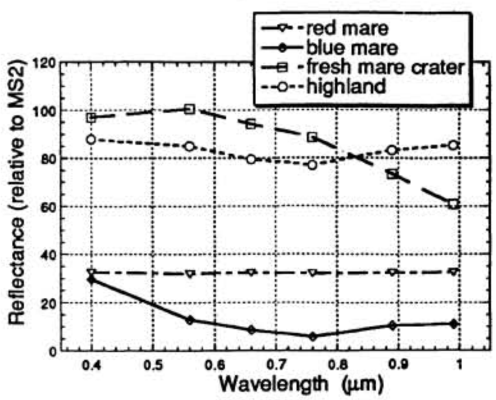


Figure 1: SSI relative reflectance spectra of endmembers used in spectral mixing analysis



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