COLOR VARIATIONS ON THE SURFACE OF PHOBOS AND THEIR RELATIONSHIP TO GEOLOGIC FEATURES. S. Murchie, D. Britt, J. Head, S. Pratt, and P. Fisher, *Dept. of Geological Sciences, Brown University, Providence, RI 02912*; B. Zhukov, A. Kuzmin, L. Ksanfomality, G. Nikitin, and A. Zharkov, *Space Research Institute, Moscow, U.S.S.R.*; F. Fanale, D. Blaney, and M. Robinson, *Hawaii Institute of Geophysics, University of Hawaii, 2525 Correa Rd., Honolulu, HI 96822.*

In addition to high-resolution images, *Viking* obtained 3-band (0.44, 0.53, 0.59 μm) color images of a portion of the trailing hemisphere of Phobos. These revealed a relatively homogeneous surface with little lateral variation in surface color in this wavelength range [1]. More recently, the VSK TV cameras and the KRFM spectrometer on *Phobos 2* have provided disk-resolved measurements of the spectral reflectance properties of Phobos's surface over a greater geographic area and spectral range than were observed by *Viking*. An accompanying abstract [2] summarizes how we have calibrated and processed the data; results of this work include 6 calibrated color ratio images of Phobos from different perspectives, constructed from visible (0.4-0.6 μm) and NIR (0.8-1.1 μm) VSK image pairs, and 8-channel 0.3-0.6 μm KRFM reflectance spectra of regions along two groundtracks that are visible in the color ratio images. This abstract describes the systematics and spatial distributions of color units that the VSK data reveal, correlation of these data with spectral reflectance measurements by KRFM, and preliminary geologic interpretations of these results. We address the following questions: **(a)** What are the color properties of different classes of craters, such as the large crater Stickney, dark-floor craters [3], and bright rim materials of younger craters [4]? **(b)** What are the nature and origin of color and reflectance variations on the surface of Phobos? **(c)** What if any color varations are associated with grooves, and are they evidence for the origin of the grooves? **(d)** Do the character and distribution of color units provide evidence for the composition and structure of Phobos's interior?

Description of Surface Color Properties. Color ratio images reveal variations of up to 45% in the surface color of Phobos. Color properties of Phobos's surface are illustrated in Figure 1, which includes 300-m resolution Gaussian-stretched visible images and color ratio images of opposite sides of the satellite. The spatial distributions and magnitudes of color ratio varations are reproducible in different ratio images to within a few percent, despite differing solar illumination geometries. Therefore the color variations are real, and are not simply artifacts of inaccurate image coregistration or instrumental noise.

Several major surface units can be recognized on the basis of their geographic distributions and relatively abrupt changes in color ratio at their contacts: **(a)** a "red" unit with a color ratio of 0.7-0.8; **(b)** a "reddish-gray" unit with a color ratio of 0.8-1.0; **(c)** a "bluish gray" unit with a color ratio of 1.0-1.1; and **(d)** a "blue" unit with a color ratio of 1.1-1.4. In general, these color variations result from variations in visible rather than near-infrared reflectance, with brighter materials being bluer.

Comparison to Results from KRFM. A 0.3-0.6 μm spectrometer and a 5-50 μm radiometer in the KRFM instrument obtained measurements along two groundtracks, whose locations are marked in Figure 1 by white bars. The groundtracks cross three of the four color ratio units, the "red," "reddish gray," and "bluish gray" units. The locally dominant "reddish gray" regolith exhibits a 20-30% falloff in reflectance from 0.6 μm to 0.3 μm, but there is evidence of a levelling in the spectra or an absorption feature at 0.45-0.55 μm. The spectra of both "red" and "bluish gray" materials are distinctive. "Bluish gray" material is characterized by a 10-20% falloff in reflectance at wavelengths shorter than 0.4 μm, a flat spectrum between 0.4 μm and 0.55 μm, and a blue slope toward longer wavelengths. "Red" material has a ~20% falloff in reflectance below 0.4 μm, and a shallow to deep absortion feature between 0.4 μm and 0.6 μm. (These spectra are illustrated in ref. [5].) These lateral differences in spectral properties of Phobos's surface corroborate the heterogeneity in surface color properties indicated by VSK images, and provide higher spectral resolution information about the color units. In addition, analysis of the radiometric results indicates that track 2 crossed a patch of low-albedo material which has a higher thermal inertia than do surrounding surfaces [6]. The location of this patch correlates with that of the "red" color unit, indicating that "red" material has a larger grain size or more bouldery surface than does the surrounding "reddish gray" material.

Relationship of Color Units to Impact Craters. The spatial distribution of the color ratio units is clearly related to specific impact craters "Blue" material occurs on the walls and floor of Stickney, and as a lobe extending ~5 km to the southwest. "Bluish gray" material surrounds the "blue" lobe as a broad aureole, and extends west approximately to the anti-Mars point where it breaks up into patchy outliers. "Red" material is geographically restricted, composing patches within and adjacent to a large degraded crater centered at 0° lat.,245°W, and interiors of dark-floor craters. "Reddish-gray" material occurs in intervening regions, and is prevalent in the trailing hemisphere. Almost all bright rims of younger craters are a similar "reddish gray" color despite a 20-30% variation in their reflectances. The bright rims are common in the "reddish gray" unit, where their color is undistinguished from that of surrounding material. They are less common in the "bluish gray" unit, where their color is distinct from surrounding darker material, and they occur predominantly in distal portions of the aureole.

Origins and Possible Implications of Color Variations. At least three mechanisms could account for large lateral variations in the color ratio of Phobos's surface: Marsshine, particle size variations, and

compositional or optical heterogeneity. The very red color ratio of Marsshine (~0.4) should result in slight reddening of the sub-Mars hemisphere [7]. However, the color ratio images reveal the sub-Mars hemisphere to be bluer than other areas, inconsistent with Marsshine alone causing color variations. Particle size fractions of carbonaceous chondrite measured in the laboratory exhibit a brightening and reddening with decreasing particle size. In contrast, the reddest areas on Phobos have a relatively higher thermal inertia implying larger particle sizes, and brighter materials are generally bluer. Lateral compositional or optical heterogeneity is supported by the lateral differences between color units in the thermal inertias and 0.3-0.6 μm reflectance spectra measured by KRFM.

The spatial association of "blue" and "bluish gray" materials with Stickney and their distribution as a lobate deposit emanating from the crater's rim are evidence that these materials are Stickney ejecta superposed upon surrounding older, compositionally or optically distinct "reddish gray" regolith. The occurrence of "red" material within and adjacent to specific large craters and the material's coarser or bouldery surface are also consistent with an origin as crater ejecta superposed on a surrounding, geologically distinct material. The reddest and bluest surface materials are therefore interpreted as having been emplaced as thin ejecta of large craters, which penetrated a widespread "reddish gray" surface layer and excavated optically and/or compositionally distinctive materials from a heterogeneous satellite interior.

Implications for the Origin of Grooves. Grooves have previously been classified into three morphologic groups [4,8]: "class I" grooves, short, raised-rimmed troughs concentrated immediately east of Stickney; "class II" grooves, bands of closely spaced or coalesced raised-rimmed pits that emanate from the rim of Stickney; and "class III" grooves, linear chains of coalescing pits generally lacking raised rims, arranged subradial to the satellite's trailing edge [9,10]. The main hypotheses for groove origin are the "fracture and drainage" model, in which grooves formed by sliding of regolith into open fractures [9,10,11]; the "fracture and degassing" model, in which grooves formed by ejection of loose material from open fractures by volatiles liberated by impact heating [9,10]; and "ejecta reimpact" models, in which grooves formed as secondary craters or as tracks left by sliding, rolling, or bouncing ejecta fragments [12,13]. Nearly all of the class II grooves observed in the color ratio images extend from the same southwestern part of Stickney's rim as does the lobe of "blue" material interpreted to be ejecta; our preliminary interpretation is that this result is consistent with "ejecta reimpact" models. We are presently assessing VSK, KRFM, and other data sets to more fully address the question of groove origin.

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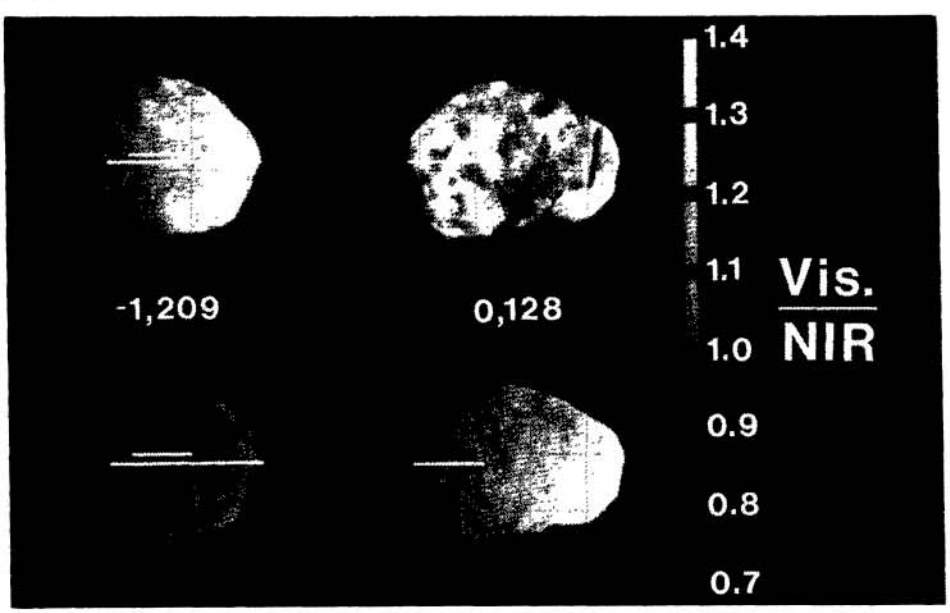

Fig. 1. Contrast-enhanced visible images (top row) and visible/NIR color ratio images (bottom row) of Phobos from different perspectives. Latitudes and longitudes are of the sub-spacecraft points. Scale bar at right is for color ratios. "1" and "2" are the numbers of the KRFM groundtracks (white bars). Constructed from image pairs 2550141-2550153 (left) and 2550051-2550063 (right). Note the bluer material extending from the southwestern part of Stickney's rim (at right) and the redder interiors of several dark-floored craters northeast and west of KRFM track 2.