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DISK-RESOLVED SPECTRAL REFLECTANCE PROPERTIES OF PHOBOS FROM 0.3-3.2 µm: PRELIMINARY INTEGRATED RESULTS FROM *PHOBOS 2*.

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Introduction. The *Phobos 2* mission provided multispectral observations of Phobos over a large wavelength range and with relatively high spectral resolution. The VSK TV cameras obtained 0.40-0.56 µm ("visible") and 0.78-1.1 µm ("NIR") images with resolutions of 0.3-0.5 km, covering the longitude region 30°-250°W [1]. The KRFM instrument obtained ~0.9-km resolution, 8-channel 0.3-0.6 µm spectra of two groundtracks in low-latitude regions [2]. The ISM imaging spectrometer obtained 128-channel, 0.76-3.16 µm spectra of part of the trailing hemisphere with a spatial resolution of ~0.7 km [3]. In this abstract we integrate results from the three multispectral detectors, by determining the UV-visible and NIR spectral properties of color and brightness features recognized in VSK images. We present evidence that there are two fundamental spectral units within the region of overlapping coverage by the detectors, we describe the units' spectral and reflectance properties, and we discuss the implications of these results for the composition of Phobos.

Synopsis of Previous Analyses. The spectral and reflectance properties of the surface of Phobos determined previously from these experiments are summarized below. Laboratory measurements of possible meteorite analogs to Phobos provide some basis for interpretation of these observations. The analogs include hydrous CI and CM carbonaceous chondrites, anhydrous CO and CV carbonaceous chondrites, and anhydrous, optically darkened ordinary chondrites or "black chondrites." (a) Color ratio images constructed from visible/NIR VSK image pairs show that the surface is spectrally heterogeneous with a color ratio of ~0.75-1.4, and may be subdivided into "red," "reddish gray," "bluish gray," and "blue" color ratio units. The "blue" and "bluish gray" units compose the interior of the crater Stickney and a surrounding lobate deposit extending west to ~160°W, interpreted as the crater's ejecta [1,4]. (b) In low phase angle images, rims of many fresh craters west of ~160°W exhibit a brightening relative to surrounding older surfaces, but bright-rimmed craters are conspicuously absent from the region extending east from ~160°W to the crater Stickney [1]. In the laboratory, analogous brightening at low phase angles is observed in particulate carbonaceous chondrites. An analogous effect is also observed in black chondrites, but only at small particle sizes characterized by unrealistically large reflectances for Phobos [5]. (c) The "red," "reddish gray," and "bluish gray" color ratio units were sampled by the KRFM spectrometer. The "red" and "reddish gray" units have similar UV-visible spectra which are relatively flat at 0.4-0.6 µm and exhibit a falloff in reflectance below 0.4 µm, but the "bluish gray" unit has a much lesser falloff in reflectance below 0.4 µm [4]. (d) The spatial distributions of the color ratio units, their reflectance systematics, and their UV-visible spectral properties indicate that color variations originate from optical or compositional heterogeneity. The reddest and bluest materials form the interiors and flanks of craters, and are interpreted to have been excavated from a heterogeneous interior overlain by a "reddish gray" surficial layer [4]. (e) The very blue color ratio of "blue" material supports a mafic, black chondrite-like composition rather than a carbonaceous chondritic composition. UV-visible spectra of "bluish gray" material are more similar to spectra of black chondrites than carbonaceous chondrites. Spectra of "reddish gray" and "red" materials also more resemble spectra of black chondrites, but are comparable to spectra of some carbonaceous chondrites [4,6]. (f) ISM observed only the "red" and "reddish gray" color ratio units. The 3-µm absorption due to hydration is very weak or negligible [3], suggesting that Phobos's regolith is anhydrous. (g) The density of Phobos, 1.90±0.1 g/cm^3, is much lower than that of meteorite analogs, indicating significant internal porosity [1]. The amount of porosity would be more realistic if high-density anhydrous carbonaceous chondrite or black chondrite were diluted by lower-density CM-like carbonaceous chondrite [4,7], if this material is has been dehydrated by regolith processes to account for NIR spectral properties.

Calibration. VSK: VSK images were calibrated initially using instrumental parameters measured on-ground and in-flight [1]. Visible/NIR color ratio images were recalibrated on the basis of a portion of Mars observed in the background of Phobos in some images, employing telescopic spectra resampled into the visible and NIR bandpasses as described by Murchie *et al.* [4]. ***KRFM:*** Initially published locations of the two groundtracks [2,8] have been refined by correlating along-track brightness profiles with portions of visible-band VSK images [4]. Previously published spectra [4] for the longer, more southern groundtrack (track 1) were recalibrated by dividing by a "standard" area with an "average" color ratio, and multiplying by the disk-integrated ("average") spectrum [9]. When recalibrated in this way, spectra of Mars obtained at the end of the track (beyond the satellite's limb) are consistent with telescopic spectra. Spectra from track 2 could not be recalibrated because this track lacks a suitable "standard" area, and because no spectra of Mars were acquired at either end of it [4], and so are therefore not used in the present analysis. ***ISM:*** These spectra have been calibrated using instrumental parameters measured on-ground and in-flight [10]. We are attempting several methods of recalibration, including (*a*) dividing by a "standard" area and multiplying by spectra of anhydrous meteorites whose spectral properties in VSK and KRFM bandpasses closely match those of the "standard" area, and (*b*) deriving revised gains and offsets for each channel using spectra of various regions on Mars.

Properties of Spectral Units on Phobos. The area west of Stickney lacking bright-rimmed craters is closely correlated spatially with materials having color ratios of ≥1.0; the western outliers of this bluish material coincide with dark patches between the easternmost bright-rimmed craters, and the bright-rim craters in the distal portion of the bluish material form outliers of the redder material prevalent to the west. The magnitude of the falloff in reflectance below 0.4 µm is also related to color ratio (Figure 1). Materials with a color ratio of >1.0 exhibit a relatively flat spectrum with only a 10-16% UV falloff; materials with a color ratio <1.0 exhibit a 20-26% falloff in reflectance, independent of color ratio within this range. These results are interpreted as revealing two basic spectral units in this region of Phobos: (a) "bluer" Stickney ejecta with a color ratio of ≥1.0, a relatively flat UV-visible spectrum, and lacking bright material on rims of young craters; and (b) "redder" material with a color ratio of <1.0, a greater falloff in UV reflectance, and exhibiting pervasive bright material on rims of young craters.

Of these two basic units, ISM observed only the "redder" one. We have focused our analysis of this data set on the 1-μm and 2-μm absorptions diagnostic of mafic minerals. The depth of the 1-μm absorption, defined as the drop in reflectance at 0.91-1.09 μm relative to a continuum between 0.8 and 1.2 μm, was found to vary laterally by up to ~5%. Depth of the absorption is independent of illumination (Figure 2), but is correlated with visible/NIR color ratio (r, 0.71±0.01) (Figure 3). Areas with relatively redder color ratios have the weakest absorption, and areas with relatively bluer color ratios have the deepest absorption. If the current calibration is nearly correct, then the 1-μm absorption is weak or absent in areas with the reddest color ratios (<0.8). A weak 2-μm absorption feature is also present in some of the areas with a relatively strong 1-μm absorption and relatively bluer color ratio. Spectra of a mixed population of meteorite analogs [11,12] reveal a similar relationship between color ratio and the depth of the 1-μm absorption. Carbonaceous chondrites generally have weak or negligible 1-μm absorptions; black chondrites generally have 1-μm absorptions with depths of ~2-7%, and as a class of materials have a bluer color ratio than do carbonaceous chondrites [4].

Implications for the Composition of Phobos. Tentatively, we interpret these results as follows: "Bluer" material considered to be Stickney ejecta is interpreted here as having a black chondrite-like composition, based on its UV-visible spectral properties, its very blue color ratio, and its lack of bright-rimmed craters. "Redder" material is a mix of a red component with a weak or negligible 1-μm absorption, and a gray component possibly containing olivine and (locally) pyroxene. Based on the correlation of the depth of the 1-μm absorption with color ratio, the character of the UV-visible spectrum, and the presence of bright-rimmed craters throughout the "redder" unit, we propose that its gray component is black chondrite-like in composition and that its red component is analogous to lower-density carbonaceous chondritic material such as CM chondrites. This mixed composition reconciles spectral evidence of a black chondrite-like composition in some areas with the satellite's low density, which requires a more reasonable porosity (~35%) if a porous interior has a large component of low-density carbonaceous chondritic material. The implied structure of Phobos's interior is a rubbly mixture of carbonaceous chondrite and either ordinary chondrite or some other mafic material containing a similar mineral assemblage. This association is not thought to be compatible with formation within a single parent body [13], and implies that the material composing Phobos originated from more than one asteroidal and/or planetary source.

References: [1] Avanesov et al., *Planetary and Space Science*, in press, 1990. [2] Ksanfomality et al., *Planetary and Space Science*, in press, 1990. [3] Langevin et al., *Lunar Planet. Sci. XXI*, 682-683, 1990. [4] Murchie et al., *J. Geophys. Res.*, in press, 1990. [5] Shkuratov et al., *Abstracts of Papers Submitted to the 12th Soviet-American Microsymposium*, pp. 78-79, Moscow, 1990. [6] Britt et al., *Lunar Planet. Sci. XXI*, 129-130, 1990. [7] Hartmann, *Lunar Planet. Sci. XXI*, 457-458, 1990. [8] Ksanfomality et al., *Nature, 341*, 588-591, 1989. [9] Pang et al., *Science, 199*, 64-66, 1978. [10] Erard et al., *Proc. Lunar Planet. Sci. Conf. 21*, in press, 1990. [11] Gaffey, *J. Geophys. Res., 81*, 905-920, 1976. [12] Britt, D. and C. Pieters, unpublished spectra. [13] Dodd, R., *Meteorites: A Chemical-Petrologic Synthesis*, Camb. Univ. Press, 1981.

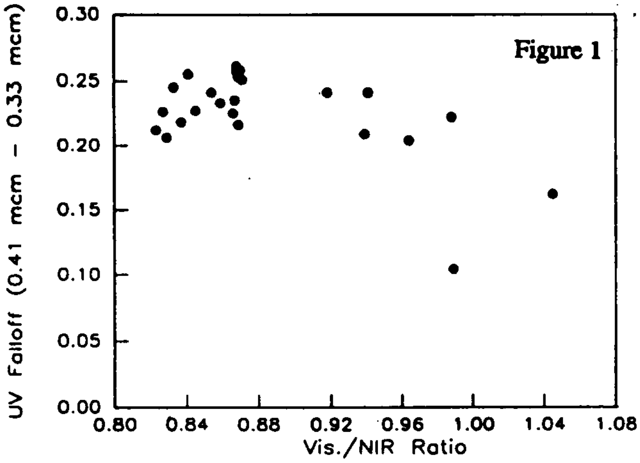
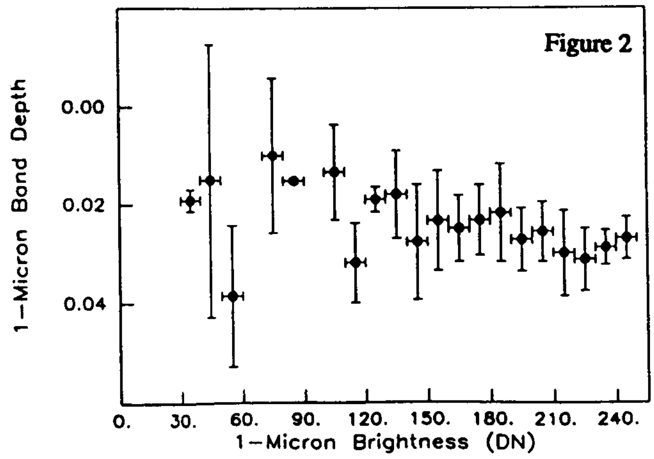


Figure 1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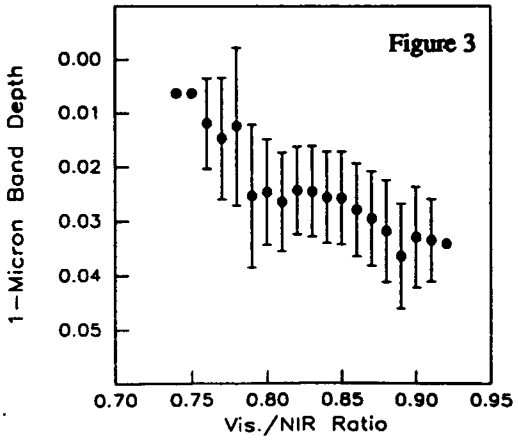
Figure 3