CHARACTERIZATION OF SURFICIAL UNITS ON MARS USING VIKING ORBITER MULTISPECTRAL IMAGE AND THERMAL DATA

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The topography of the northern hemisphere of Mars is dominated by three areas of high elevation (up to 5 km above the datum for Elysium and Arabia, and up to 27 km for Tharsis) separated by areas of low elevation (about 1 to 2 km below the datum). Albedo and thermal properties correlate fairly well with this regional topography [1]. The high elevation areas have relatively high albedos (0.32 - 0.33) and low thermal inertias (< 2.5 x 10^{-3}cal·$cm^{-2}s^{-1/2}K^{-1}$), while the lower elevation areas generally have lower albedos (< 0.15) and higher thermal inertias (5 - 14). In order to examine these correlations on a more local scale, a detailed study was conducted [2] of the types and origins of materials exposed in the central equatorial region (335°W - 15°W, 10°S - 30°N). The region is part of the heavily cratered terrain, located on the western edge of Arabia where the topography is changing from the high elevations of Arabia in the east to lower elevation in the west. This area was selected because it displays a wide variation in color, albedo and thermal properties over a small area of the planet and has good data coverage, relatively free from dust and haze.

Three surficial units can be distinguished in this region on the basis of spectral reflectance properties determined from radiometrically calibrated Viking Orbiter color images and thermal properties determined from the Viking Infrared Thermal Mapper. These units are: (1) a bright red unit that has a relatively high reflectance in both red (average reflectance of type area = 0.17) and violet wavelengths (0.06) and a low fine component thermal inertia (modal value of the unit = 2.4); (2) a dark violet unit that has a relatively low reflectance in both red (0.10) and violet wavelengths (0.05) and a relatively high thermal inertia (6.4); and (3) a brown unit that has a reflectance that is relatively low in the violet wavelengths (0.04), but intermediate in value relative to the other units in the red wavelengths (0.13), and a thermal inertia that is also intermediate in value (4.6). Reflectance values for the region produce two trends. These trends suggest that a bright red end-member material is mixing with each of the darker end-members. The darker units, however, do not mix with each other.

These units can be mapped to contiguous, well defined locations by use of simple parallelepiped techniques. Material that produces the brighter reddish trend, at the apex of the two mixing trends, is located in the east where it corresponds to Arabia and in the very south where it corresponds to Deucalionus Regio. Dark violet material is located in the south and southwest where it corresponds to Sinus Meridiani and Sinus Sabaeus. The dark violet material also exists as dark splotches in large craters within the Oxia Palus quadrangle, as well as dark streaks associated with the splotches. Brown material is located in the north to northwest where it is the dominant unit in the western half of the Oxia Palus quadrangle. In addition to the contiguous units, bright red material can be found as bright crescents within the large craters in Oxia, opposite to the dark splotches, and as bright margins surrounding the dark streaks.

Color/albedo boundaries are relatively sharp and distinct in all places, yet they are not correlated with abrupt changes in regional morphology, as determined from medium and high resolution Viking Orbiter images, nor do they exhibit any systematic correlation with topographic boundaries. Crater statistics, derived from high resolution Viking Orbiter images and Mariner 9 A-frames, indicate that the units are indistinguishable in terms of age, and that only a relatively minor amount of crater obliteration (< 0.008 μm/year depositional rate) could have occurred over the past several billion years.

A major objective of the Mars Observer Mission is to map the physical, elemental and mineralogical characteristics of the surface, for the purpose of characterizing both the surficial materials and bedrock geology. The results of this study [2] suggest that the dark violet unit is probably composed of sand-sized deposits [3]. The bright red unit is composed of dust, probably a globally homogenized deposit emplaced during dust storms [4 and 1]. The thermal inertia of the brown unit, and the lack of mixing between the brown and the dark violet units, are consistent with significant duricrust formation in the brown unit, as suggested by Kieffer et al. [5]. This possibility is supported by Viking Lander color data. Duricrust exposed at the Viking 1 Lander site occupies the same relative position on a two-dimensional histogram of the number of pixels as a function of their red and blue albedos for Frame A168 (VL1, Sol 28), as the brown unit does on a red-violet histogram from Viking Orbiter Apoapsis color. These data support the possibility of extensive duricrust formation and exposure in the brown unit.

If there are significant amounts of duricrust within the brown unit, then the thermal inertia of the unit suggests that the matrix must be composed of very fine-grained sand or dust. Thus the brown unit may be composed of fine-grained bright red material that has been cemented to produce a duricrusted surface. Although the resultant spectra of matrix and cement would not be a simple linear addition of end-member spectra, since the cement would probably form an intimate mixture [6] with its matrix, the spectra would nonetheless be intermediate between those of the cement and the matrix. A salt that is transparent in the visible, such as Kieserite, $MgSO_4 \cdot H_2O$, which has been suggested as a likely candidate at the Viking Lander sites by Toulmin et al. [7], could not produce a composite spectra for the brown unit that is lower in albedo than the red unit. Trans-opaque minerals, such as iron sulfates (Quenstedtite, $Fe_2(SO_4)_3 \cdot 10H_2O$, for example [8]), however, may present some interesting possibilities, and spectral properties of such compounds should be investigated.

Another possibility is that the brown unit is simply a lag deposit composed of a mixture of particles with an effective grain size in the range of fine sand. This is also consistent with Viking Lander observations. Viking Lander high resolution color images synthesized by Dale-Bannister [9] show exposures of brown and bright red materials, with the brown materials underlying the brighter, redder deposits. Only the redder deposits form tails or drifts, suggestive of eolian deposition. The absence of dark violet materials in these images is consistent with Viking Orbiter Apoapsis color data, which show only brown and bright red materials in the region of the Chryse Landing site.

A global view shows that both the bright red material and the brown material occupy large regions of the planet, regardless of morphology or inferred geology. Together with the results summarized here, this observation implies that these two units are thin eolian deposits completely decoupled from the underlying bedrock. The higher elevations of the bright red unit imply that deposition and/or erosion are being controlled by topography. Data utilized in this study are insufficient to determine whether the dark violet unit is locally derived from bedrock, or whether it is also a thin eolian deposit. Earth-based spectra of the dark regions, however, indicate that Fe^{2+} absorptions around 1 μm vary with location on the planet. These are believed to reflect differences in the mafic mineralogy, primarily pyroxenes and olivines [10]. These variations suggest that the dark material is derived from local sources. Since the material of the dark violet unit is the most likely to be derived from bedrock, data collection by the Mars Observer Mission should concentrate on these areas, and other dark regions like them. At any rate, a major problem in analyzing Mars Observer data will be in determining to what extent a surficial material may be related to underlying crustal geology or to laterally homogenized eolian deposits.

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